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Abstract: This study examines the impact of multiple quasifixed assets on the imputed returns to farmland. The results indicate that the presence of additional quasifixed assets causes the true shadow value of farmland to deviate from its imputed value. The results also indicate that when the potential existence of multiple quasifixed assets is explicitly modeled, the shadow value of farmland approaches reported cash rental values.

***Keywords*:** quasifixed assets, farmland values, imputed returns.

Introduction

The issue of the valuation of farmland for agricultural purposes is a perennial topic of interest for agricultural policymakers and farmers. Between 1960 and 1999, farmland in the United States accounted for 70 percent of the agricultural assets. Thus, changes in farmland values can have significant consequences for the sector solvency and, hence, its financial viability. However, despite its important role efforts to explain changes in farmland values have met with limited success. Efforts to model land values as functions of the returns to farmland, interest rates and other factors have typically found that significant unexplained variation remains, particularly in the short-run. Schmitz (1995) indicates that while the present value formulation holds in the long-run, significant correlation in the residuals points to the existence of short-run disequilibria. This finding is consistent with the findings of Chavas and

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Thomas (1999) and Lence and Miller (1999) who find that transaction cost may limit the adjustment of farmland prices.

This study proposes a slightly different approach based on the construction of the data. Specifically, most studies of farmland valuation have analyzed the effect of residual returns on average farmland values (Moss (1997), Featherstone and Baker (1986)) while notable exceptions have used cash rents (Alston(1986)). The use of residual returns is consistent with the Ricardian notion of residual returns to the most fixed factor. The assumption is then that farmland is the most fixed factor in agricultural production in general. However, while farmland may be the most fixed factor of production, it is not the only fixed factor of production. For example, most agricultural machinery has limited value outside the sector, and farm labor and management may be fixed into agriculture in the short-run.[1] This study demonstrates how the presence of multiple quasi-fixed factors affects the measurement of residual rents. In general, the presence of multiple quasi-fixed factors implies that the rate of return to farmland is understated by residual measurement.

The Basic Imputed Value Problem

The literature on asset valuation is typically developed along two lines: the use of cash rents and imputed returns. In both cases, researchers are attempting to determine "what is the value of land in production?" The use of cash rents is based on the assumption that the value of land in a perfectly operating market can be observed as the price reached by a buyer and seller. This approach (cash rents), however, leaves the greater question unanswered.

[1] Most would agree that a significant amount of labor has left the sector in the post-war period. However, the labor leaving the sector may be mostly young making the career decision whether to remain in agriculture or leave. Once the decision to remain in agriculture is made, middle age producers have fewer options for either their labor or management.

Specifically, it does not address how the renter determines the value of farmland. The concept of imputed cash returns follows from the Ricardian notion of cash rents as that amount left over after all other factors of production have been paid. Following this basic notion, the appropriate return to farmland is the revenue less all variable costs minus an appropriate return for other factors such as labor, management, and capital. It is at this point that the traditional definition raises some difficulties. Specifically, we may ask: "what is the appropriate price for labor and capital?" To develop the answer to this question, we turn to the most basic profit maximization problem:

$$\begin{aligned} &\max_{x_1,x_2,x_3,x_4} p\, f(x_1,x_2,x_3,x_4) - w_1 x_1 - w_2 x_2 \\ &\qquad s.t.\ \ x_3 = x_3^0, x_4 = x_4^0 \end{aligned} \tag{1}$$

In this case, x_1 and x_2 are variable inputs and x_3 and x_4 are quasi-fixed inputs. Forming the optimization problem in Lagrange form:

$$L = p\, f(x_1,x_2,x_3,x_4) - w_1 x_1 - w_2 x_2 + \lambda_3\left(x_3^0 - x_3\right) + \lambda_4\left(x_4^0 - x_4\right) \tag{2}$$

Taking the first difference with respect to the variable inputs implies

$$dL = \left[p\frac{\partial f}{\partial x_1} - w_1\right]dx_1 + \left[p\frac{\partial f}{\partial x_2} - w_2\right]dx_2 + \left[p\frac{\partial f}{\partial x_3} - \lambda_3\right]dx_3 + \left[p\frac{\partial f}{\partial x_4} - \lambda_4\right]dx_4 \tag{3}$$

The first two terms relate the traditional equilibrium condition that the marginal value product equals the price of each respective input while the second two terms relate to the value of quasi-fixed inputs. Dividing through by the differential with respect to x_3 yields:

$$\frac{dL}{dx_3} = \left[p\frac{\partial f}{\partial x_1} - w_1\right]\frac{dx_1}{dx_3} + \left[p\frac{\partial f}{\partial x_2} - w_2\right]\frac{dx_2}{dx_3} + p\frac{\partial f}{\partial x_3} - \lambda_3 + \left[p\frac{\partial f}{\partial x_4} - \lambda_4\right]\frac{dx_4}{dx_3} = 0 \tag{4}$$

Developing this expression from left to right, if the current solution is optimum with respect to the two variable inputs, the first two terms on the right hand side of the equation are zero. Specifically, the level of each variable input is set so that its marginal value product is equal to its market price. Ignoring the last term for the moment, this result implies that at the maximum, the shadow value of the quasi-fixed variable equals its marginal value product. Next, solving explicitly for the shadow value of x_3 assuming that the variable inputs are paid their marginal values, we have:

$$\lambda_3 = p\frac{\partial f}{\partial x_3} + \left[p\frac{\partial f}{\partial x_4} - \lambda_4 \right]\frac{dx_4}{dx_3} \tag{5}$$

Under this representation, the shadow value of x_3 is correctly imputed if either the return to x_4 is set equal to its true value, or the production function is separable in the inputs. Comparing this expression with the assumption that x_4 is a variable input yields:

$$\lambda_3 = p\frac{\partial f}{\partial x_3} + \left(\lambda_4 - w_4\right)\frac{dx_4}{dx_3} \tag{6}$$

where w_4 is the "market price" for input 4[2]. Using these results, we see that the marginal value of input 3 is overstated if $\lambda_4 > w_4$ and the two inputs are compliments. Alternatively, the shadow value of input 3 is understated if $\lambda_4 < w_4$ and the two inputs are compliments.

In conclusion, the appropriateness of imputed rates of return is dependent on the proper classification of variable and quasi-fixed inputs. If a quasi-fixed input is treated as variable by using a market price in place of a shadow value, then the imputed value of the input in question is misstated. By extension, these results also suggest that a dual specification is required to

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[2] This derivation is based on adding and subtracting $w_4 dx_4/dx_3$ to equation (5) yielding

$$\lambda_3 = p\frac{\partial f}{\partial x_3} + \left(p\frac{\partial f}{\partial x_4} - \lambda_4 + w_4 - w_4 \right)\frac{dx_4}{dx_3}$$

$$\lambda_3 = p\frac{\partial f}{\partial x_3} + \left(p\frac{\partial f}{\partial x_4} - w_4 \right)\frac{dx_4}{dx_3} + \left(w_4 - \lambda_4\right)\frac{dx_4}{dx_3}.$$

Assuming that x_4 is paid its true marginal value at the market price implies that

$$p\frac{\partial f}{\partial x_4} - w_4 = 0 \qquad \text{which yields (6).}$$

truly allocate the return to fixed factors when more than one fixed factor exists in the production function.

Empirical Model

Empirical models using quasi-fixed variables have most recently relied on a dual profit function. Assuming a multivariate form of equation (1) we could derive a profit function such that the optimal level of profit is a function of output prices, input prices and the level of quasi-fixed variables. Following the standard methodology, we choose a flexible function form based on some second-order expansion of the profit function:

$$\begin{aligned}\pi(p,w,z) = \alpha_0 + \alpha g(p) + \tfrac{1}{2} g(p)' A g(p) + \beta g(w) + \tfrac{1}{2} g(w)' B g(w) + g(p)' \Gamma g(w) + \\ g(z)\phi + g(z)' \Phi g(z) + g(p)' \Psi_1 g(z) + g(w)' \Psi_2 g(p)\end{aligned} \qquad (7)$$

where $\pi(.)$ is the profit, $\alpha, A, \beta, B, \Gamma, \phi, \Phi, \Psi_1$, and Ψ_2 are estimated parameters, g(.) is a general functional mapping the allows for either the quadratic, translog, or generalized Leonteif, p is the vector of output prices, w is the vector of input prices, and z is the vector of quasi-fixed variables. Applying Sheppard's lemma to the general profit specification in equation (7) yields a system of output supply and input demand equations which, together with the profit function, can then be estimated using either seemingly unrelated regression or maximum likelihood.

Given the estimated values, the derivative of the profit function with respect to each quasi-fixed input yields the estimated shadow value for each input. Assuming a normalized quadratic for explanatory purposes, the dual value of one of the quasi-fixed variables becomes

$$\lambda_i = \phi_i + \Phi_{\bullet i} z + \Psi_{1,\bullet i} p + \Psi_{2,\bullet i} w \qquad (8)$$

where $\Phi_{.i}$ denotes the i$^{\underline{th}}$ row the Φ matrix, $\Psi_{1,.i}$ denotes the i$^{\underline{th}}$ row of the Ψ_1 matrix and $\Psi_{2,.i}$ denotes the i$^{\underline{th}}$ row of the Ψ_2 matrix. Following standard procedures, the test for the effect of multiple quasi-fixed variables would then be a Wald test for

$$\lambda_i = r_i \; \forall \, i = 1,...k \tag{9}$$

where r_i is the observed market price for the i$^{\underline{th}}$ quasi-fixed variable. Single variable examples of this procedure in the agricultural economics literature include Chambers and Vasavada and Taylor and Kalaitzandonkes.

This study proposes a related, but somewhat different approach to valuing the quasi-fixed inputs. Specifically, starting with the profit function in equation (1):

$$p'y - w'x = \kappa_0 + \kappa_1 Land + \kappa_2 Labor + \kappa_3 Intermediate \tag{10}$$

where p is the output price, y is the level of outputs, w is the price of variable inputs, x is the level of variable inputs, Land is acres in agriculture, Labor is the labor hours used, and Intermediate is the quantity of intermediate capital. Explicitly, this specification examines whether residual profit is a function of land, labor, and capital. If each quasi-fixed input is in market equilibrium, then the estimated regression coefficient will equal the market price for each input. Focusing on the labor input (κ_2) will equal the wage rate if labor is in equilibrium. If the coefficient is less than the wage rate, labor is trapped in agriculture. If the estimated coefficient is greater than the wage rate, then some barrier of entry exists for labor. Focusing on the point of our analysis: if labor, or intermediate capital is significantly different from its market value, the residual approach systematically misstates the rate of return to farmland.

Comparing the formulations in equations (8) and (10), it is apparent that the formulation in equation (10) imposes a strong form of homotheticity on the production process. Specifically, the model in equation (10) does not allow for the shadow value of each input to change as the price of outputs or other quasi-fixed factors change. Implicitly, changes in relative output prices or input prices are assumed not to affect the values of each quasi-fixed input. Some support for this restriction can be found in Capalbo and Denny (1986). In the current study, we estimate the model specified in equation (10) using a cross-sectional data approach. Thus, the simple linear form of the model is parsimonious and will allow for the use of greater statistical information

Data

Data for the analysis are from 4 different (1996, 1997, 1998, 1999) Agricultural Resource Management Studies (ARMS). The ARMS is a collaborative effort between the USDA's Economic Research Service (ERS) and the National Agricultural Statistics Service (NASS) to annually collect and summarize information on farm resource use and finances. Unfortunately, since different farms are sampled each year, we do not have a longitudinal data set. The survey collects data to measure the financial condition (farm income, expenses, assets, and debts) and operating characteristics of farm businesses, the cost of producing agricultural commodities. In addition, the survey also collects information on time-spent working on the farm by the operator, spouses, and other unpaid family members, value of machinery and equipment on the farms, and total acres operated.

When survey data are collected using a complex stratified design, as in the ARMS, there is no easy analytical way to produce unbiased and design-consistent estimates of variance. The variance of survey statistics using standard statistical packages (such as SAS or SPSS) is inappropriate (Brick et al.). Therefore, the replication approach employing a delete-a-group jackknife method is used as the variance estimator (Kott, 1998). A major advantage of using the replication approach with the ARMS is that survey weight adjustments, such as for post-stratification and non-response, can be reflected in the variance estimates.

The dependent variable in this analysis (*G_INCOME*) measures the gross income to the farming operation. There are three independent variables in the model. The value of intermediate capital (*I_CAPTIAL*) were based on three categories of capital goods: (1) automobiles; (2) farm tractors; and (3) farm equipments and agricultural machinery excluding tractors. The variable, *OP_LAND*, is the total operated acres including owned, rented, and leased. The variable, *FO_LABOR*, measures the number of hours worked on the farm, as reported by the farm operator. The analysis is conducted at an aggregate level (U.S.) level for 4 years. Additionally, the analysis is conducted by farm size and for the Heartland region of the United States for the same years. The Heartland region is the major farming region of the United States.

Results

Two regressions were estimated for each year from 1996 to 1999. The first regression includes the intercept term. Excluding the intercept term in the second regression assumes that returns are fully exhausted among factors of production. Table 1 presents parameter estimates of the model at the aggregate level (U.S., 48 states). Results suggest that a dual specification is required to properly allocate the returns when more than one fixed factor. At the national level the coefficients for *FO_LABOR*, *OP_LAND*, and *I_CAPITAL* are all significant at the 5% level of significance or higher. The parameter estimates are consistent with or without the intercept term. Results indicate that in 1996 a dollar increase in intermediate capital (*I_CAPITAL*) increases gross farm income by 60 to 62 cents. The lowest estimates were obtained for year

1998, where a dollar increase in intermediate capital leads to a 42-cent increase in gross farm income.

The coefficient on labor (*FO_LABOR*) is significant at the 5% level of significance. The coefficient on *FO_LABOR* decreases in magnitude from 16.08 in 1996 to 10.82 in 1999. Results indicate that an additional hour spent on the farm by the farm operator increases gross farm income from approximately $16 in 1996 to $11 in 1999. However, if returns are fully exhausted then only the 1996 parameter estimate on *FO_LABOR* is significant. Basically, an additional hour spent farming increases gross farm income by approximately $6 in 1996 and $2 in 1999. These results are consistent with the fact that returns to farming were higher in 1996 and 1997 then they were in 1998 and 1999.

The coefficient on land (*OP_LAND*) is statistically significant for all 4 years at the 1% level of significance. However, the magnitude of the coefficient varies over time. Results show that an additional acre of land increased gross farm income by $154 in 1996 and $228 in 1997. A possible explanation is the increase in both current and expected returns to farming (Melichar). The shadow price of land (reflected by cash rents) decreased from a high of $228 in 1997 to about $90 in 1999. The estimated coefficient (shadow price) approaches the average cash rent charged by landlords. The fall in the cash rents (in 1999) reflects lower current and expected farm income.

Farm size has important effect on land, labor, and intermediate capital. In our analysis farm size ranges from small farms (such as limited resource, retirement, and residential farms), small farms focused on farming, i.e, farming is the main occupation of the farm operator (includes farming as main occupation: lower sales and farming as main occupation: higher sales), and large farms (large and very large family farms).

The parameter estimates of land, labor, and intermediate capital differ by farm size. Table 2 presents parameter estimates for seven different farm sizes for 1999. The coefficients on land and labor are significant for all sizes of farms at the 5% level of significance. However, the coefficient on intermediate capital (*I_CAPITAL*) is only significant for 5 farm sizes. The coefficient on *I_CAPITAL* for limited resource and retirement farms is not significant because many of these farms are small and have little intermediate capital. Limited resource and retirement farms are relatively more labor intensive than other farms. It is worth noting that the parameter estimates on land (*OP_LAND*), labor (*FO_LABOR*), and intermediate capital (*I_CAPITAL*) are higher in magnitude and statistically significant when returns are fully exhausted/allocated (without intercept) to factors of production.

In general, the estimates on land and labor are similar for three highest (gross income) farm sizes (farming as main occupation, high sales: large farms; and very large farms). If the returns were fully exhausted then operators of very large farms would increase their gross income three times as much as operators of large farms by working an additional hour on the farm. However, an additional acre of land would increase the gross income of very large farms by approximately $4. Further, an additional dollar decreases the gross farm income of very large farms by 3 cents when compared with large family farms.

Limited resource and residential farms are unique in their ways. For example, by working an additional hour on the farm, operators of limited resource farms could increase theirs gross farm income by approximately $11. On the other hand, the gross farm income of residential farms increases by approximately $12. However, the estimates become even smaller ($9) if the intercept is included in the regression. Any increase in intermediate capital has the largest impact on the residential farms. The coefficient on I_CAPITAL is statistically significant at the 1% level of significance. Results indicate that an additional dollar increase in intermediate capital increases gross farm income by 23 cents. Finally, the shadow price of land for limited resource farms is higher ($54) than for residential farms ($43). This indicates that farmland is more valuable to limited resource farmers than to residential farmers. However, comparing the results for limited resource farmers with large and very large farms, we see that the value of farmland is higher for larger farms than for limited resource farms. This implies that limited resource farmers are not able to compete with large farms in the farmland market at the margin.

Finally, Table 3 presents the estimates of land, labor, and intermediate capital for the Heartland region. The Heartland region is the major farming region of the United States. Farms in this region mainly grow corn, soybean, wheat, and other mix of enterprises such livestock (dairy, hog, and beef cattle). Farms in the Heartland account for 45% of the farms in U.S and 25% of the total wealth in the farm sector. The parameter estimates are statistically significant at 1% level of significance. Results are similar to the national level as reported in Table 1. Results indicate that, when returns are fully exhausted, an additional acre of land increases the gross farm income by $106 in 1996 and $108 in 1999. The shadow price of land is consistent with the trend in cash rent value in the Midwest. The trend in returns to labor and intermediate capital follows the returns to farm income in the regions and at the national level. In 1996 we observe that an additional dollar increase in intermediate capital (*I_CAPITAL*) increases gross farm income by 66 cents. However, the return to intermediate capital drops to only 12 cents in 1999. On the other hand, an additional hour spent working on the farm by the farm operator increases gross farm income by approximately $5 in 1996. A weaker farm economy and lower farm income in 1999 decreases the returns to labor to approximately $4.

Summary and Conclusions

This study examined the implications of multiple quasifixed inputs for the use of imputed returns to model farmland values. The results indicate that in several cases, inputs other than farmland may be valued below their market price. In these cases, using market prices for these inputs to impute the rate of return to farmland introduces noise to the estimation of farmland values. Assuming that the quasifixed variable complements farmland in the production process, the imputed value of farmland is lower than the actual shadow value of farmland in production.

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Table 1: Estimates of Land, Labor, and Intermediate Capital for U.S. (48 States) (1996-1999)

Year	Parameter Estimates			
	Intercept	Labor (FO_LABOR)	Land (OP_LAND)	Intermediate Capital (I_CAPITAL)
1999	-21026.00	10.82*	89.81***	0.9797***
1999		1.98	89.59***	0.9812***
1998	-22997.00	10.81**	203.24***	0.4195***
1998		1.65	201.67***	0.4191***
1997	-20277.00	12.57**	227.52***	0.7000***
1997		4.61	229.83***	0.7036***
1996	-25576.01	16.08***	154.08***	0.6061***
1996		5.73*	149.18***	0.6233***

Note: Single, Double, and triple asterisks indicate significance at 10, 5, and 1 percent level.
Source: Agricultural Resource Management Study (ARMS) survey, 1996, 1997, 1998, and 1999.

Table 2: Estimates of Land, Labor, and Intermediate Capital by Farm Typology, 1999

Farm Typology	Parameter Estimates			
	Intercept	Labor (FO_LABOR)	Land (OP_LAND)	Intermediate Capital (I_CAPITAL)
Limited Resource Farms	-0.88	11.24***	54.31*	0.0576
		11.24***	54.31*	0.0577
Retirement Farms	8366.39*	2.13	59.26***	0.0373
		6.64*	70.78***	0.0555
Residential Farms	8511.47*	9.09***	39.14***	0.2181***
		11.65***	42.53***	0.2327***
Farming Occupation (Lower-sales)	92420***	9.17***	42.88***	0.0923***
		32.98***	66.6***	0.1356***
Farming Occupation (Higher-sales)	262719***	7.46	65.06***	0.0938
		70.48***	97.51***	0.1534**
Large Farms	116002***	6.55**	69.46***	0.0530
		31.55***	101.41***	0.12017***
Very Large Farms	191630***	19.29**	68.82***	0.0179
		63.18***	104.775***	0.0933*

Note: Single, Double, and triple asterisks indicate significance at 10, 5, and 1 percent level.
Source: Agricultural Resource Management Study (ARMS) survey, 1999.

Table 3: Estimates of Land, Labor, and Intermediate Capital in Heartland Region (1996-1999)

Year	Parameter Estimates			
	Intercept	Labor (FO_LABOR)	Land (OP_LAND)	Intermediate Capital (I_CAPITAL)
1999	7084.16	0.54	89.034***	0.1089***
1999		3.78*	108.52***	0.1187***
1998	714.86	6.11**	109.42***	0.1774***
1998		6.57**	110.04***	0.1777***
1997	1393.45	4.86***	111.13***	0.2317***
1997		5.67***	112.36***	0.2345***
1996	-20556.00	13.80***	111.47***	0.6500***
1996		5.02***	106.16***	0.6589***

Note: Single, Double, and triple asterisks indicate significance at 10, 5, and 1 percent level.
Source: Agricultural Resource Management Study (ARMS) survey, 1996, 1997, 1998, and 1999.