1988

ESTIMATING THE DEMAND RELATIONSHIPS BETWEEN AGRICULTURAL INPUT USE AND FARM CREDIT*

by

John W. Kimble

Calum Greig Turvey

and

Timothy G. Baker**

Credits Agricultural

*Selected paper, 1988 AAEA annual meetings, Knoxville, Tennessee, August 1-3, 1988.

**Cal Turvey is assistant professor, Department of Agricultural Economics and Business, University of Guelph. John Kimble is a graduate research assistant, and Tim Baker is associate professor in the Department of Agricultural Economics, Purdue University.

ESTIMATING THE DEMAND RELATIONSHIPS BETWEEN AGRICULTURAL INPUT USE AND FARM CREDIT

ABSTRACT

A multiproduct cost function is used to investigate the influence of operating and mortgage interest rates on farm input use. Results show that there are substantial substitution and complementarity effects between input usage and debt indicating a need to more closely examine the interrelationships between production and finance.

ESTIMATING THE DEMAND RELATIONSHIPS BETWEEN AGRICULTURAL INPUT USE AND FARM CREDIT

The purpose of this paper is to investigate the influence of changing interest rates on the demand for farm inputs and the influence of changing input prices on the demand for farm operating and mortgage credit. Although there has been considerable debate on the role of real money balances on aggregate production functions (Sinai and Stokes; You; Nguyen) and agricultural production functions (LeBlanc et. al.) there has been no investigation as to the role of interest rates.

The effects of changing interest rates on farm input use merits examination. In Indiana the cost share of total farm debt increased from 4.7% in 1960 to 17.16% in 1983, exceeding the cost shares of feed (13.7%), and fertilizer, (9.9%). These numbers raise specific questions about farm operating behavior; as interest rates increase, and hence, the effective cost of inputs, does farm input use decrease? As input prices increase do farmers tend to increase or decrease their debt holdings? The answers to these questions have important implications for agricultural production economics, agricultural finance, policy analyses and banking.

This paper uses a translog cost function to estimate output compensated demand elasticities for operating and mortgage credit in Indiana. The formulation differs from conventional duality theory in that intangible (non-physical) inputs, operating and mortgage credit, are considered part of the production process. The demand functions for credit are Hicksian compensated and are expressed in terms of farm output and the prices of farm inputs. Hence the influence of factor substitution and expansion effects can be examined. In order to justify the use of non-physical inputs in the production process the envelope theorem is used to derive duality results which are consistent with Shephard's derivative property.

METHOD

The Credit Demand Function

As interest rates increase, and the cost of borrowing increases, it is expected that farmers reduce farm inputs until the marginal value product of the input equals the cost of the input plus the cost of credit (Baker). Similarly a reduction in product prices causes an increase in input demand which increases the demand for credit. As such the credit demand function can be expressed in terms of the demands for all inputs.

(1) $M = m(X(P,r,Y))$

Where $X(P,r,Y)$ is the vector of Hick's output compensated demand functions expressed in terms of factor prices, P, the interest charge on credit, r, and outputs Y.

Following the envelope theorem outlined in Beattie and Taylor, it is shown that Shephard's lemma can be used to derive the demand for credit from a dual indirect cost function. Satisfying this envelope condition implies that the cost function is increasing in P, r and Y, concave in P and r, and convex in Y. The cost function is homogenous of degree 1 in P and r. The compensated demands, $X(\cdot)$ and $M(\cdot)$, are homogenous of degree zero in P and r. The primal production function is concave and increasing in $X(\cdot)$ and $M(\cdot)$.

The indirect cost function is defined as the sum of factor prices times output compensated demands for each of the inputs;

(2) $$C(P,r,Y) = \sum_{i=1}^{n} P_i X_i(P,r,Y) + rm(X(P,r,y))$$

Where P is a vector of input prices $P=(P_1...P_n)$; Y is a vector of output quantities $Y = (Y_1...Y_m)$; X(P,r,Y) is a vector of factor demands $X(\cdot) = (X_1(\cdot)...X_n(\cdot))$; r is the price of credit; and m(X(P,r,Y)) is the demand for credit expressed in terms of the quantity demanded for each of the n physical inputs.

Differentiating (2) with respect to r yields

$$(3) \quad \frac{\partial C(P,r,Y)}{\partial r} = \sum_{i=1}^{n} P_i \frac{\partial X_i(P,r,Y)}{\partial r} + m(X(P,r,Y)) + r\frac{\partial m(X(P,r,Y))}{\partial X(P,r,Y)} \cdot \frac{\partial X(P,r,Y)}{\partial r}.$$

The implicit production function for the farm firm can be expressed in terms of physical and non-physical inputs and outputs as

$$(4) \quad 0 = F(Y_1...Y_m; X_1(P,r,Y)...X_n(P,r,Y,); m(X[P,r,Y]))$$

for fixed output levels ($dY_1 = dY_m = 0$) the total differential of (4) with respect to r and P_i are

$$(5a) \quad 0 = \sum_{i=1}^{n} \frac{\partial F(\cdot)}{\partial X_i(\cdot)} \frac{\partial X_i(\cdot)}{\partial r} + \frac{\partial F(\cdot)}{\partial m(\cdot)} \left[\sum_{i=1}^{n} \frac{\partial m(\cdot)}{\partial X_i(\cdot)} \frac{\partial X_i(\cdot)}{\partial r}\right], \text{ and}$$

$$(5b) \quad 0 = \sum_{i=1}^{n} \frac{\partial F(\cdot)}{\partial X_i(\cdot)} \frac{\partial X_i(\cdot)}{\partial P_i} + \frac{\partial F(\cdot)}{\partial m(\cdot)} \left[\sum_{i=1}^{n} \frac{\partial m(\cdot)}{\partial X_i(\cdot)} \frac{\partial X_i(\cdot)}{\partial P_i}\right].$$

The primal minimization problem is

$$(6) \quad \text{Min}_{x,m}\ \theta = \sum_{i=1}^{n} P_i X_i + rM - \mu\,(F(Y_1...Y_m, X_1...X_n, M)).$$

The first order conditions for a minimum are

(7a) $$\frac{\partial\theta}{\partial m} = r - \mu\left[\sum_{i=1}^{n}\frac{\partial F(\cdot)}{\partial X_i}\frac{\partial X_i}{\partial r} + \frac{\partial F}{\partial m}\left[\sum_{i=1}^{n}\frac{\partial m}{\partial X_i}\frac{\partial X_i}{\partial r}\right]\right] = 0, \text{ and}$$

(7b) $$\frac{\partial\theta}{\partial X_1} = P_i - \mu\left[\sum_{i=1}^{n}\frac{\partial F(\cdot)}{\partial X_i}\frac{\partial X_i}{\partial P_i} + \frac{\partial F}{\partial m}\left[\sum_{i=1}^{n}\frac{\partial m}{\partial X_i}\frac{\partial X_i}{\partial P_i}\right]\right] = 0.$$

By 5a and 5b the bracketed terms in 7a and 7b are zero, hence $P_i = r = 0$. This implies that (3) can be reduced to

(8) $$\frac{\partial C(P,r,Y)}{\partial r} = m(X(P,r,Y)) = m(P,r,Y)$$

which is the derivative property analogue to Shepard's lemma for credit demand.

The Translog Cost Function

Elasticities are estimated using a multiproduct translog cost function for crops, Y_c, and livestock Y_l over the period 1950 to 1983.

(9) $$\ln C(P,r,Y) = \alpha_o + \sum_{y=c,l}\alpha_y \ln Y_y + 1/2\sum_{y=c,l}\alpha_{yy}(\ln Y_y)^2$$
$$+ \sum_{y=c,l}\sum_{i=1}\alpha_{yi}\ln Y_y \ln P_i + \sum_{i=1}^{n}\alpha_i \ln P_i$$
$$+ 1/2\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}\ln P_i \ln P_j + \sum_{t=1}^{3} B_t D_t$$

Where the subscript y denotes output quantities, the subscripts i,j, denote input prices, and the subscript t denotes time period. In order to measure technological change three dummy variables were included in the model for the periods of 1950 through 1959 (t1), 1960 through 1969 (t2), and 1970 through 1979 (t3). These act as intercept shifters relative to the 1980 through 1983 time period.

The cost function was not measured directly. Logarithmic differentiation of (9) yields a system of marginal cost and factors share equations. The factor share equations result from applying Shephard's lemma. The dummy variables are included in each of the equations. The equations estimated are two marginal cost equations.

$$(10)\quad \frac{\partial \ln C}{\partial \ln y_y} = \alpha_y + \alpha_{yy} \ln Y_y + \sum_{i=1}^{n} \alpha_{yi} \ln P_i + \sum_{t=1}^{3} B_t D_t$$

and nine factor share equations,

$$(11)\quad \frac{\partial \ln C}{\partial \ln P_i} = \alpha_i + \sum_{y=c,1} \alpha_{iy} \ln Y_y + \sum_{j=1} \alpha_{ij} \ln P_j + \sum_{t=1} B_t D_t$$

where $\partial \ln C/\partial \ln Y_y = Y_y P_y/C$ if marginal cost pricing of output is assumed (Ray) and the cost shares are $\partial \ln C/\partial \ln P_i = P_i X_i/C$.

For the cost function (9) to be valid it is required that it is homogenous of degree 1 in prices. The share equations must, therefore, be homogenous of degree 0. In addition, the Hessian of the cost function must be symmetric. These restrictions are imposed on the system as:

$$\sum_{i=1}^{n} \alpha_i = 1; \qquad \alpha_{yi} = \alpha_{iy}; \qquad \alpha_{ij} = \alpha_{ji}$$

$$\sum_{i=1}^{n} \alpha_{yi} = 0; \qquad \sum_{j=1}^{n} \alpha_{ij} = 0.$$

Because the cost shares sum to 1, one of the share equations is redundant and dropped from the system. The dropped equation is the "other" share. Note that revenue shares need not sum to one (Ray). The ten equations were estimated as a restricted system using seemingly unrelated regression techniques (SUR).

Data

All quantity, share, and price data are gathered from the United States, Indiana, or the Corn-belt state statistical summaries (Indiana, Illinois, Iowa, Missouri, Ohio) for the years 1950 to 1983. In all there are 234 degrees of freedom before homogeneity and symmetry restrictions are imposed. The estimated system includes eight share equations (one share equation was dropped) and two marginal cost equations, each with nine explanatory variables. The marginal costs and cost shares (dependent variables) for Indiana are summarized in Table 1. The independent variables are quantity and price indices. Outputs for crops and livestock were measured by quantity indices for the corn belt region of the United States (USDA, ERS). Price indices for feed, livestock replacement (stocker), seed and fertilizer are aggregate indices of prices paid by farmers in the United States (USDA, ERS) since no regional or state summaries for these data are available. The wage rate is the wage paid to family and non-family labor for Indiana (Indiana Crop and Livestock Summary). The land price is taken as the index number of average value per acre for Indiana farm real estate (Indiana Crop and Livestock Summary). The price of other goods is the United States Price Index of prices paid by farmers excluding interest, taxes and wages (USDA, ERS). The operating and mortgage interest rates are taken from a series compiled by Lucier, Chesley, and Ahearn and are effective interest rates which include interest costs on new and old debt. All price and quantity series are converted to 1967 as the base year (1967 = 100).

Results

Econometric results are presented in Table 2 and the elasticities of substitution and Allen partial elasticities of demand are presented in Tables 3 and 4.

Of the 110 estimated parameters (Table 2) 58 were statistically significant at the 5% level. Of the 40 intercept and intercept shift parameters 26 were statistically significant at the 5% level. This indicates that for most inputs and outputs the marginal cost and cost shares underwent substantial changes over the 34 year period. The cost shares for seed and fertilizer have remained virtually constant relative to the 1980 - 1983 period. Labor and land inputs remained constant through the 1960's and 70's but show substantial increases in the 1950's.

The two share equations for farm operating and mortgage credit show substantial and significant increases throughout the 34 year period indicating an increase use of leverage in farm production. The fact that these two cost share equations are the only ones in which all intercept and dummy variable coefficients were significantly different from zero reinforces the claim that credit is an important input into the production process.

Imposing symmetry and homogeneity on the system of demand equations allowed for the recovery of the 9th share equation, "other". The 9 x 9 elasticity matrix in Table 3 shows the compensated own and cross price elasticities of the nine inputs. Examination of the diagonal elements reveal that at the point of approximation (the simple mean of shares) all own price elasticities are negative which is consistent with the theory. Both operating and mortgage credit have own price effects which are elastic. Long term credit is more elastic than operating credit (-2.07 vs. -1.41). Since long run credit in this model is used primarily for land (real estate) purchases it is not surprising that both are own price elastic. An increase in the effective interest rate on long term debt of 1.% decreases the demand by 2.07%. Hence, Indiana farmers have shown a marked response to increased interest rates. Similarly as the effective price of operating credit increases farmers decrease their demand for this input.

Positive cross elasticities indicate complementary factors and negative cross elasticities indicate substitutable factors. The substitution complementarity relationship between physical inputs are consistent with previous work. With the exception of seed and mortgage, operating credit substitutes for physical inputs. A 1% increase in the price of operating credit causes a .04% decrease in the demand for fertilizer. Similarly a 1% increase in the price of fertilizer causes a .12% fall in the demand for operating credit. With the exception of labor and "other" categories, farm inputs are complementary with respect to mortgage credit. This is expected since expansion in the demand for farm real estate is likely to cause increased demand for mortgage credit. As more land is made productive the demand for farm inputs including operating credit will increase.

The Allen partial elasticities of substitution measures cross elasticity effects of farm inputs holding all other inputs constant. Hence these reflect the relative importance of the factor shares (Binswanger). Examination of the cross elasticities in Table 4 reveal the importance of mortgage and operating credit in production response relative to the physical inputs. In fact the complementarity and substitution relationships show substantial influences on the physical input demands. This is much more prevalent with mortgage credit than operating credit.

The estimated coefficients in the two marginal cost equations provide a measure of the elasticities of input demand with respect to scale. Positive parameter estimates indicate decreasing returns to scale and normal inputs. Negative parameter estimates indicate increasing returns to scale and inferior inputs. Credit is an inferior input into the livestock process but a normal input to the crop process. This suggest that mortgage credit is not being utilized to expand livestock facilities, but is being used to expand crop production. This conclusion is strengthened by the livestock quantity index increasing from a value of 89.1 in 1950 peaking at 100 in 1967 and decreasing to 90 in 1982. Over the same period of time the crop production index increased from 57.9 in 1950 to 155.8 in 1982. Similarly cash receipts from livestock sales decreased from 72.2% for total nominal cash receipts in 1950 to 39.8% of total nominal cash receipts in 1982.

The major result of this study is that operating and mortgage credit can enter the production process as non-physical inputs. There are decreasing returns to scale with respect to credit in crop production and increasing returns to scale with respect to livestock production. The majority of inputs are net substitutes with respect to operating credit and net complements with respect to mortgage credit.

Policies which are structured to reduce operating interest costs or factor prices may be counterproductive since in crop production farmers tend to increase the use of inputs, thus increasing output, as interest rates fall. Similar expansion is not found in livestock production. Policies which promote farm expansion through long-term borrowing tend to increase crop production and decrease livestock production. A less diversified economy can be destabilizing for the farm sector as a whole.

Rural banks and financial intermediaries should be aware of the substitution effects induced by changes in the interest rate on farm loans and changes in farm prices. An observed decrease in the price of most farm inputs can provide a signal to banks to increasing demand for operating credit. In both cases the elasticity measures presented in this paper provide an estimate of the magnitude of changes for the demand for credit in agriculture.

REFERENCES

Baker C. "Credit in the Production Organization of the Firm", American Journal of Agricultural Economics, 50-3 (1968):507-520.

Beattie, B.R. and C.R. Taylor. The Economics of Production, John Wiley and Sons, New York, 1985.

Binswanger H. "A Cost Function Approach to the Measurement of Factor Demands and Elasticities of Substitution", American Journal of Agricultural Economics, 56-3 (1974):377-86.

Ray S.C. "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77", American Journal of Agricultural Economics, 64-3 (1982):490-498.

Sinai A. and H. Stokes. "Real Money Balances: An Omitted Variable from the Production Function", Review of Economics and Statistics, 54-3 (1972):290-296.

LeBlanc, M., J.F. Yanagida and R.K. Conway. "The Derived Demand for Real Cash Balances in Agricultural Production", Western Journal of Agricultural Economics, 12-1 (1987):78-85.

Nguyen, H. V. "Money in The Aggregate Production Function", Journal of Money, Credit and Banking, 18-2 (1986):141-151.

Lucier, E., A. Chesley and M. Ahearn. "Farm Income Data: A Historical Summary", USDA, ERS Statistical Bulletin Number 740, 1985.

You, J.S. "Money, Technology and the Production Function: An Empirical Study". Canadian Journal of Economics, 14-3 (1981):515-524.

USDA. Agricultural Statistics, various issues.

USDA. "Indiana Crop and Livestock Statistics: Annual Crop and Livestock Summary", various issues.

Table 1. Definitions of marginal cost and cost share dependent variables (Indiana).

Scrop:	Total cash receipts from crop production divided by total costs.
Slive:	Total cash receipts from livestock production divided by total cost.
Sfeed:	Total expenditure on Feed for livestock divided by total cost.
Sstock:	Total expenditures on livestock divided by total cost.
Sseed:	Total expenditures on seed divided by total cost.
Sfert:	Total expenditures on fertilizer divided by total cost.
Slabor:	Total wages paid to farm laborers divided by total cost.
Sland:	Total taxes paid on land plus net rent to nonoperator landlords divided by total cost.
Sreal:	Total interest payments on real estate loans divided by total cost.
Snon:	Total interest payments on nonreal estate loans divided by total costs.
Sother:	Machinery repair, operation, hire and custom plus insurance plus depreciation plus miscellaneous divided by total costs.

SOURCE: Lucier, Eary, Ayres Chesley and Mary Ahearn, "Farm Income Data: A Historical Summary" USDA, ERS Statistical Bulletin Number 740, 1985.

Table 2. Seemingly Unrelated Regression Results for System of Marginal Cost and Cost Share Equations. (t-statistics in parenthesis).

	Intercept	Crop Quantity	Livestock Quantity	Feed Price	Stocker Price	Seed Price	Fertilizer Price	Wage	Land Value	Mortgage Interest	Operating Interest	Other Price	T1	T2	T3
SCROP	1.467 (4.115)	.0366 (.630)	-.229 (-4.123)	-.0273 (-1.706)	-.034 (2.416)	.010 (3.099)	.028 (1.882)	-.016 (-1.562)	.048 (2.084)	.006 1.549	.005 1.766	-.019 (-0.962)	-.073 (-1.521)	-.024 (.688)	.082 (3.139)
SLIVE	5.157 (6.072)	-.299 (-4.12)	-.810 (-4.885)	.0166 (4.133)	.172 (5.945)	.005 (.484)	-.005 (.138)	.105 (-3.584)	-.127 (-3.104)	-.018 (-1.492)	.010 -.989)	.089 (-1.563)	.123 (3.273)	.097 (3.391)	.019 (1.922)
SFEED	-.741 (-3.322)	-.027 (-1.71)	.166 (4.132)	.077 (3.589)	-0.013 (-1.361)	.007 (1.576)	.005 (.342)	-.0003 (-.027)	-.037 (-2.867)	-.050 (-10.01)	-.001 (-.329)	.013 (.538)	.025 (2.457)	.02 (2.557)	.020 (3.559)
SSTOCK	-.688 (-4.86)	-.034 (2.416)	.172 (5.945)	-.013 (-1.361)	.034 (3.405)	-.001 (-.409)	-.003 (-.301)	.009 (1.075)	-.0004 (-.036)	-.027 (-7.299)	.007 (2.028)	-.005 (-.234)	.038 (3.599)	.022 (2.839)	.01 (1.697
SSEED	.149 (-2.92)	.01 (3.099)	.005 (.484)	-.007 (1.567)	.001 (-.409)	.019 (4.804)	-.015 (-3.22)	-.016 (3.359)	.017 (-4.73)	.017 (-5.096)	-.005 (-1.878)	.013 (1.027)	.001 (.536)	.002 (.932)	.0008 (.625)
SFERT	-.222 (-1.124)	.029 (1.882)	.005 (.138)	.005 (.343)	-.003 (-.301)	-.015 (-3.22)	.068 (4.004)	.029 (2.289)	-.013 (-1.099)	-.037 (-7.673)	.001 (.198)	-.034 (-1.19)	-.016 (-1.495)	-.006 (-.763)	.005 (.8652)
SLABOR	.809 (4.693)	-.016 (-1.562)	-.105 (-3.584)	-.0003 (-.027)	.009 (1.075)	.016 (3.359)	.029 (2.289)	-.053 (-3.19)	-.022 (2.095)	.033 (5.80)	.011 (2.01)	-.067 (-2.365)	-.019 (-2.716)	-.004 (-.779)	.005 (1.337)
SLAND	.438 (1.916)	.048 (2.084)	-.127 (-3.014)	-.037 (-2.857)	-.0004 (-.036)	-.017 (-4.73)	-.013 (-1.10)	.022 (2.096)	-.133 (-7.097)	-.028 (-5.816)	.017 (4.857)	.189 (9.034)	-.037 (-2.262)	.009 (.7379	.013 (1.42)
SREAL	-.165 (-2.103)	.006 (1.549)	-.018 (-1.49)	-.05 (-10.01)	-.027 (-7.299)	-.017 (-5.10)	-.037 (-7.67)	.033 (5.80)	-.028 (-5.816)	-.047 (-7.94)	-.012 (-3.097)	.185 (12.79)	-.024 (-.806)	-.017 (-7.22)	-.02 (-12.4)
SNON	-.056 (-.879)	.005 (1.766)	-.009 (-.989)	-.001 (-.329)	.007 (2.028)	-.005 (-1.878)	.001 (.198)	.011 (2.01)	.017 (4.858)	-.012 (-3.097)	-.015 (-4.35)	-.003 (-.218)	-.016 (-6.998)	-.015 (-8.52)	-.018 (-14.4)

Table 3. Compensated Elasticities of Demand.

	Feed Price	Stocker Price	Seed Price	Fertilizer Price	Labor	Land Value	Mortgage Interest	Operating Interest	Other Price
FEED	-0.35814	-0.03298	0.07422	0.12726	0.04881	-0.10731	-0.27498	0.02426	0.49887
STOCKER	-0.10121	-0.29108	0.00152	0.03265	0.23183	0.11885	-0.47383	0.16202	0.31925
SEED	0.41967	0.00280	-0.27645	-0.44299	0.63222	-0.49430	-0.56966	-0.14246	0.87117
FERTILIZER	0.21438	0.01792	-0.13197	-0.17989	0.35603	-0.01471	-0.35374	0.04250	0.04949
LABOR	0.15201	0.23521	0.34815	0.65811	-1.99079	0.55377	0.70022	0.23963	-0.89631
LAND	-0.13519	0.04878	-0.11012	-0.01100	0.22403	-1.93398	-0.17725	0.17152	1.92320
MORGAGE	-1.02227	-.57394	-0.37451	-0.78063	0.83596	-0.52305	-2.07230	-0.24381	4.75453
OPERATING	0.11598	0.25242	-0.12047	0.12064	0.36796	0.65102	-0.31358	-1.41167	0.33770
OTHER	0.19005	0.03963	0.05869	0.01119	-0.10965	0.58156	0.48721	0.02691	-1.28558

Table 4. Allen Elasticities of Partial Demand.

	Feed Price	Stocker Price	Seed Price	Fertilizer Price	Labor	Land Value	Mortgage Interest	Operating Interest	Other Price
FEED	-2.26141	-0.63907	2.64993	1.35364	0.95981	-0.85364	-6.45494	0.73236	1.20001
STOCKER		-5.64109	0.05430	0.34731	4.53835	0.94542	-11.12270	4.89176	0.76795
SEED			-9.87085	-4.71221	12.43110	-3.93199	-13.37230	-4.30132	2.09557
FERTILIZER				-1.91353	7.00037	-0.11702	-8.30359	1.28320	0.11904
LABOR					-39.14410	4.40506	16.43710	7.23507	-2.15604
LAND						-15.38430	-4.16070	5.17867	4.62818
MORTGAGE							-48.64510	-7.36103	11.43680
OPERATING								-42.62150	0.81233
OTHER									-3.09241