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Farm Size, Farm Labor, and Off-Farm Labor: A Simultaneous Estimation

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A model of simultaneous determination of farm household choice variables of farm and off-farm labor, land input, and livestock enterprise is developed and estimated. Simultaneity is shown to exist in these variables and the effects are asymmetric. Wage and income effects are shown to depend heavily on the households view of comparative advantage in market and nonmarket production between husband and wife.

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A growing proportion of the total income of farm households is from nonfarm sources. Studies of wealth and asset holdings indicate the vast majority of the farm households' resources are still farm associated. The increased proportion accounted for by nonfarm income is a result of increased participation in the nonfarm wage work market by household members.

This paper presents a model of joint determination of farm household resource allocation and annual operated acres of the farm. Other models of farm and off-farm labor by household members have treated farm size as fixed, Rosenzweig (1980). Given the active annual land rental market this assumption is likely to be inappropriate. The approach presented here of simultaneous determination of the farm family's labor, operated acres, and livestock enterprise should achieve improved parameter estimates of the determinants of these farm choice variables.

I. The Model

The household utility function is assumed to be a monotone twice-continuously differentiable, strictly concave function:

(1) $U = U(Y_H, T_L)$,

where Y_H is household output, and T_L is a vector of leisure time of the husband and wife, respectively.[1] The vector of time endowments is assumed to be allocated to four uses:

(2) $T = T_F + T_W + T_H + T_L$,

where T_F is farm labor, T_W is market (nonfarm) wage labor, T_H is household labor, and T_L is leisure. The household receives income from off-farm wage work, sale of net farm output and other nonfarm nonwage income and it is spent on inputs for farm and household production:

(3) $WT_W + P_F Y_F + V - P_X X \geq 0$,

where W is a vector of market wage rates for the husband and wife, P_F is a vector of exogenous received farm prices, V is nonfarm nonwage income and P_X is a vector of exogenous input prices. If some of the husband's and wife's time are allocated to market labor, then (2) and (3) can be combined into a full-income constraint:

(4) $R = WT + P_F Y_F + V - W(T_F + T_H + T_L) - P_X X \geq 0$.

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

(5) $Y_F = G(Y_H, T_H, T_F, X, \gamma) \geq 0$,

where Y_F is net farm output and γ is a vector of environmental and fixed inputs. The environmental inputs are characteristics that affect the efficiency of transforming inputs into outputs. The variables include weather, age (experience), education of husband and wife, and number (stock) of children at home. The Lagrangean for this problem is:

(6) $\Psi = U(Y_H, T_{1L}, T_{2L}) + \lambda_1[Y_F - G(Y_H, T_H, T_F, X, \gamma)]$
$+ \lambda_2[WT + P_F Y_F + V - W(T_F + T_H + T_L) - P_X X]$,

and the necessary conditions for interior solutions for choice variables of interest are:

(7) $-\lambda_1 G_X - \lambda_2 P_X = 0$,

(8) $-\lambda_1 G_{T_F} - \lambda_2 W = 0$,

(9) $U_{T_L} - \lambda_2 W = 0$,

(10) $-\lambda_1 G_{T_H} - \lambda_2 W = 0$,

where $G_X = \partial G/\partial X$, $G_{T_F} = \partial G/\partial T_F$, $U_{T_L} = \partial U/\partial T_L$, and $G_{T_H} = \partial G/\partial T_H$. Assuming elements of γ are not household choice variables the full set of first order conditions give a set of structural equations that can be solved (locally) for household decision rules, the demand and supply equations:

$$(11) \quad \Omega = \Omega(W, P_F, P_X, V, \gamma), \ \Omega = T_F, T_W, T_H, T_L, X, Y_F.$$[2]

Corner solutions, such as zero hours of wage work, are addressed in the discussion of the empirical model.

II. The Data

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).[3] 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; and the ownership and rental of farm land. In general, Iowa farm wives allocate most of their time to house work and husbands allocate most of their time to farm 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. 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. The Iowa survey data are from a random sample of a broadly defined population of farm households, as opposed to other farm household samples by low income or otherwise not randomly selected households.

III. 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 bias, and provide empirical results which can be generalized with confidence.

Consider the econometric model:

(12) - (13) $\ln W_j^o = Z_j \alpha_j + u_j$, $j = 1, 2$ (husband, wife)

(14) $T_{jw} = Z_j \beta_j + \nu_j$ w = wage work

Data are available on w_j if $T_{jw} > 0$.

(15) $I_1 = 1$ iff $T_{1W} > 0$,
$= 0$ iff $T_{1W} \leq 0$,

(16) $I_2 = 1$ iff $T_{2W} > 0$,
$= 0$ iff $T_{2W} \leq 0$.

This allows the sample selection rule on the observance of W_j to be written as:

(17) $E(\ln W_j | Z_j, T_{jw} > 0) = Z_j \alpha_j + E(u_j | \nu_j > Z_j \beta_j)$.

The disturbance term $\nu_{2i}(\nu_{1i})$, ith household, of the market participation equation is in general correlated with the disturbance term $u_{2i}(u_{1i})$ of the wage offer equation, so the probability of a wife (husband) being included in the subsample of wives (husbands) with observed wage earnings differs across individuals.[4] To correct this problem we follow Heckman (1980) and modify the estimated market wage equations by including the inverse of the Mills ratio, λ_j, derived from the maximum likelihood estimation of I_j as a regressor in equations (18) - (19).

(18) $\ln W_1 = Z_1 \alpha_1^* + \delta_1 \lambda_1 + u_1^*$.

(19) $\ln W_2 = Z_2 \alpha_2^* + \delta_2 \lambda_2 + u_2^*$.

(20) - (23) $T_{jk} = \beta_{j1} \ln W_1 + \beta_{j2} \ln W + Z_{j3}^{k} \beta_{j3}^{k} + \sum_{j}\sum_{k} \beta_{j4}^{k} T_{i1} + \beta_{j5}^{k} X_F + \beta_{j6}^{k} Liv + e_{jk}$

where $i, j = 1, 2$ (husband, wife) and $1, k = F, W$ (farm work, wage work).

(24) $X_{Fi} = Z_4 \phi_1 + \sum_{j}\sum_{k} \phi_{j2}^{k} T_{jk} + \phi_3 Liv_i + e_{xi1}$ where i = household index

(25) $Liv_i = Z_5 \theta_1 + \sum_{j}\sum_{k} \theta_{j2}^{k} T_{jk} + \theta_3 X_{Fi} + e_{Liv}$.

The terms u_j, ν_j, u_1*, u_2*, e_{jk}, e_X, e_{Liv}, are vectors of random disturbances. All of these disturbance terms have a zero expected value, except e_{jW} and u_j. The vector Z_j^k in these demand and supply equations contains nonwage explanatory variables, including household asset income, age, schooling and vocational training of husband and wife, and number of children at home.

In some studies of market-labor supply of farm household members, the land input has been treated as exogenous or as a fixed factor, e.g., Rosenzweig (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 farm operation and (or) livestock enterprises are activities capable of employing larger amounts of the household's 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 (20) - (25). In this study, the time inputs of farm and off-farm labor of the husband and wife, the land input and the presence of a livestock enterprise are treated as endogenous variables determined simultaneously.

IV. 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. See Table 1 for exact definitions of variables used in this study.

V. The Parameter Estimates

In this section, our model of household resource allocation, operated acres, and nature of farm enterprise is tested against the Iowa micro-data set.

Table 1. A Summary of Empirical Definitions of Variables

Variable	Definition
Endogenous household	
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.
X_F	Farmland input--the number of acres owned and operated plus acres rented in and operated. This is one measure of farm size.
Liv	Dairy activity--a 1-0 dummy variable, taking the value of 1 if the farm reports a dairy livestock activity or other livestock operation, 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.
$D(FVT_i)$	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.
$D(H_i)$	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 wage specific number of children in the household. The wage 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_O 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.

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

$D(DGD_q)$, q=1-5 Growing-season dummy variable 5. The normal crop growing season is measured as average growing-degree-days accumulated between spring and fall dates of $\leq$ 10% 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.

Table 2. Summary Statistics of Variables

Variables	Mean	Standard deviation
Endogenous household		
Wife's: Wage labor	262.6	585.5
Farm labor	416.1	629.8
Participation in wage labor	0.28	
Husband's: Wage labor	285.3	666.9
Farm labor	2,601.6	1,233.2
Participation in wage labor	0.25	
Farmland input	332.5	256.3
Livestock Enterprise	.28	
Exogenous household		
Wage offer, predicted: Husband	1.47	
Wife	1.28	
Age: Husband	47.8	
Wife	45.3	13.3
Education: Husband	11.3	12.8
Wife	12.7	2.2
Experience: Husband	30.5	1.7
Wife	26.6	
Market-specific voc. training: Husband	0.73	
Wife	0.80	
Home-specific voc. training: Wife	0.72	
Farm-specific voc. training: Husband	0.29	
Farm-raised: Husband	0.93	
Poor health status: Husband	0.01	
Wife	0.02	
Number of children: Under age 6	0.37	
age 6-11	0.38	
age 12-18	0.78	
Asset income: permanent farm	10,923.3	13,573.7
other income	690.1	2,936.6
Miles to city	27.9	14.5

Instrumental variables of sex specific labor force probabilities and wage offers are estimated using the procedure noted earlier. The wage offer estimations are: (standard error in parentheses)

$$\ln W_1 = \underset{}{1.324} + \underset{(.023)}{0.054 ED_1} + \underset{(.013)}{0.026 EX_1} - \underset{(.0002)}{0.0005 EX_1^2} - \underset{(.08)}{0.114 D(WEST)}$$

$$- \underset{(.13)}{0.12 D(MVT_1)} - \underset{(.135)}{0.465 \lambda_1} \quad R^2 = .21,\ F = 6.35 \quad n = 153,$$

$$\ln W_2 = 0.22 + \underset{(.05)}{0.078 ED_2} + \underset{(.026)}{0.054 EX_2} - \underset{(.0005)}{0.001 EX_2^2} - \underset{(.15)}{0.3 D(WEST)} -$$

$$- \underset{(.178)}{0.234 D(MVT_2)} - \underset{(.292)}{0.332 \lambda_2} \quad R^2 = .09,\ F = 2.68 \quad n = 171.$$[5]

Following Mincer (1974) and Heckman and Polachek (1974), the natural logarithm of the sex specific hourly wage rates are assumed to depend on the individual's personal characteristics: schooling attainment, experience, completion of market-specific vocational training, a regional variable, and the sample-selection correction term. The rationale for including a geographical variable is that sufficient geographical immobility exists that differences in density of industrialization between the eastern and western sections of the state can be expected to offset wage offers. The estimated coefficients of schooling and experience are similar to estimates for nonfarm married males (Da Vanzo, et. al., 1976) and females (Heckman 1980).

The estimated coefficients of the market-specific vocational training dummy are negative, however, not significantly different from zero at the 5 percent level. These results are opposite of expectations based upon a hypothesis of skill enhancement, but to the extent that vocational training was obtained in high school (or college), it was at the expense of more general training. Thus our results, considered together, suggest market-specific-vocational training is less valuable in raising wage rates than general schooling.[6]

The estimates of the second-stage equations are reported in Table 3. Due to the truncation at zero of the time measures T_{1W} and T_{2W} these equations were estimated with a Tobit procedure. The probability of a livestock enterprise on the farm has as 0, 1 dependent variable and is estimated with a Probit procedure. The results indicate simultaneity exists among the endogenous variables.

The estimated coefficient on wife's farm labor, T_{2F}, is negative and significant in her market labor equation and positive and significant in husband's market labor equation. The elasticities of supply for the wife's and husband's market labor with respect to the wife's farm labor, evaluated at sample means, are -3.25 and 2.41, respectively. The coefficient for wife's market labor, T_{2W}, is negative and significant in the wife's farm labor equation and positive and significant in the probability of a livestock enterprise equation. The elasticity of farm household demand for the wife's farm labor with respect to her market labor is -0.09. The results also show a strong negative relationship between the husband's hours of market labor and increases in his farm labor, T_{1F}. The elasticity of supply for the husband's market labor with respect to his own farm labor is -6.50.

The coefficients on the husband's market labor, T_{1W}, are negative and significant in the operated acres, husband's farm labor and livestock enterprise equations. The elasticities of demand for husband's farm labor and operated acres with respect to the husband's market labor are -0.05 and -0.04, respectively. The estimated coefficient on operated acres is negative and significant in the wife's farm labor equation. The elasticity of demand for wife's farm labor with respect to acres operated is -0.82, evaluated at sample means.

Table 3. Demand and Supply Equations, Hours of Work, Acres Operated and Livestock Enterprise

	Wife's Farm	Wife's Market [a]	Husbands Farm	Husbands Market [a]	Acres Operated	Probability of Livestock [b]
AG_1	-9.323 (5.13)	-9.86 (-.67)	-18.54 (5.70)	12.90 (.15)	21.79 (5.93)	-0.025 (.013)
ED_1	-59.42 (28.87)		-116.30 (42.49)	-228.18 (-2.12)		-0.168 (.096)
V_O	-19.71 (9.26)	-54.87 (-1.77)	-23.69 (14.91)		7.99 (3.52)	-0.036 (.034)
V_F		-121.81 (-2.94)		83.76 (1.81)	15.90 (2.78)	-0.027 (.043)
$\ln W_1$	1002.53 (512.83)	323.63 (.42)	2799.7 (601.7)	6048.7 (3.35)		
$\ln W_2$	-194.48 (139.53)	-403.21 (-.94)	-453.77 (230.54)	-799.19 (-1.62)		
K_1	-175.83 (60.23)	-821.48 (-4.49)				
K_2	-16.48 (38.57)	-303.41 (-2.98)				
K_3	-22.00 (24.92)	-106.75 (-1.37)				
$D(H_2)$	-468.98 (244.59)					
AG_2					-0.328 (.071)	
AG_1^2				-0.98 (-1.03)		
$D(FVT_1)$			-88.47 (108.93)			
AARF					15.30 (4.42)	
ED_2		91.31 (1.70)				

$D(DGD_1)$						-0.705 (.335)
$D(DGD_2)$						-0.353 (.308)
$D(DGD_3)$						-1.172 (.421)
$D(DGD_4)$						-0.917 (.298)
$D(DGD_5)$						-0.253 (.481)
$\hat{T}_{2F}$		-2.05 (-2.19)	0.420 (.433)	2.62 (2.91)	-0.033 (.084)	0.001 (.001)
$\hat{T}_{2W}$	-0.148 (.07)		-0.121 (.07)	-0.02 (-.15)	-0.015 (.016)	0.00002 (.00001)
$\hat{T}_{1F}$	-0.186 (.154)	0.25 (.56)		-2.53 (-5.81)	-0.013 (.038)	-0.001 (.0007)
$\hat{T}_{1W}$	-0.028 (.045)	0.13 (.94)	-0.325 (.063)		-0.048 (.015)	-0.0002 (.0001)
$\hat{X}_F$	-0.708 (.328)	3.61 (1.84)	-0.152 (.63)	3.60 (1.68)		0.004 (.003)
$\hat{Liv}$	242.28 (84.49)	79.76 (2.22)	112.82 (160.5)	-414.53 (-1.29)	-103.52 (38.25)	
Constant	529.91 (445.92)	-1376.00 (-1.02)	-968.6 (840.7)	-1809.7 (-1.11)	-596.47 (224.59)	-0.166 (1.18)
R^2	.07		.14		.14	
F	3.87		11.44		11.92	
S.E.	627.78		1150.1		245.80	

Standard errors in parentheses.

[a] Estimated with Tobit, normalized asymptotic t-ratios in parentheses.

[b] Estimated with Probit, standard errors in parentheses.

The existence of livestock enterprise, i.e., Liv = 1, substantially increases the hours of annual farm labor and market labor for the wife, and reduces the operated acres of the farm. The increases in hours of work by the wife are 58% of the average observed annual hours of farm labor and 28% of the average of hours of market labor. The reduction in farm size is 31% of the observed average operated acres.

The relative insensitivity of the demand for household farm choice inputs with respect to the supply market labor is strongly demonstrated. At the same time, market labor supplies are shown to be sensitive to farm input demands. Cross-person effects are also evident, as well as scale effects in operated farm size and livestock enterprise.

The estimated coefficients on husband's market wage are positive and significant in the wife's farm labor, husband's farm labor, and husband's market labor equations. The elasticities of demand for the wife's farm labor and husband's farm labor are 3.50 and 0.87, respectively. The elasticity of supply of the husband's market labor with respect to his wage is 2.52. An increase in the wage offer induces increased market labor supply by farm husbands and apparently some replacement or increased farm labor by the wife.

The coefficients on husband's age and education are significant in most equations. Increases in husband's age reduce his wife's and own farm labor, reduce the probability of a livestock enterprise and increase the operated acres. A one year increase in the level of formal education of the husband reduces his wife's annual farm labor by 59 hours and approximately double that amount in his own farm labor reduction.

The presence of very young children, up to 5 years of age, results in large decreases in the wife's annual hours of market and farm labor. The much larger impact on market hours may reflect the differences in opportunities to perform some tasks in farm production while also providing child care when compared to market labor. The presence of slightly older children is also shown to have a large negative effect on the wife's annual hours of market labor. The importance of children and endogenous farm inputs in the wife's farm and market labor equations may act to reduce the influence of wages by themselves.

The estimated coefficients of permanent other income are negative and show roughly equal magnitudes in the husband and wife farm labor equations, although only significant in the wife's equation. The coefficient on permanent other income is positive and significant in the operated acres equation. The estimated elasticities of demand for wife's farm labor and operated acres with respect to permanent other income are -0.05 and 0.03. Again the demands for household choice variables in farm production appear to be relatively insensitive to nonfarm variables. The estimated coefficients on permanent farm income are negative in the wife's market labor equation and positive in the operated acres equation. The elasticities for wife's market labor supply and operated acres with respect to permanent farm income are -0.47 and 0.06. A differential exists in the impacts of the permanent income measures. Some increased sensitivity appears to exist to changes in permanent farm income.

VI. Summary and Conclusions

We have shown that simultaneity exists in farm household choice variables of farm and off-farm labor, land input, and livestock enterprise. The demands for household choice inputs in farm production are shown to be relatively insensitive to the supplies of market labor by the husband and wife. Market labor supplies, on the other hand, are found to be sensitive to farm input demands. Income and wage effects are found to be significant in the determination of farm and off-farm labor decisions and these labor decisions are made simultaneously with the land input.

Policy implications are complex due to the cross-person effects. Policies which successfully increase permanent farm and other income will reduce the annual hours of farm labor for both husband and wife and market labor the wife. And, increasing operated acres, allowing an apparent substitution of land for own farm labor. The income effect seems to operate strongly on the scale effect of household production, altering nonmarket time allocations.

Policies which increase the relative attractiveness of livestock enterprises increase the farm labor inputs of the wife and decrease operated acreage. It would appear that the farm household tends to reduce land inputs rather than increase the husband's farm labor input in the presence of a livestock enterprise. Thus, such enterprises become much more time intensive relative to other farm types.

Policies attempting to increase wages or market labor opportunities for farm family members do not appear to change relative factor intensities. Wages alone do not appear to influence the wife's time allocation to market and farm labor. The elasticity of supply of the husband's market labor is 2.52, however increases in the husband's market labor, reduce the operated acres and husband's annual hours of farm labor. The impacts of rising wage offers for market labor then depend heavily on the household's view of comparative advantage in market and nonmarket (household and farm) production between husband and wife.

Footnotes

1. Our view is that Y_H, T_{1L}, and T_{2L} are each composite goods. We assume that the household utility function, equation (1), is weakly separable in the underlying components of these composite goods so that Y_H, T_{1L}, and T_{2L} are appropriate subaggregates. This requires that the marginal rate of substitution between any two components of a given composite good be independent of the consumption of all goods outside the composite good.

2. Some researchers, e.g., Rosenzweig and Wolpin (1980), and Fleisher and Rhodes (1979), consider a household's completed family size to be a choice variable. Others, Heckman (1979, 1980), and Cogan (1980) continue to treat the number of children as exogenous. Our approach seems to be consistent with completed family size being endogenous, provided age distribution of a household's children is random.

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

4. The truncation of the error term in the wage offer equation is clearly developed in Cogan (1980). The expected value of $e_{jW} \neq 0$ due to the severe truncation of the distribution of observed hours of off-farm wage work.

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

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

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