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A Nonparametric Efficiency Analysis for a Sample of Kansas Swine Operations

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ABSTRACT

This study evaluates the economic competitiveness of a sample of Kansas farrow-to-finish operations by estimating relative firm efficiency using nonparametric mathematical programming techniques. Measures of technical, allocative, scale, economic, and overall efficiency are then related to farm characteristics to identify sources of efficiency. Results indicate that overall efficient farms produce a high quantity of pork per litter, produce a portion of their own feed grains, generate a large portion of their income from swine and other livestock enterprises, and have a lower debt-to-asset ratio.

Key Words: cost frontier, farrow-to-finish, minimum efficient scale, overall efficiency.

The U.S. swine industry has been undergoing rapid change and reorganization for several years. The total number of U.S. hog farms dropped from 239,000 to 188,000 between 1987 and 1992, which represents a 21% decrease in the number of hog farms [U.S. Department of Commerce (USDC), *1992 Census of Agriculture*]. The trend in hog farms for the Kansas swine industry is similar to the national trend. The number of farms producing hogs in Kansas declined from 14,000 in 1980 to 4,300 in 1995 (Kansas Department of Agriculture). While the number of producers has decreased, the average number of hogs marketed per farm in Kansas between 1980 and 1995 has increased 118%, from 236 to 516. Decreasing farm numbers, combined with increasing average hogs marketed per farm, indicates larger hog operations are replacing the traditional small, diversified Kansas hog farm.

The existence of profits in the swine industry and high variation in costs among hog operations have encouraged structural change. Even recently, some producers have achieved in excess of 25% annual average rate of return on investment (Hurt). There is also a wide variation in costs of production. A $0.06 difference was found in total cost per pound of pork produced, or a $16 difference per market hog, between the top and bottom cost quartiles for a sample of 43 Kansas farrow-to-finish farms in 1992, 1993, and 1994 (Rowland). Rhodes reports that farm records from several states show a difference in total cost per cwt of about $10 for producers in the top and bottom one-third groups. High returns and wide cost differences have contributed to the entry of new industry participants and the rapid expansion of profitable units, increasing the pressure for high-cost producers to make changes in their operations.

Economies of size in hog production rep-

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resent an additional force behind structural change. Advances in technology, improved managerial practices, and increased access to capital via outside investors allow operators to achieve levels of production today much greater than those of the past. Rhodes and Grimes estimated that average marketings increased 9% between 1990 and 1991 for a set of 26,832 operations. Mega-producers, or those marketing in excess of 50,000 head of hogs, experienced a 25% increase in average marketings during the same period. In a recent study, Foster, Hurt, and Hale found that economies of size result in a cost advantage of $4.40 per cwt of live hogs for a 1,200-sow operation relative to a 300-sow operation.

The rapidly changing role of pork production in Kansas has potential ramifications for industry participants including current producers, farm input suppliers, financial institutions, and cooperatives. Kansas is losing market share relative to surrounding states. Market share fell from 6.1% to 4.4% between the late 1970s and early 1990s, representing roughly a 30% decrease in less than 20 years (Featherstone, Mintert, and Goering). There are Kansas producers, however, who consistently operate small, efficient hog farms on a cost-competitive basis. Participants in the hog industry should be interested in identifying efficient farms and their characteristics.

This study evaluates the relative economic competitiveness of Kansas pork producers. This is accomplished by: (*a*) using nonparametric mathematical programming techniques to determine the relative measures of technical, allocative, scale, economic, and overall efficiency for a sample of Kansas farrow-to-finish swine operations, and (*b*) using regression to examine the relationship among efficiency, profit, and farm characteristics.

Data and Methods

The data used in the efficiency analysis consist of 43 Kansas farrow-to-finish producers reporting swine enterprise records for 1992, 1993, and 1994 to the Kansas Farm Management Association.[1] The Kansas farm management enterprise data report 75 variables specific to swine production, thus allowing for an in-depth evaluation of the economic performance of individual farms. The analysis implicitly assumes that technology did not change over the three-year period studied.

The mathematical programming efficiency models employ several variables in the analysis. The enterprise data were manipulated to obtain six input cost categories and one output category, forming the basis for a multiple-input/single-output model. The six hog-production input categories include: utilities and fuel, labor, capital, feed, veterinary, and miscellaneous expenses. The output variable is pounds of pork produced.

The data underwent a series of feasibility tests and adjustments in order to provide meaningful economic results. Farms with incomplete data were eliminated from the sample as well as farms with data that could not be verified. If a farm reported unreasonable values or values more than two standard deviations from the mean, it was eliminated from the data set. The procedures outlined by Charnes, Cooper, and Rhodes, and by Banker, Charnes, and Cooper were then used to adjust for slack levels since there were multiple inputs. Fourteen of the 129 observations exhibited slack in at least one input variable. Output slacks did not exist because the specified efficiency models contained only one output, pounds of pork.

Table 1 presents the average and standard deviation of gross income, cost, profit, and selected farm characteristics for the sample of 43 farrow-to-finish operations. The financial variables were converted to real 1994 dollars using the implicit price deflator for personal consumption expenditures (USDC, *Survey of Current Business*). The mean of the business organization variable indicates that 16% of the farms were organized as corporations, and

[1] The 43 farms used in this study do not represent a random sample. Each of the farms participated in Kansas Farm Management Association programs in 1992, 1993, and 1994. In addition, each farm had farrow-to-finish enterprise and whole-farm information for each of the three years.

Table 1. Summary Statistics for a Sample of 43 Kansas Farrow-to-Finish Producers

Variable	Mean	Standard Deviation
Income, Cost, and Profit ($/cwt)		
Gross Income	41.16	5.83
Utilities and Fuel	1.69	0.88
Labor	5.61	2.42
Capital	5.88	2.72
Feed	27.47	5.71
Veterinary	0.87	0.65
Miscellaneous	1.41	1.10
Profit	−1.77	8.71
Farm Characteristics		
Number of Litters	257.53	298.04
Pounds of Pork Produced per Litter	1,910.32	358.71
Hired Swine Labor as Percentage of Total Labor	18.20	25.99
Feed Grains as Percentage of Total Acres	27.77	16.77
Percentage of Income from Swine	55.60	21.38
Percentage of Income from Other Livestock	11.64	13.64
Age of Operator	48.63	11.98
Type of Business Organization	0.16	0.37
Total Real Assets ($)	725,937.67	609,479.65
Debt-to-Asset Ratio	32.96	26.77

Note: Based on data provided by the Kansas Farm Management Associations.

84% were organized as partnerships or were sole proprietors. Implicit input quantities were needed to examine technical efficiency. These implicit quantities were obtained by dividing each input cost category by a real price index. Nominal price indices (U.S. Department of Agriculture) were converted to real dollars using the implicit price deflator for personal consumption expenditures (USDC, *Survey of Current Business*).

Nonparametric production efficiency analysis developed by Färe, Grosskopf, and Lovell, and implemented by Chavas and Aliber, was applied to the farrow-to-finish data. The multiple-input/single-output nonparametric technique provides relative measures of technical, allocative, scale, economic, and overall efficiency by solving a system of mathematical equations. Technical efficiency measures whether a farm is producing on the production frontier. Allocative efficiency measures whether a farm is using the optimal mix of inputs, and scale efficiency measures whether a farm is producing at the most efficient size. Economic efficiency is the product of technical and allocative efficiency. Economically efficient farms are producing on the total and average cost frontiers. Overall efficiency is the product of technical, allocative, and scale efficiency. Overall efficient farms have the lowest per unit cost of production.

Technical efficiency under variable returns to scale (VRS) is computed by solving the following linear program for each observation or farm:

$$\text{Min } TE_j = \Theta_j$$

s.t.:

$$Xz \leq \Theta_j x_j,$$

$$y'z \geq y_j,$$

$$z_1 + z_2 + \ldots + z_n = 1,$$

$$z_j \in \Re^+,$$

where Θ_j, a scaling variable used to adjust an input bundle to efficient scale for a fixed output level, represents technical efficiency for the jth farrow-to-finish producer; X is a matrix of input levels for each farm; x_j is the jth producer's input levels; z represents a column vector of variable weights; y is a column vector of fixed output levels; and y_j is output for the jth farrow-to-finish producer.

Allocative efficiency indices (AE_j) are computed using the following equation:

$$AE_j = (CM_j^v)/(C_jTE_j),$$

where C_j is the actual cost of production for the jth producer, and CM_j^v is minimum cost to produce y_j under VRS. CM_j^v is derived by solving the following linear program for each farm:

$$\text{(1)} \qquad \text{Min } CM_j^v = w_j'\bar{x}_j$$

s.t.:

$$Xz \leq \bar{x}_j,$$

$$y'z \geq y_j,$$

$$z_1 + z_2 + \ldots + z_n = 1,$$

$$z_j \in \Re^+,$$

where w_j is a column vector of input prices paid by the jth producer, and $\bar{x}_j$ is a cost-minimizing input bundle for the jth producer. VRS is imposed by constraining the sum of z's (z-sum) to equal one. Other scale assumptions are imposed by altering the z-sum constraint. Under constant returns to scale (CRS), z-sum is unconstrained. Under decreasing returns to scale (DRS), z-sum is less than or equal to one, and under increasing returns to scale (IRS), z-sum is greater than or equal to one.

Scale efficiency measures (SE_j) are calculated by minimizing total cost under CRS and scaling the result using minimum cost when VRS is assumed:

$$SE_j = CM_j^c/CM_j^v.$$

Minimum cost under CRS (CM_j^c) is obtained using model (1) with z-sum unconstrained. Economic efficiency (EE_j) is derived from TE and AE:

$$EE_j = TE_j \times AE_j.$$

Overall efficiency (OE_j) is the product of TE, AE, and SE:

$$OE_j = TE_j \times AE_j \times SE_j.$$

The relationships between profit and efficiency measures are explored using three separate OLS regressions. The first regression examines the relationship between profit/cwt and technical, allocative, and scale efficiency. The second regression examines the relationship between profit/cwt and economic and scale efficiency, while the third regression examines the relationship between profit/cwt and overall efficiency. The regression coefficient on each efficiency measure in these regressions represents the change that occurs in profit/cwt given a change in efficiency.

Because each efficiency measure is bounded at one, tobit models are employed to examine the relationship between efficiency and specific farm characteristics. The regression used for each efficiency measure is as follows:

$$EI_j = \beta_0 + \beta_1 X_{1j} + \ldots + \beta_n X_{nj} + e_j,$$

where EI_j represents the efficiency index for the jth farm, the βs represent regression coefficients, X_1 through X_n are explanatory variables, and e_j is a normally distributed error term. Independent variables include swine enterprise and whole-farm information.

Swine enterprise characteristics used in the tobit regressions include: the number of litters per farm per year, pounds of pork produced per litter, and the amount of hired swine labor as a percentage of total swine labor. The number of litters per farm is used as a measure of operation size. A positive (negative) coefficient on this variable would indicate that efficiency increases (decreases) with operation size. Pounds of pork produced per litter is used as a measure of biological efficiency. Unless farms are using relatively high levels of inputs to achieve biological efficiency, the coefficient on this variable would be positive. Hired labor as a percentage of total swine labor is used to measure the impact of hiring labor.

Whole-farm variables used in the tobit regressions include: feed grain acres as a percentage of total acres operated, swine income as a percentage of total income, other livestock income as a percentage of total income, age of operator, business organization, real-farm assets, and the debt-to-asset ratio. Feed grain acres as a percentage of total acres operated, and other livestock income as a percentage of total income are measures of potential economies of scope between feed grain and swine production, and other livestock and swine production. If the coefficient on either of these variables is positive, economies of scope exist. Swine income as a percentage of total income measures the impact of specialization on efficiency. If specialization increases (decreases) efficiency, the coefficient on this variable will be positive (negative). The operator age variable measures the importance of experience. The business organization variable examines the difference in efficiency between corporations, and sole proprietors and partnerships. The real-farm assets and debt-to-asset ratio measure the impact of whole-farm size and financial leverage on efficiency. In addition to reporting the regression coefficients, elasticities are computed and reported for each independent variable. The R^2 between observed and predicted values is used as a goodness-of-fit measure for the tobit regressions.

Results

Relative Efficiency Estimates

Table 2 provides a statistical summary of the efficiency measures. Technical efficiency (TE) measures ranged from 0.54 to 1.00, with an average of 0.89. Inputs could be reduced by 11% on average if all operations produced along the production frontier. About 40% of the observations were technically efficient, and 74% of the observations exhibited technical efficiency measures greater than 0.80. All but eight of the observations exhibited a TE measure greater than 0.70. Allocative efficiency (AE) ranged from 0.56 to 1.00, with an average of 0.84. Approximately 72% of the observations exhibited allocative efficiency measures greater than 0.80. Seven observations were allocatively efficient.

Scale efficiency (SE) varied from 0.46 to 1.00, with an average of 0.90. Over 90% of observations exhibited scale measures greater than 0.80, and all but one of the observations were more than 0.60 scale efficient. Analysis of the 129 observations reveals that 32 operate under increasing returns to scale (or on the decreasing region of the average cost curve), one operates under constant returns to scale, and 96 operate under decreasing returns to scale.

Economic efficiency (EE) is the difference between the actual total cost of production for each operation and the total cost frontier. On average, observations were 0.75 economically efficient, implying that the same quantity of output could be produced with 25% less cost if all observations were located on the minimum cost frontier. EE ranged from 0.47 to 1.00, with 48 observations exhibiting an economic efficiency rating better than 0.80, and seven observations exhibiting an economic efficiency rating of 1.00. Mean economic efficiency was lower than mean scale efficiency. Thus, failing to produce on the cost frontier appears to add more additional cost for these farms than costs added by failing to produce at the optimal scale.

Overall efficiency averaged 0.67 and ranged from 0.34 to 1.00. Operators who produce on the minimum cost frontier under constant returns to scale achieve the same level of output with 33% less cost on average. The farm possessing the lowest rating of 0.34 could theoretically decrease costs by 66% and still maintain a constant level of output. Approximately 64% of the observations were between 0.60 and 0.80 overall efficient. Overall efficiency is the product of technical, allocative, and scale efficiency measures; thus farm inefficiency can be attributable to any of those three measures.

Table 3 presents the means of standard deviations of the efficiency measures for the cross-section of farms over time and for each year. The cross-sectional information was obtained by averaging the standard deviation of efficiency for each farm. The mean of the standard deviations for the cross-section of farms is smaller for each measure than the standard deviation of each measure for the individual years. This result suggests that there is less

Table 2. Efficiency Measures for a Sample of 43 Kansas Swine Operations

	Efficiency Measures				
Variable	Technical	Allocative	Scale	Economic	Overall
Summary Statistics					
Mean	0.89	0.84	0.90	0.75	0.67
Standard Deviation	0.12	0.09	0.09	0.13	0.11
Minimum	0.54	0.56	0.46	0.47	0.34
Maximum	1.00	1.00	1.00	1.00	1.00
Distribution of Farms					
Less than 0.40	0	0	0	0	1
0.40 to 0.50	0	0	1	2	7
0.50 to 0.60	3	2	0	12	22
0.60 to 0.70	5	7	6	34	43
0.70 to 0.80	25	27	5	33	39
0.80 to 0.90	22	57	41	32	12
0.90 to 1.00	22	29	75	9	4
1.00	52	7	1	7	1

variability in efficiency measures for the farms over time than there is among farms in a given year. In other words, farms that are relatively efficient (inefficient) in a given year tend to remain relatively efficient (inefficient) over time. It is also evident from table 3 that there was less variability in scale efficiency for a given farm over time than there was in technical or allocative efficiency. Random weather and health events make it relatively more difficult to remain economically efficient.

Profit Coefficients

The relationship between profit/cwt and efficiency is reported in table 4. The first column examines the relationship between profit/cwt and technical, allocative, and scale efficiency. The second and third columns examine the relationship between profit/cwt and economic and scale efficiency, and the relationship between profit/cwt and overall efficiency, respectively. The results in table 4 show a positive and significant relationship exists between profit and each type of efficiency. Using the information in column (1), a 0.10 increase in technical, allocative, and scale efficiency implies an increase in profit/cwt of $4.31, $3.96, and $4.60, respectively. From column (2), a 0.10 increase in economic efficiency results in an increase in profit/cwt of $4.62, while from column (3), a 0.10 increase in overall efficiency results in increased profits of $5.12 per cwt. The square root of the R^2 for each efficiency measure in table 4 is a measure of linear correlation. Profit/cwt was highly correlated (0.67) with overall efficiency.

Farm Characteristic Tobit Model Results

Table 5 reports results of the tobit models examining the relationship between efficiency and selected farm characteristics. Elasticities are reported in table 6 for the independent variables that were significant in at least one of the efficiency regressions.

Two variables were found to have a positive and significant impact on technical efficiency: the number of litters per farm per year and pounds of pork produced per litter per year (table 5). Technically efficient farms tend to produce more total litters per year and a larger amount of pork per litter than technically inefficient farms. These farms may be using technologies such as superior genetics, split-sex feeding, all-in/all-out, and segregated early weaning. Use of any of these technologies could lead to increased efficiency.

Hired swine labor as a percentage of total swine labor is negatively related to technical efficiency and significant at the 1% level. Farms that employ relatively less hired labor

Table 3. Means of Standard Deviations of Efficiency Measures Among Farms and Years

		Year		
Efficiency Measure	Cross-Section[a]	1992	1993	1994
Technical Efficiency	0.0772	0.1024	0.1309	0.1132
Allocative Efficiency	0.0653	0.0868	0.0954	0.0956
Scale Efficiency	0.0295	0.0882	0.1016	0.0939
Economic Efficiency	0.0919	0.1162	0.1199	0.1381
Overall Efficiency	0.0865	0.1014	0.1117	0.1202

[a] Mean per farm standard deviation.

as a percentage of total labor are more technically efficient. This suggests that owner/operator labor is more productive relative to hired labor on a per unit cost basis, or simply that technically efficient farms use less total labor. The negative relationship between hired labor as a percentage of total swine labor and technical efficiency could reflect the role of shirking and its negative effect on hired labor.

Number of litters per farm per year is positively related to allocative efficiency and significant at the 5% level. Allocatively efficient farms tend to farrow a greater number of total litters. Larger hog farms possibly may be better able to minimize input costs by purchasing inputs in bulk to avoid transactions costs, thus making them more allocatively efficient. None of the other variables were significantly related to allocative efficiency.

Scale-efficient hog production is best explained by number of litters per year, feed grain acres as a percentage of total acres, income contribution from swine, and income from other livestock. Scale efficiency evaluates all farms relative to farms that produce at a level of constant returns to scale. Number of litters per farm is negatively related to scale efficiency and significant at the 1% level. This is likely due to the fact that the most scale-efficient farm in the sample was relatively small, resulting in the majority of farms being larger than the most scale-efficient operation. In addition, farms approaching the optimal scale tend to produce a portion of their own

Table 4. Relationship Between Profit/cwt and Efficiency Measures

	Regression		
Efficiency Measure	(1)[a]	(2)[b]	(3)[c]
Intercept	−115.28***	−77.97***	−36.40***
	(10.93)	(7.78)	(3.42)
Technical Efficiency	43.10***		
	(4.89)		
Allocative Efficiency	39.60***		
	(6.35)		
Economic Efficiency		46.16***	
		(4.70)	
Scale Efficiency	46.04***	45.89***	
	(6.37)	(6.41)	
Overall Efficiency			51.23***
			(4.98)
R^2	0.48	0.47	0.45

Notes: Triple asterisks (*) denote significance at the 1% level. Numbers in parentheses are standard errors.

[a] Relationship between profit/cwt and technical, allocative, and scale efficiency.

[b] Relationship between profit/cwt and economic and scale efficiency.

[c] Relationship between profit/cwt and overall efficiency.

Table 5. Relationships Between Efficiency and Farm Characteristics Using Tobit Regression Analysis

Variable	Efficiency Measures				
	Technical	Allocative	Scale	Economic	Overall
Intercept	0.6505***	0.7539***	0.8694***	0.5158***	0.4484
	(0.1237)	(0.0662)	(0.0592)	(0.0849)	(0.0738)
Number of Litters	0.0004***	0.0001**	−0.0001***	0.0003***	0.0001
	(0.0001)	(0.0001)	(0.0000)	(0.0001)	(0.0001)
Pounds of Pork Produced per Litter	0.0001***	0.0000	−0.0000	0.0001***	0.0001**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Hired Swine Labor as Percentage of Total Labor	−0.0038***	0.0003	0.0003	−0.0013**	−0.0008
	(0.0010)	(0.0004)	(0.0004)	(0.0006)	(0.0005)
Feed Grains as Percentage of Total Acres	−0.0009	0.0003	0.0015***	0.0001	0.0014**
	(0.0010)	(0.0005)	(0.0005)	(0.0007)	(0.0006)
Percentage of Income from Swine	−0.0005	−0.0004	0.0016***	−0.0003	0.0011*
	(0.0010)	(0.0005)	(0.0005)	(0.0007)	(0.0006)
Percentage of Income from Other Livestock	0.0007	0.0009	0.0014**	0.0013	0.0022***
	(0.0012)	(0.0006)	(0.0006)	(0.0008)	(0.0007)
Age of Operator	0.0003	0.0011	−0.0010	0.0008	−0.0001
	(0.0013)	(0.0007)	(0.0006)	(0.0009)	(0.0008)
Type of Business Organization	−0.0555	0.0001	0.0112	−0.0305	−0.0245
	(0.0444)	(0.0243)	(0.0218)	(0.0312)	(0.0272)
Total Real Assets	4.245E-08	−3.295E-08	1.512E-08	−1.126E-08	6.198E-09
	(5.430E-08)	(2.629E-08)	(2.315E-08)	(3.386E-08)	(2.889E-08)
Debt-to-Asset Ratio	−0.0005	−0.0000	−0.0004	−0.0005	−0.0008**
	(0.0006)	(0.0003)	(0.0003)	(0.0004)	(0.0004)
R^2	0.2270	0.1284	0.2878	0.2571	0.2338

Notes: Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% levels, respectively. Numbers in parentheses are standard errors.

Table 6. Elasticities for Farm Characteristic Tobit Regressions

Variable	Efficiency Measures				
	Technical	Allocative	Scale	Economic	Overall
Number of Litters	0.072	0.040	−0.047	0.097	0.030
Pounds of Pork Produced per Litter	0.200	0.027	−0.018	0.237	0.184
Hired Swine Labor as Percentage of Total Labor	−0.048	0.007	0.006	−0.032	−0.020
Feed Grains as Percentage of Total Acres	−0.017	0.011	0.040	0.002	0.057
Percentage of Income from Swine	−0.018	−0.026	0.086	−0.022	0.088
Percentge of Income from Other Livestock	0.005	0.012	0.016	0.020	0.039
Debt-to-Asset Ratio	−0.012	−0.002	−0.014	−0.022	−0.037

feed grains. This result suggests that scale efficiency becomes more important as an operation becomes more diversified in terms of grain and swine production, and provides indirect evidence that economies of scope exist between these enterprises. Income from swine and income from other livestock are both positively related to scale efficiency and significant at the 1% and 5% levels, respectively. The positive relationship between scale efficiency and percentage of income from swine suggests that scale efficiency increases with specialization. The positive relationship between the percentage of income from other livestock and scale efficiency provides indirect evidence of economies of scope between swine and other livestock production. The results for feed grains and other livestock conflict with the specialization results. The elasticities in table 6 can be used to determine whether specialization effects dominate the diversification effects. The elasticity for the specialization variable is larger than the elasticities for the feed grain and other livestock variables, providing evidence of incentives for swine farms to become more specialized.

Three variables were found to have a significant impact on economic efficiency: number of litters per farm per year, pounds of pork produced per litter per year, and hired swine labor as a percentage of total swine labor. The number of litters per farm per year is positively related to economic efficiency and significant at the 1% level. Therefore, larger hog operations tend to achieve actual costs that are located closer to the average minimum cost frontier. Pounds of pork produced per litter per year is also positively related to economic efficiency and significant at the 1% level. Farms that produce large quantities of pork per litter report costs closer to the average minimum cost frontier than farms that are less productive per litter. Hired swine labor as a percentage of total swine labor is negatively related to economic efficiency and significant at the 5% level. Thus, farms that utilize mostly owner-operator labor, or farms that employ less expensive hired labor per unit of output, achieve actual costs closer to the average minimum cost frontier.

Economic efficiency, or the firm's ability to produce on the cost frontier, is the most sensitive to changes in pounds of pork produced per litter and the number of litters produced. Using the elasticity estimate in table 6, an increase of one standard deviation in mean pounds of pork produced results in a 4.45% increase in economic efficiency. Although the average number of litters produced per farm was 257, the number of litters varied widely among farms in the sample, ranging from 30 to 1,391. Using the elasticity estimate from table 6, a farm that is twice as large as the average farm would have an efficiency index 9.69% higher than that for the average farm.

Four variables were found to be statistically significant and positively related to overall efficiency: pounds of pork produced per litter, feed grains as a percentage of total acres, percentage of income from swine, and percentage of income from other livestock. Overall efficient farms tend to produce larger quantities of pork per litter. High levels of pork produced per litter may be a result of farms that possess superior genetics, superior feeding techniques, or managerial expertise. Overall efficient firms tend to possess a feed grain enterprise within the whole farming operation. Thus, operators avoid purchasing feed grains from outside the farm, as well as the associated transactions costs. Overall efficient farms also tend to generate a relatively higher percentage of their income from swine and other livestock.

The debt-to-asset ratio was found to be significant and negatively related to overall efficiency. This suggests that farms with lower levels of debt are more overall efficient, which may be a result of farms utilizing fewer or older buildings and equipment to raise hogs. It may also suggest that these farmers have the ability to invest in technology without the use of debt.

Overall efficiency is sensitive to changes in pounds of pork produced. A one standard deviation increase in mean pounds of pork produced increases overall efficiency by 3.46%. Overall efficiency is more sensitive to changes in the percentage of income from swine and feed grains as a percentage of total acres than either the percentage of income from livestock or the debt-to-asset ratio. A one standard deviation increase in the percentage of income from swine and feed grains as a percentage of total acres results in approximately 3.40% and 3.42% increases in overall efficiency, respectively.

Three farm characteristic variables were found to have no significant effect on any of the efficiency measures: age of operator, the type of business organization, and real-farm assets. Thus, there is no statistical evidence that age of operator, business organization, or level of real assets affect hog production efficiency. This indicates that farms held in sole proprietorships and partnerships are just as efficient in their use of resources as farms held in family corporations. Similarly, younger operators are just as efficient as older operators. The results with respect to the level of real assets suggest that farms with relatively few assets produce hogs just as efficiently as farms possessing large quantities of assets.

Summary

Findings based on the three-year, continuous sample of 129 observations showed, on average, that farms were 0.89 technically, 0.84 allocatively, 0.90 scale, 0.75 economically, and 0.67 overall efficient. Thus, the same quantity of pork may be produced with 33% less cost if all operators produce on the minimum cost frontier under constant returns to scale. Approximately 74% of observations were better than 0.80 technically efficient, 72% were better than 0.80 allocatively efficient, and 91% were better than 0.80 scale efficient. Improving economic inefficiency (the product of technical and allocative inefficiency) would reduce costs on these farms more than adjusting the scale of the hog operation. This result suggests that controlling economic inefficiency, regardless of operation size, is extremely important in the swine industry.

The minimum cost of production occurred at 149,355 pounds of pork produced per year, or roughly 600 market hogs assuming 250 pounds/hog. Individual farm analysis revealed that 32 farms operated under increasing-returns-to-scale technology, one under constant returns to scale, and 96 under decreasing returns to scale. However, about 60% of the observations had a scale efficiency measure above 0.90. This finding shows that the average cost curve was relatively flat.

Efficiency and profitability were positively and significantly related. The analysis indicates that a 0.10 increase in overall efficiency resulted in a $5.12 increase in profit/cwt of pork produced. The correlation coefficient between overall efficiency and profit/cwt was 0.67.

Tobit regression results show that overall efficient farms in the sample tended to produce a relatively high quantity of pork per litter, produced a portion of their own feed grains, generated a large portion of their income either through specialization in swine or through production of other livestock enterprises, and had a lower debt-to-asset ratio. The number of litters produced, hired labor as a percentage of total labor, age of operator, type of business organization, and total real assets were not significantly related to overall efficiency.

Results with respect to overall efficiency suggest that small, efficient producers marketing fewer than 1,000 head of hogs are able to compete on a cost basis with producers who market from 1,000 to 10,000 head. Economic efficiency was positively related to the number of litters produced, indicating that larger producers tended to produce closer to the cost frontier. Scale efficiency, in contrast, was negatively related to the number of litters produced.

Results also suggest that farrow-to-finish producers will continue to become more specialized. Farms that obtained a higher percentage of their gross farm income from swine production were relatively more efficient. Many swine industry participants are further specializing by only producing weaned pigs or by only finishing pigs. Additional efficiency gains from this further specialization remains an important area for future research to address.

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