Cooperative and Investor-Oriented Firm Efficiency: A Multiproduct Analysis

by

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Articles

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A multiproduct variable cost function was used to compare the efficiency of midwestern cooperative and investor-oriented grain and farm supply firms. Results suggest that cooperatives are no less efficient in a variable cost sense than their investor-oriented counterparts. Concerning fixed input-variable cost elasticities, investor-oriented firms may be more effective in their use of plant and equipment, but cooperatives make more efficient use of other fixed inputs. However, both types of firms are overinvested in both types of fixed inputs.

With public support of cooperative agribusinesses generating closer scrutiny, the performance of cooperatives relative to investor-oriented agribusinesses continues to be an important area of research (Lang et al.; Schrader et al.).[1] In particular, there has been considerable debate about potential differences in economic efficiency between these two forms of firm organization (Babb and Keen; Porter and Scully). The primary purpose of this research is to analyze the issue of relative efficiency in the context of a multiple product cost function. By controlling for output level and mix, the multiple product cost function framework permits cost comparisons between hypothetical firms producing identical output bundles. Such a direct comparison allows cost differences due solely to variation in product mix to be disentangled from those differences that result from inefficiency. This approach represents an important extension of previous research in this area, which has failed to treat the issue of output diversity properly when making efficiency comparisons between cooperative and investor-oriented firms.

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Previous research has reported that both agribusiness experts and farmers perceive investor-oriented firms to operate more efficiently than cooperative firms (Boynton and Babb; Schrader et al.). This is the first hypothesis to be examined below. By contrast, cooperatives are believed to cater to farmer needs more effectively than their investor-oriented counterparts. In particular, they are seen as providing more services to their farmer-patrons with little regard for the profitability of such services. These additional services may raise operating costs for cooperatives relative to those of investor-oriented firms. If the output of these services is measured accurately, then the multiple product cost function framework will control for this difference in product mix, and any cost differences will be the result of inefficiency in the provision of services. However, the service output quantity is difficult to measure (for reasons discussed below), and measurement errors are likely. This suggests a second hypothesis, namely that cooperatives provide a higher level of services in their bundle of outputs. Indirect tests of this hypothesis are possible using the multiple product cost function.

The article begins with discussion of the theoretical model and a formal statement of the hypotheses to be tested. Cross-sectional data on 120 midwestern grain and farm supply firms are discussed in the second section. The empirical cost model is then developed and estimation of the model briefly considered. The results of this study are presented in the fourth section and then compared with results from previous research. The closing section summarizes the key findings and offers suggestions for further research.

Theoretical Model

In the short run, retail grain and farm supply firms are assumed to minimize variable costs, given vectors of outputs (Y), variable input prices (W), and fixed inputs (K). Solving the firm's short-run cost minimization problem yields the variable cost (C) function:

$$C = f(Y,W,K). \tag{1}$$

Writing equation (1) in logarithmic form and applying Shepherd's lemma gives a vector of variable input cost share equations:

$$S = g(Y,W,K) \tag{2}$$

where S is a vector of variable input cost shares.

The cost model summarized in equations (1) and (2) must be modified to permit examination of the two hypotheses posed in the introduction. Consider first the issue of relative efficiency. If cooperative firms are less efficient, then they must incur higher costs to produce a given output vector, holding variable input prices and fixed input levels constant. This hypothesis is formally stated as:

$$C_c(Y,W,K) > C_{io}(Y,W,K) \tag{H1}$$

where $C_c(Y,W,K)$ is the total variable cost incurred by cooperative firms to produce output vector Y holding variable input prices at W and fixed input levels at K, and C_{io} is the total variable costs incurred by investor-oriented firms to produce the same output vector, again holding variable input prices and fixed input levels constant. It is important to note that (H1) could be rejected for some combinations of (Y,W,K) and not for others—i.e., cooperative firms could be more efficient than investor-oriented firms for some output, variable input price, and fixed input levels and less efficient for others.

This formulation of (H1) controls for any cost differentials having to do with subsidized inputs, tax preferences, or differing output choices, given firm level data on output, variable input price, and fixed input levels. These are frequently offered as explanations for observed differences in firm efficiency, but this theoretical formulation abstracts from them by evaluating both cost functions at the same output, input price, and fixed factor levels.

Although this theoretical multiproduct model permits more accurate cost comparisons than more traditional single product models, models that ignore input prices, or models that assume long-run cost minimization, data limitations remain an issue. In practice, firm level price data are extremely difficult to obtain. In addition, measures of fixed inputs may be subject to the standard limitations of accounting data (Akridge; French). Hence, some measurement errors may persist even with this formulation.

Of additional interest is the question of efficient use of fixed inputs. In long-run equilibrium, the firm will substitute fixed inputs for variable inputs until the reduction in variable costs from an additional unit of capital stock is equal to the rental rate of a unit of capital:

$$\overline{V_K}C_i(Y,W,K) = -R \tag{3}$$

where $\overline{V_K}$ is the gradient of $C_i(Y,W,K)$ $(i = c$ or $io)$ with respect to K, and R is the vector of (positive) fixed input rental rates facing the firm. Due to the convexity of $C_i(Y,W,K)$ in fixed inputs (K), $\overline{V_{Kj}}C_i(Y,W,K) = -R_{ij}$ implies overinvestment in K_j. Without data on fixed input rental rates, it is impossible to draw any conclusions about fixed input use if this gradient is negative. However, if the gradient of the variable cost function with respect to a fixed input is positive, the firm is overinvested in this fixed input, regardless of the actual rental rate.

Comparison of the respective gradients at identical output, variable input price, and fixed input levels provides insight into the relative efficiency of fixed input investment by cooperative and investor-oriented firms. If cooperatives and investor-oriented firms are assumed to face the same vector of fixed input rental rates, then cooperatives are relatively more inefficient in their use of fixed inputs if the gradient of their variable input cost function with respect to a particular fixed input quantity is greater than the corresponding gradient for investor-oriented firms. The grain and farm supply firms in this study employ two fixed inputs—plant and equipment and other fixed inputs. For this case, the fixed input efficiency hypotheses can be stated formally as:

(H2) Cooperative firms are relatively more inefficient in their use of plant and equipment relative to investor-oriented firms:

$$\overline{V_{K1}}\ C_c(Y,W,K) > \overline{V_{K1}}\ C_{io}(Y,W,K) \tag{H2}$$

where $\overline{V_{K1}}C_i(Y,W,K)$ is the gradient of the variable cost function with respect to the quantity of plant and equipment.

(H3) Cooperative firms are relatively more inefficient in their use of other fixed inputs relative to investor-oriented firms:

$$\overline{V_{K2}}\, C_c(Y,W,K) > \overline{V_{K2}}\, C_{io}(Y,W,K) \qquad \text{(H3)}$$

where $\overline{V_{K2}}C_i(Y,W,K)$ is the gradient of the variable cost function with respect to the quantity of other fixed inputs.

For both (H2) and (H3), $\overline{V_{Kj}}C_c(Y,W,K)$ must be greater than zero. Note that if both gradients are negative, this test is inconclusive.

The second general hypothesis posed in the introduction cannot be directly tested in the framework summarized by equations (1) and (2) since output levels are exogenous in this model. In fact, if the difference between cooperative and investor-oriented firms is simply a matter of the level of services to be provided (all else constant), then equations (1) and (2) take full account of this difference and there is nothing to be tested. However, the issue is more complex due to problems measuring the actual type and quality of service. If the service output is not measured correctly and if cooperatives do provide more of this output, then it would be possible to conclude that cooperatives were inefficient when in fact the cost difference was due to differences in product mix. The suggested relevance of services in cooperative firms' product mix suggests that an indirect test of the hypothesis that cooperatives provide more service is needed.

Services like feed grinding, custom fertilizer application, and petroleum delivery tend to be relatively high cost/low profit outputs, but they are presumably in demand by farmers. The level at which these services are provided is difficult to measure with available budget data. Firms typically track revenues generated from such services. However, in many instances, the price charged for the service does not cover the full cost of providing the service and some of the cost is recovered through the margin earned on an associated product. An example would be the cost of delivering and applying fertilizer for a farmer. Some firms may price such a service at full cost, while other firms may charge a lower per-acre price for the service, recovering the remainder of the cost through a higher price for the fertilizer. This practice leads to an understatement of the level of services provided when service revenue dollars are used to measure the service output.

If cooperatives' service prices are typically lower than those of investor-oriented firms and both types of firms are equally efficient in the provision of services, then a measure of service quantity based on sales dollars will understate the true quantity of services provided by cooperatives. Hence, for any given observed level of service output, cooperative variable costs will be higher than those of investor-oriented firms since the observed level of services for cooperatives is understated. This cost difference, driven solely by measurement error, would be attributed to inefficiency in the model presented in equations (1) and (2). Evidence on the likelihood of this problem will make interpretation of the (H1) test more straightforward.

Among the outputs of a retail grain and farm supply operation, services are unique. For most products typically handled by these firms such as

Table 1.—Tabulation of Retail Grain and Farm Supply Firms by State and Form of Organization

	Form of Organization					
	Cooperative		Investor-Oriented		Total	
State	Number	Percent	Number	Percent	Number	Percent
Illinois	22	18.3	12	10.0	34	28.3
Indiana	34	28.3	23	19.2	57	47.5
Iowa	10	8.3	10	8.3	20	16.7
Kansas	8	6.7	1	0.8	9	7.5
Total	74	61.7	46	38.3	120	100.0

grain, fertilizer, feed, petroleum, chemicals, and so on, the firm acts as a reseller, buying the products from a wholesaler or manufacturer and then selling them to farmers with little or no physical transformation of the product. For services, the retail grain and farm supply firm combines capital, labor, and energy in order to provide a transformed product. Hence, we would expect a firm that has a higher quantity of services in the product mix to use more labor and energy than does a firm producing a lower quantity of services. The labor and energy intensive nature of the service output can be used to formulate two indirect tests of the service hypothesis:

(H4) Cooperative firms are more labor intensive than investor-oriented firms:

$$S_{cL}(Y,W,K) > S_{ioL}(Y,W,K) \qquad \text{(H4)}$$

where $S_{iL}(Y,W,K)$ is the labor variable input cost share.

(H5) Cooperative firms are more energy intensive than investor-oriented firms:

$$S_{cE}(Y,W,K) > S_{ioE}(Y,W,K) \qquad \text{(H5)}$$

where $S_{iE}(Y,W,K)$ is the energy variable input cost share.

Note that $S_{ij}(Y,W,K)$ is obtained by partially differentiating $\ln C_i(Y,W,K)$ $(i = c$ or $io)$ with respect to the logarithm of the jth variable input price. Again, all tests are conducted holding output, variable input price, and fixed input levels constant for both groups of firms.

Data

Output, variable input cost, and fixed input data were obtained from a cross-section survey of 301 retail farm supply firms conducted in 1980 for a study comparing cooperative and investor-oriented firm performance (Babb and Keen; Keen). Sample firms were located in Illinois, Indiana, Iowa, and Kansas (table 1). Single location firms and branches of multiple-outlet firms were included in the sample. The output mix for the sample firms included a maximum of seven products—grain, fertilizer, petroleum, feed, chemicals, services, and other farm supplies.

After correcting coding errors, using available price information to impute missing output quantities and eliminating any remaining observations with incomplete data, a sample of 120 usable observations remained. Summary statistics for the 120-firm sample are presented in table 2. Some 62 percent of the sample firms were cooperatives and the remaining 38 percent were investor-oriented firms. The cooperative firms tended to be larger than the investor-oriented firms. In particular, the average cooperative reported much higher volumes of fertilizer and petroleum sales than did the average investor-oriented firm (table 2).

Construction of the cost, output, variable input price, and fixed input quantity variables is outlined below. A detailed discussion of the data set is presented in Akridge.

Variable Costs: Total variable costs were defined as those costs that change in response to changes in the level and mix of outputs produced by a firm during its fiscal year. Variable costs were divided into three categories: labor, energy, and other variable inputs. The labor category included all salary and wage expenses, payroll taxes, personnel insurance, and other personnel benefits. The energy category consisted of utility expense, grain dryer expense, and outlays for gasoline and motor oil. The residual category, other variable inputs, included selling and communications expenses, repair and maintenance outlays, demurrage, and other variable operating expenses such as office and warehouse supplies.

Outputs: Of the seven output categories, four were measured in physical units and three were based on sales dollars. Grain (bushels/year) was measured by total bushels of corn, soybeans, wheat, and other grains purchased during the fiscal year. Fertilizer (tons/year) represented the total annual sales of dry and fluid fertilizer and anhydrous ammonia. Petroleum (gallons/year) included all gasoline, diesel fuel, LP gas, and fuel oil sales. Feed (tons/year) was the total of bulk, bagged, and liquid feed sales.

In many instances, output sales dollars were reported but sales tonnages or bushels were not. Dropping all observations where output quantity data were missing would have severely limited the size of the data set. To infer the needed quantity data from available sales data reported in dollars, the data set was broken into 20 clusters (five from each state) of four contiguous counties each. The cluster median output price was obtained from those firms in the cluster reporting both sales dollar and physical unit data. This cluster median price was used to impute the missing physical sales quantity data from available sales dollar data.

The chemical output (dollars/year) was defined as total chemical sales divided by a chemical price index. Service revenue included receipts from grain drying and storage, feed grinding and mixing, and fertilizer custom application. The sum of revenues from these sources was deflated using a service price index to arrive at the service (dollars/year) output. Total general farm supply sales—including sales of seed, lumber, and hardware—were deflated using a general farm supply price index to measure the other farm supplies (dollars/year) output.

Variable Input Prices: No variable input price data were available from sample firms. Department of Commerce county-level wage data provided

Table 2.—Descriptive Statistics for Sample of 120 Retail Grain and Farm Supply Firms

	Cooperative Firms		Investor-Oriented Firms		Full Sample			
Variable[a]	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Minimum Value	Maximum Value
C—Variable Cost ($/yr.)	168,443	137,830	114,926	77,955	147,928	120,973	17,494	774,065
Y_1—Grain (bu./yr.)	1,055,233	806,720	795,990	556,356	955,856	729,588	0	4,054,578
Y_2—Fertilizer (tons/yr.)	2,356	2,972	573	1,597	1,673	2,672	0	13,209
Y_3—Petroleum (gallons/yr.)	451,578	863,667	12,252	58,985	283,170	710,567	0	4,189,554
Y_4—Feed (tons/yr.)	1,155	1,219	1,159	1,161	1,157	1,192	0	6,000
Y_5—Chemicals ($/yr.)	153,584	203,906	65,991	156,186	120,006	191,205	0	905,573
Y_6—Services ($/yr.)	112,778	89,730	67,483	61,834	95,415	82,910	0	416,782
Y_7—Other Farm Supplies ($/yr.)	279,655	732,836	120,439	225,843	218,622	595,634	0	4,624,082
W_1—Labor Price ($/yr.)	7,703.70	1,143	7,961.95	849.58	7,802.69	1,044.46	4,697.66	9,606.76
W_2—Energy Price ($/mil. btu)	3.24	0.28	3.26	0.23	3.25	0.26	2.75	3.63
K_1—Plant and Equipment ($)	294,303	254,464	127,066	98,711	230,196	223,771	4,475	1,302,571
K_2—Other Fixed Inputs ($)	27,446	19,752	22,729	17,241	25,638	18,896	3,369	97,457
S_1—Labor Share (% of Variable Cost)	59.95	8.70	57.11	13.82	58.86	10.98	24.36	78.12
S_2—Energy Share (% of Variable Cost)	15.57	7.62	24.89	12.60	19.14	10.79	2.68	54.16
S_3—Other Variable Inputs Share (% of Variable Cost)	24.49	10.76	18.01	8.96	22.00	10.55	5.33	52.52

[a]Costs and variable input prices measured in 1977 dollars.

the needed labor price information. The wage rate for the nondurable wholesale goods industry was averaged over the four counties in each cluster, and this cluster average was used as the labor price (dollars/year) for all firms in the cluster. The state average energy price for the commercial sector served as a proxy for the price of energy (dollars/million btu). Finally, other variable inputs were assumed to follow the general price level of the economy. The implicit GNP price deflator was used as a proxy for the price of all other variable inputs.

Fixed Inputs: The accounting book value of assets as reported on the balance sheet was divided by a price index for machinery and equipment to arrive at the measure of plant and equipment investment. Other fixed inputs included insurance, state and local taxes, professional services, and rent and lease expense. The sum of these items was divided by the implicit GNP price deflator to determine the quantity of other fixed inputs employed.

Procedure

Empirical Model: The multiproduct variable cost model should permit neutral shifts in costs between cooperative and investor-oriented firms. In addition, the fixed input elasticities and variable input cost shares should be allowed to vary in order to test the hypotheses that cooperatives are more inefficient in their use of fixed inputs and that they provide higher levels of service than investor-oriented firms.

The general model takes a form similar to the Lau and Yotopoulos efficiency model:

$$C = f(D,Y,W,K) \quad (4)$$

$$S = g(D,Y,W,K) \quad (5)$$

where D is a zero-one variable permitting differences in cost response between cooperative and investor-oriented firms. The variable D is incorporated in the empirical formulation of equations (4) and (5) to (a) permit a neutral cost shift between the two groups, (b) reflect relative differences in fixed input investment, and (c) allow the variable input cost shares to differ.

Functional Form: Various flexible functional forms are available to formulate the estimating model. The translog is a popular choice, but is inadequate when the number of zero output observations is large (Cowing and Holtman). In this sample, no single firm produced all seven outputs. And, although 117 (97.5 percent) of the firms provided services, only 40 (33.3 percent) sold petroleum. An alternative functional form is the generalized translog (Caves, Christensen, and Tretheway).[2]

The generalized translog uses the Box-Cox metric on the output terms to eliminate the problem caused by zero output values. Applying the Box-Cox metric to the output variables gives:

$$y_{ij}' = \frac{(y_{ij}^{\lambda} - 1.0)}{\lambda} \quad (6)$$

where y_{ij}' is the transformed observation on the <u>jth</u> output (i = c or io) and λ is the Box-Cox parameter (which must be estimated).

Estimation: The full estimating form of the generalized translog model is shown in the appendix. All variables are scaled over their (full sample) arithmetic mean. This is the point of local approximation in the generalized translog model. Nonlinear seemingly unrelated regression using the Gauss-Newton iterative minimization algorithm was employed to estimate the generalized translog model (SAS). Nonlinear SUR estimates have unknown small sample properties, but are asymptotically efficient.

Hypotheses Testing: The modifications of the standard multiproduct variable cost model that permit the hypotheses tests are shown below:

$$\ln C = \theta_0 D + \theta_1 D W_1 + \theta_2 D W_2 + \gamma_1 D K_1 + \gamma_2 D K_2 + \ldots \tag{7}$$

where W_1 is the price of labor, W_2 is the price of energy, K_1 is the quantity of plant and equipment, and K_2 is the quantity of other fixed inputs. (The full model is shown in the appendix.)

Given the logarithmic formulation of the model and the arithmetic mean scaling of the data, all variables except the intercept term dropped out when the cost function was evaluated at sample mean output, variable input price, and fixed input levels. Hence, testing (H1) required a standard t-test of the estimated parameter θ_0 above. The remaining hypotheses were also tested using a t-test of the appropriate estimated parameter from equation (7). Finally, a joint test of all the parameters on the zero-one variables was conducted as a more general test of differences in the cost structure of cooperative and investor-oriented firms.

Results

The estimated parameters for the generalized translog variable cost function are presented in table 3. The estimated model generally satisfied the output monotonicity condition. Only the grain cost elasticity was negative when evaluated at the arithmetic mean for all variables.[3] The variable input cost shares were positive, implying monotonicity in variable input prices. Symmetry conditions and homogeneity in variable input prices were imposed on the estimating model. These results implied that the estimated variable cost function was generally consistent with economic theory (Varian).

When all output quantities, variable input prices, and fixed input quantities were held at arithmetic mean levels, we rejected the hypothesis that cooperatives are less efficient than investor-oriented firms (H1). The estimated parameter on the zero-one intercept variable D (θ_0) was not statistically significant at the 0.10 level (table 3). In fact, the parameter carried a negative sign, which suggested that cooperatives are actually more efficient than investor-oriented firms when the cost function is evaluated at the arithmetic mean for all variables. Although the cost difference was not statistically significant, the cooperative firm producing the sample mean output vector incured total variable costs of $159,252—6.6 percent less than the $170,526 it cost the investor-oriented firm to produce the same output vector (table 4).

For the formulation of the estimating model given by equations (4) and (5), it is possible that investor-oriented firms would be more efficient than

Table 3.—Estimated Parameters for Retail Farm Supply Firm Generalized Translog Multiproduct Variable Cost Function[a]

Variable[b]	Estimated Parameter[c]	t-ratio	Variable	Estimated Parameter	t-ratio	Variable	Estimated Parameter	t-ratio
λ	0.4067**	5.23	$Y'_3Y'_4$	0.0246	0.83	$Y'_3 lnW_1$	0.0057	0.79
Intercept	0.1422	0.85	$Y'_3Y'_5$	-0.0137	-0.40	$Y'_3 lnW_2$	-0.0024	0.40
D	-0.0684	-0.52	$Y'_3Y'_6$	-0.1225*	-1.90	$Y'_4 lnW_1$	0.0075	0.85
Y'_1	-0.1134	-0.82	$Y'_3Y'_7$	-0.0637	-1.63	$Y'_4 lnW_2$	0.0043	0.55
Y'_2	0.0445	0.47	$Y'_4Y'_5$	-0.0495	-0.94	$Y'_5 lnW_1$	0.0174	1.39
Y'_3	0.0823**	2.01	$Y'_4Y'_6$	0.0550	0.94	$Y'_5 lnW_2$	-0.0271**	-2.56
Y'_4	0.1275*	1.79	$Y'_4Y'_7$	0.3950	0.55	$Y'_6 lnW_1$	0.0114	0.79
Y'_5	0.0403	0.41	$Y'_5Y'_6$	0.0628	0.51	$Y'_6 lnW_2$	0.0342**	-2.75
Y'_6	0.0792	0.58	$Y'_5Y'_7$	0.0379	0.49	$Y'_7 lnW_1$	-0.0035	-0.33
Y'_7	0.1106	1.40	$Y'_6Y'_7$	0.0177	0.22	$Y'_7 lnW_2$	-0.0153*	-1.74
$Y'_1Y'_1$	0.0618	0.27	lnW_1	0.5772**	23.56	$lnK_1\ lnW_1$	-0.0096	-0.66
$Y'_2Y'_2$	0.0978	1.08	lnW_2	0.2223**	10.59	$lnK_1\ lnW_2$	0.0177	1.50
$Y'_3Y'_3$	0.0685	1.50	lnW_1 *D	0.0271	1.12	$lnK_2\ lnW_1$	0.0464**	1.99
$Y'_4Y'_4$	-0.0781	-1.26	lnW_2 *D	-0.0799**	-4.02	$lnK_2\ lnW_2$	-0.0166	-0.86
$Y'_5Y'_5$	0.0427	0.61	$lnW_1\ lnW_1$	-0.1859**	-2.51	$Y'_1\ lnK_1$	-0.0278	-0.26
$Y'_6Y'_6$	0.1213	0.91	$lnW_2\ lnW_2$	0.1414	1.13	$Y'_1\ lnK_2$	0.1389	0.61
$Y'_7Y'_7$	0.0478	0.74	$lnW_1\ lnW_2$	0.1033*	1.68	$Y'_2\ lnK_1$	-0.0270	-0.25
$Y'_1Y'_2$	0.0699	0.52	lnK_1	0.0280	0.16	$Y_2\ lnK_2$	-0.1398	-0.66
$Y'_1Y'_3$	-0.0087	-0.11	lnK_2	0.4882	1.53	$Y'_3\ lnK_1$	-0.0506	0.98
$Y'_1Y'_4$	-0.0373	-0.56	lnK_1*D	0.1590	1.14	$Y'_3\ lnK_2$	0.0824	0.71
$Y'_1Y'_5$	-0.0890	-0.58	lnK_2*D	-0.2986*	-1.75	$Y'_4\ lnK_1$	-0.0188	-0.31
$Y'_1Y'_6$	-0.1103	-0.75	$lnK_1\ lnK_1$	0.0583	0.61	$Y'_4\ lnK_2$	0.0342	0.38
$Y'_1Y'_7$	-0.0374	-0.39	$lnK_2\ lnK_2$	-0.2397	-0.66	$Y'_5\ lnK_1$	-0.0490	-0.34
$Y'_2Y'_3$	0.0028	0.07	$lnK_1\ lnK_2$	0.1729*	1.67	$Y'_5\ lnK_2$	0.0726	0.36
$Y'_2Y'_4$	0.0304	0.71	$Y'_1\ lnW_1$	-0.0035	-0.19	$Y'_6\ lnK_1$	-0.0953	-0.91
$Y'_2Y'_5$	-0.0695	-1.05	$Y'_1\ lnW_2$	-0.0164	-1.07	$Y'_6\ lnK_2$	-0.0084	-0.07
$Y'_2Y'_6$	0.0454	0.44	$Y'_2\ lnW_1$	-0.0279**	-2.20	$Y'_7\ lnK_1$	0.0151	0.16
$Y'_2Y'_7$	-0.0055	-0.07	$Y'_2\ lnW_2$	0.0067	0.66	$Y'_7\ lnK_2$	-0.1288	-0.99

[a]Box-Cox transformation on output variables is given by: $Y'_i = :(Y_i^{\lambda} - 1.0)/\lambda$.
[b]Variable definitions are: Y_1 = grain, Y_2 = fertilizer, Y_3 = petroleum, Y_4 = feed, Y_5 = chemicals, Y_6 = services, Y_7 = other farm supplies, W_1 = labor price, W_2 = energy price, K_1 = plant and equipment, K_2 = other fixed inputs.
[c]Single asterisk indicates significance at the .10 level; double asterisk indicates significance at the .05 level.

Table 4.—Comparative Measures of Cooperative and Investor-Oriented Firm Performance[a]

Measure	Generalized Translog[b] Investor-Oriented	Cooperative
Variable Cost ($)		
Average Firm	170525.85	159252.00
Fixed Input Elasticity		
Plant and Equipment	0.028	0.187
Other Fixed	0.488*	0.189*
Cost Share		
Labor	0.577	0.604
Energy	0.222**	0.142**
Other Variable	0.201	0.254

[a]All measures calculated at arithmetic mean levels of outputs, variable input prices, and fixed inputs.
[b]Single asterisk indicates differences between cooperative and investor-oriented firms significant at the .10 level; double asterisk indicates difference significant at the .05 level.

cooperatives for some combinations of variable input prices and fixed input quantities and less efficient for others. Note, however, that changes in output level and mix would not affect the results presented here. Given a larger data set, incorporating a set of zero-one variables on the output terms to explore the impact of output changes on relative efficiency would be a useful area for further research.

The fixed input-variable cost elasticities and variable input cost shares are presented in table 4. For both cooperatives and investor-oriented firms, the fixed input-variable cost elasticities were positive for plant and equipment and other fixed inputs (table 4). For positive rental rates, a positive fixed input-variable cost elasticity implied overinvestment in fixed inputs. Assuming both groups of firms faced the same cost of capital, we rejected the hypotheses that cooperatives are less efficient in their use of fixed inputs relative to investor-oriented firms (H2 and H3).

The plant and equipment-variable cost elasticity difference for the two groups of firms was not statistically significant at the 0.10 level—i.e., the parameter on the $\ln DK_1$ term (γ_1) was positive and not significant (table 3). Although not significant, the plant and equipment elasticity was substantially larger for cooperative firms (table 4). If both groups of firms faced the same rental price for plant and equipment, the larger elasticity for cooperatives suggested the degree of overinvestment was greater in cooperatives (H2). Plant and equipment investment was expected to be heavier in service-oriented firms.[4] For other fixed inputs, the parameter on the $\ln DK_2$ term (γ_2) was negative and statistically significant at the 0.10 level (table 3). This suggested that cooperatives, although overinvested in this fixed input, are more efficient in their use of other fixed inputs relative to investor-oriented firms (H3).

The hypotheses that cooperatives are more labor intensive (H4) and energy intensive (H5) were rejected (table 4). The sign on the $\ln DW_1$ parameter (θ_1) was small and not statistically significant at the 0.10 level (table 3). At mean levels for all variables, this implied that cooperatives and investor-oriented firms employed nearly identical labor shares (H4). The sign on the $\ln DW_2$ parameter (θ_2) was negative and significant at the .05 level (table 3). Hence, the energy share for cooperative firms was considerably lower than the investor-oriented firm energy share (H5). The results for both the labor share and energy share failed to support the hypothesis that cooperatives provide more services than do investor-oriented firms. However, as indicated earlier, the cost share approach used here is a crude test of the service hypothesis. Additional research on the relationship between services and efficiency is needed.

Three of the five parameters on the zero-one variables were not significant at the 0.10 level (table 3). However, the joint test that the five cooperative zero-one parameters equal zero was rejected at the 0.01 level using the criterion function test procedure (Chi-square test) suggested by Gallant and Jorgenson. Although not conclusive, these results supported Babb and Keen's assessment of the relative efficiency of cooperatives when output level and mix are controlled. Porter and Scully found cooperative milk-processing plants to be much less efficient than investor-oriented plants using a single-product frontier production function approach. The results presented here suggest that careful modeling of the firm output vector is required to make valid efficiency comparisons.

Summary

This research has implications for the cooperative/investor-oriented firm efficiency debate. First, the more general cost model used in this study has reinforced earlier findings that cooperative firms are no less efficient in a cost sense than their investor-oriented counterparts. It is important to note that only variable costs were directly compared in this research. Comparing fixed input-variable cost elasticities, results suggest that investor-oriented firms may be more effective in their use of plant and equipment, while cooperatives make more efficient use of other fixed inputs. However, both types of firms are overinvested in both types of fixed inputs. Evidence on service levels presented here must be considered a first approximation. Cooperatives were no more labor intensive than investor-oriented firms and were actually less energy intensive. These results suggest the hypothesis of higher service levels in cooperatives should be rejected and hence reinforce the variable cost efficiency conclusion.

Finally, the variable cost function model developed in this paper can be used to investigate differences in economies of scale and scope between the two types of firms (Akridge and Hertel). Extension of the research presented in this article may offer much additional insight into the cooperative efficiency question.

Notes

1. For purposes of this paper, the term "investor-oriented" encompasses all agribusiness firms not organized as a cooperative.
2. Another possible functional form is the quadratic (Lau). Since no transformation metric is required for the quadratic functional form, zero output values do

not present a problem. Although the generalized translog is the preferred form, parameter estimates for this form are potentially unstable due to the nonlinear estimation process used to estimate the model. The quadratic model was estimated to explore the impact of functional form choice on the results (Akridge). Both the generalized translog and quadratic models lead to the same general conclusions. Hence, the quadratic model is not discussed in this article.

3. Using the full data set, Keen also reported an inverse relationship between grain volume and costs. However, his estimated parameter on the grain variable, like ours, is not statistically significant.

4. Real or perceived cost of capital differences may also account for this finding. As one reviewer pointed out, if cooperatives underestimate the price of equity capital from retained patronage refunds, they would underestimate the cost of capital and, hence, overinvest in fixed inputs.

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Appendix
Estimating Form of the Generalized Translog Variable Cost Model

The generalized translog variable cost function takes the form:

$$\begin{aligned} \ln C = {} & \alpha_0 + \theta_0 D + \sum_r \alpha_r y_r + \sum_i B_i W_i + \sum_i \Theta_i (D^* W_i) + \sum_k \gamma_k K_k + \sum_k \gamma_k (D^* K_k) \\ & + 1/2 \, [\sum_r \sum_s \alpha_{rs} y_r y_s + \sum_i \sum_j B_{ij} W_i W_j + \sum_k \sum_l \gamma_{kl} K_k K_l \qquad \text{(A.1)} \\ & + \sum_r \sum_i \sigma_{ri} y_r W_i + \sum_r \sum_k \varphi_{rk} y_r K_k + \sum_i \sum_k \Phi_{ik} W_i K_k \\ & + \sum_i \sum_r \sigma_{ir} W_i y_r + \sum_k \sum_r \varphi_{kr} K_k y_r + \sum_k \sum_i \Phi_{ki} K_k W_i] \end{aligned}$$

where C is total variable cost, y is the (transformed) output quantity, W is the price of variable inputs, K is the quantity of fixed inputs, and D is a zero-one variable equal to one if the observation is a cooperative firm and equal to zero if the observation is an investor-oriented firm.

The variable input cost share equations are given by:

$$S_i = \frac{\partial \ln C}{\partial \ln W_i} = B_i + \theta_i D + \sum_j B_{ij} W_j + \sum_r \sigma_{ir} y_r + \sum_k \Phi_{ik} K_k \qquad \text{(A.2)}$$

where S is the variable input cost share. The symmetry and homogeneity restrictions are imposed on equation (A.1) for estimation. In addition, the cost share equation for other variable inputs (the numeraire) is dropped from the system when estimating the model.