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EFFICIENCY MEASURES USING THE RAY-HOMOTHETIC FUNCTION: A MULTIPERIOD ANALYSIS

David L. Neff, Philip Garcia, and Robert H. Hornbaker

Abstract

Recent investigations have provided mixed assessments of farm firm efficiency. This analysis examined the efficiency of a homogeneous sample of central Illinois grain farms over a six-year period. A best-practice frontier was constructed using the ray-homothetic function, which allowed optimal farm output to vary with factor intensity. Efficiency measures were found to increase with temporal aggregation. The ray-homothetic approach was found to attribute high scale inefficiencies to larger sample farms in cases where the factor shares did not vary appreciably across farms. The findings suggest that policy recommendations regarding farm efficiency must be made with care.

Key words: technical efficiency, ray-homothetic function, temporal aggregation, Illinois grain farms

Firm efficiency has long been an area of interest in the investigation of farm operations. Its absence or presence can have important implications for issues related to economic survival, the size distribution of farms, technological adoption, and the overall level of input usage in the agricultural sector. These issues are of critical importance in the current public and private dialogue about the continued existence of medium-sized family farms and potential viability of limited input agriculture.

Recent investigations in predominantly grain-producing areas have produced somewhat mixed assessments of farm firm efficiency. Byrnes et al., employing a linear programming approach to assess the efficiency of 107 south-central Illinois grain farms in 1980, found that farms were producing only four percent below their efficient level. Overall efficiency was relatively consistent across size distribution, except for farms of less than 100 acres. Aly et al. constructed a best-practice frontier using a ray-homothetic production function which permits returns to scale to vary with output. Pure technical,

scale, and total efficiency were assessed using 1982 records from 88 south-central Illinois farms. Farms were found to be producing roughly 42 percent below their efficient levels—a surprisingly low result considering that their sample contained farms from the same three-county area used in the Byrnes et al. study. Aly et al. further concluded that overall efficiency increases with larger farm size and gross revenue categories.

Various factors might explain the differences in findings. Each of the studies focused on a particular year, which means that the results may be conditioned by specific temporal events. In agriculture, weather and its variability can have dramatic effects on production, and this can, clearly influence measurements of efficiency. Another possible explanation may reside in the limited homogeneity of the samples. Differences in the definition of grain farms, output mix, and soil quality can confound the measurement of efficiency in agricultural settings. Finally, the differences in the previous results may be a function of the different methodologies employed. Byrnes et al. estimated a piecewise-linear best practice frontier using linear programming whereas Aly et al. econometrically constructed a smooth frontier using a ray-homothetic production function and corrected ordinary least squares.

The purpose of this paper was to provide insight into the mixed assessments of farm firm efficiency. Here, for various temporal aggregates, the technical efficiency of a sample of well-defined central Illinois grain farms was examined by employing the ray-homothetic approach. Time-series, cross-section data were used over a six-year period. Measures of technical efficiency and its components were generated for various time periods and farm size classifications.

Temporal units of aggregation (i.e., based on averages of two, three, and six years) were formed to identify their effect on efficiency measurement using revenue and expenditure data. As previously mentioned, weather and its variability may influence

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efficiency measures over time. Additionally, often in agriculture, part of the input expenditures (particularly for fertilizer and capital) in one year may be carried over and applied to production in subsequent years. Even if accrual revenue and expenditure data are used, measurement errors may inappropriately attribute cash expenditures for inputs to particular years. Furthermore, certain crop rotation plans are known to provide beneficial yield, weed control, and tillage effects from year to year. Studies which examine efficiency using a single year's expenditure and revenue data as proxies for inputs and outputs may not be able accurately to account for these issues.

The ray-homothetic function (RHF) has been widely applied in evaluating efficiency using cross-section data (i.e., Aly et al.; El-Osta, Pelly, and Whittaker; Elyasiani and Mehdi; Fare, Jansson and Lovell; Grabowski and Belbase). Its use here is primarily motivated by the differences in findings and implications generated by its application to Illinois grain farms and by a desire to examine its usefulness in this environment (Moll).

The RHF is appealing because of its flexibility in measuring the pure technical and scale efficiency of individual firms and because it allows returns to scale and the optimal scale to vary with factor intensity. However, Moll, in a recent comment on Grabowski and Belbase, has suggested that the RHF specification imposes increasing returns to scale and decreasing returns to scale on the smallest and largest sample firms, respectively.¹ He also indicates that the mean firm size experiences constant returns to scale and that, for the RHF specification employed, the effect of factor intensities on optimum size and returns to scale is dominated by the effect of output on scale, resulting in decreasing returns for the largest firms. Grabowski, in reply, correctly reinforces that conceptually, scale returns are influenced by both factor intensities and the level of output. He implicitly argues that the exact nature of economies of scale for any production technology is

an empirical issue. He also provides empirical evidence demonstrating that the mean firm size is not characterized by constant returns to scale and the presence of increasing returns for large firms. Because of the importance of economies of scale in the U.S. agricultural sector, the present analysis further investigates several of these issues. Here, the sample is divided into small and large farm size groupings to provide additional insight into the potential effects of using the RHF to identify the magnitude and composition of inefficiency.

DATA AND METHODOLOGY

The data come from farms in central Illinois that keep production, income, and cost records with the Illinois Farm Business Farm Management (FBFM) record keeping service. To address the questions associated with single-year efficiency measurement and limited homogeneity of farms, a 6-year (1982-1987) sample of records for 170 "exclusive" cash grain farms was used. Normally, FBFM defines a *grain farm* as one in which the value of feed fed is less than 40 percent of the crop returns and where the value of feed fed to dairy or poultry is not more than one-sixth of the crop returns. The *exclusive grain farms* used in this analysis were ones in which less than 1 percent of the gross value of farm production was from livestock sales. In addition, FBFM classifies farms by a soil productivity rating (SPR). Only farms with an SPR of 90 or above (on a scale from 1 to 100) were included in this study. In this way, a more homogeneous group of grain farms was examined than in the Byrnes or Aly studies.² Moreover, the sample examined here included farms which were relatively uniform in crop mix—primarily in corn and soybeans.³ By controlling for sample homogeneity, efficiency measures could more effectively be estimated.

Following Aly et al., the ray-homothetic function,⁴

¹This specification of the ray-homothetic function was introduced by Fare and Yoon.

²These studies use the FBFM definition of a grain farm and, do not, to the author's knowledge restrict SPR ratings.

³Over the six-year period, the farms allocated on average 44, 46, 1 and 9 percent of their tillable acreage to corn, soybeans, wheat, and set-aside, respectively.

⁴Using revenue and cost data to measure technical efficiency assumes that producers face the same input and output prices. This assumption and the use of revenue for output and/or expenditures for some or all of the inputs to estimate production frontiers has been used frequently. In addition to the Byrnes and Aly studies, see Bagi and Huang; Battese and Coelli; Bravo-Ureta and Rieger; Elyasiani and Mehdi; Fare, Grosskopf and Lee; Grabowski and Belbase; Grabowski and Mehdi; Huang and Bagi; Kalirajan and Flinn; Tauer and Belbase; and Timmer. Using this assumption here seems reasonable given that the farms are located in a relatively homogenous 15-county area in central Illinois. An analysis of the average corn and soybean prices received by these farms reveals no significant differences (at the 5 percent level) between the mean prices of the 85 most and least efficient farms for five of the six years examined. The effect of using revenue and cost data which could reflect differences in prices faced by producers means that measures of inefficiency may incorporate some allocative inefficiency as well (Aly et al.).

Table 1. Average Values of Average Farm Revenue, Expenditures, Acreages, and Yields for 170 Central Illinois Grain Farms, 1982-1987

Item	Mean	St. Dev.
----- dollars -----		
Revenue	183,070	73,882
Fertilizer	18,861	8,264
Pesticides	9,809	4,924
Seed	8,671	3,826
Capital	33,241	13,790
Buildings	8,899	5,017
Labor	16,500	4,973
Land	52,868	20,704
----- acres -----		
Tillable Acres	559	223
Corn Acres	245	102
Soybean Acres	253	108
----- bu./ ac. -----		
Corn Yield	149	12
Soybean Yield	46	4

$$\begin{aligned}
 R = & \ln \alpha_0 + \alpha_f K_f \ln F + \alpha_p K_p \ln P \\
 (1) \quad & + \alpha_s K_s \ln S + \alpha_c K_c \ln C \\
 & + \alpha_b K_b \ln B + \alpha_n K_n \ln N \\
 & + \alpha_l K_l \ln L
 \end{aligned}$$

was estimated, where R denotes gross (accrual) farm revenue and F, P, S, C, B, N, and L represent accrual fertilizer, pesticides, seed, capital (power and equipment), buildings, labor, and land expenditures, respectively. All measures of receipts and expenditures are on a total farm basis.⁵ Capital includes expenditures on utilities, machinery repair and hire, fuel, oil, and machinery depreciation. Building expenditures include drying, storage, and building repair and depreciation. Labor includes

both hired labor and operator's unpaid labor.⁶ The land expenditure was calculated by multiplying an interest charge⁷ times a total land value and reflects the net rents which a landlord would receive each year. The land value was market-based and determined by FBFM according to an index which values different parts of the farm according to soil-specific SPRs. Table 1 presents average values of these variables, acreages, and yields over the six-year period (averages of six-year average farm values). The K_i ($i = f, p, s, c, b, n, l$) are expenditure shares and the α_i are the parameters to be estimated. Equation (1) was estimated using ordinary least squares.⁸

To determine the extent to which farms are efficient in a technical sense, a corrected ordinary least squares (COLS) method was used. The potential output of the sample of farms was calculated by adjusting the intercept of (1) upward by the largest residual. This procedure ensures that production falls within the efficient frontier. The level of pure technical inefficiency for each farm was then calculated by subtracting actual revenue from potential revenue, which was generated by using actual farm values of the inputs and expenditure shares in the adjusted equation (1).

The extent to which farms are efficient in a scale sense was also examined. The procedure described in Aly et al. was used to identify the extent of scale inefficiency by farm. From equation (1), the level of output under constant returns to scale is expressed as a function of the expenditure shares:

$$\begin{aligned}
 (2) \quad \text{OPTR} = & \alpha_f K_f + \alpha_p K_p + \alpha_s K_s + \alpha_c K_c \\
 & + \alpha_b K_b + \alpha_n K_n + \alpha_l K_l
 \end{aligned}$$

This optimal level of output (OPTR) was adjusted upward or downward along a constant returns to scale function according to each particular farm's level of input use to calculate a farm's constant returns to scale revenue. The level of scale inefficiency was then derived by subtracting potential

⁵The data were not deflated over the six-year period. While deflating would change the levels of actual and estimated revenues, it would not affect the efficiency ratio estimates or other inter-year comparisons discussed in this analysis.

⁶The total unpaid labor is the product of a monthly labor rate and the number of months of unpaid labor. The monthly operators' unpaid labor rate is defined uniformly over all farms within each year. The monthly unpaid labor rates (\$/month) are: 1982: 1075, 1983-1984: 1100, 1985-1986: 1150, 1987: 1225. The total expenditures on unpaid labor differ for each farm as the number of months of unpaid labor varies.

⁷The interest charge calculated by FBFM is based upon observed rental returns from farms with crop-share leases. These rates are: 1982: 2.8 percent, 1983-1984: 3.2 percent, 1985: 4.2 percent and 1986-1987: 5.0 percent.

⁸The original data set included 197 farm observations. In practice, all frontier estimations (whether deterministic or stochastic) are sensitive to outliers, and no definitive methodology exists for identification purposes. Because of this, a method that examines the regression residuals of the six yearly estimations was used. Observations whose regression residuals were greater than plus or minus two standard deviations in any one of the six years were eliminated from the analysis. This resulted, in any particular year, in from four to seven percent of the farms being eliminated from the sample. While the elimination of what may appear to be some of the most technically efficient and inefficient farms from the sample may appear undesirable, in reality some allowance must be made in frontier estimation for data outliers. In addition, the resulting sample (which includes 170 farms) still exhibits a rather wide range of total and pure technical efficiency estimates.

Table 2. Estimates of Actual Revenue (R), Potential Revenue (POTR), Constant Returns to Scale Revenue (CRTSR), Absolute Pure Technical, Scale, and Total Inefficiency, and Pure Technical and Total Efficiency Ratios by Year and Two-Year, Three-Year, and Six-Year Average Periods for 170 Central Illinois Grain Farms

Year	Obs.	R	POTR	CRTSR	Inefficiency			Efficiency Ratio	
					Pure Tech.	Scale	Total	Pure Tech.	Total
	No.	----- dollars -----							
82	170	174,226	285,798	332,029	111,572	46,231	157,803	0.61	0.52
83	170	179,652	274,069	312,087	94,417	38,018	132,435	0.66	0.58
84	170	177,850	299,171	351,930	121,321	52,759	174,080	0.59	0.51
85	170	209,303	303,156	346,306	93,853	43,150	137,003	0.69	0.60
86	170	177,529	270,589	309,620	93,060	39,031	132,091	0.66	0.57
87	170	179,869	274,205	322,502	94,336	48,297	142,633	0.66	0.56
82-83	170	176,939	242,074	263,946	65,135	21,872	87,007	0.73	0.67
83-84	170	178,751	268,751	299,868	90,000	31,117	121,117	0.67	0.60
84-85	170	193,577	293,233	335,071	99,656	41,838	141,494	0.66	0.58
85-86	170	193,416	283,049	320,308	89,633	37,259	126,892	0.68	0.60
86-87	170	178,699	261,415	297,491	82,716	36,076	118,792	0.68	0.60
82-84	170	177,243	252,647	276,984	75,404	24,337	99,741	0.70	0.64
83-85	170	188,935	270,621	299,535	81,686	28,914	110,600	0.70	0.63
84-86	170	188,228	278,448	314,640	90,220	36,192	126,412	0.68	0.60
85-87	170	188,900	273,277	308,963	84,377	35,686	120,063	0.69	0.61
82-87	170	183,072	256,844	281,955	73,772	25,111	98,883	0.71	0.65

revenue from the constant returns to scale revenue. The sum of the two types of inefficiency, pure technical and scale, was thus a measure of the total inefficiency associated with each sample farm. A total efficiency ratio is expressed as actual revenue divided by the constant returns to scale revenue.

RESULTS

Six yearly and ten aggregate estimates of farm efficiency were examined in this analysis. The yearly estimates include farm data by year and are comparable to efficiency estimates of previous studies while demonstrating changes in single-year estimates over time. The aggregate estimates were obtained by averaging income and expenditure data by farm for the two-year periods 1982-1983, 1983-1984, 1984-1985, 1985-1986, and 1986-1987; for the three-year periods 1982-1984, 1983-1985, 1984-1986, and 1985-1987; and for the six-year period 1982-1987.

Yearly and Multiple-Year Efficiency

The first six rows of Table 2 summarize the estimates of the extent of pure technical, scale, and total

inefficiency, on average, by year. Each of the yearly equation estimations used to calculate the efficiency measures fit extremely well with R^2 s in the 0.83-0.91 range. All explanatory variables are significant at the 1 percent confidence level. Because the parameter estimates have limited economic meaning, only the results from one of the estimations (1982-1987 average data, the last line in Table 2) are presented (Table 3). The actual revenue (R) of the farms ranged, on average, from \$174,226 in 1982 to \$209,303 in 1985. The potential revenue (POTR) in each year represents the amount that could be produced by an average farm in the absence of any pure technical inefficiency. The constant returns to scale revenue (CRTSR) indicates the potential level of revenue attainable in the absence of pure technical and scale inefficiencies. Two efficiency ratios are reported, the pure technical efficiency ratio (R/POTR) and the total efficiency ratio (R/CRTSR). The total efficiency ratio of the farms throughout the 1982-1987 period ranges from a low of 0.51 in 1984 to a high of 0.60 in 1985. The total inefficiency of the farms can be approximately divided up as 70 percent pure technical inefficiency and 30 percent

Table 3. Regression Results of the Estimation of the Ray-Homothetic Revenue Function for 170 Central Illinois Grain Farms, 6-year Average Data

Parameter	Estimated Coefficient	Standard Error	R ²
1n α_0	-1,863,705*	61,838	0.92
α_f	194,376*	7,943	
α_p	210,353*	10,127	
α_s	201,046*	17,450	
α_c	180,879*	6,424	
α_b	222,108*	9,067	
α_n	215,129*	11,211	
α_l	208,650*	6,175	

* Significant at the 1 percent confidence level.

scale inefficiency each year. Aly et al. find a 0.58 total efficiency ratio for their sample of 88 south-central Illinois grain farms from 1982 data. It was anticipated that the more uniform sample of exclusive grain farms utilized in this analysis would provide higher total efficiency ratios. However, the efficiency measurement for 1982 in this analysis is 0.52, lower than that of Aly et al. Regardless, it is clear from Table 2 that the measurement of farm firm efficiency is dependent upon the time period analyzed.⁹

Table 2 also provides the aggregate results. The estimated models fit as well or better than the yearly regression models with R²s in the 0.90-0.92 range and all estimated coefficients significant at the 1 percent confidence level. In all but one instance (1984-1985), the total efficiency ratios of the averaged time periods are equal to or higher than those of any of the associated individual time periods. This suggests that in specific years farms may be further away from the frontier.

⁹Duncan's Multiple Range and Fisher's Least Significant Difference Tests were conducted upon the pure technical and total efficiency ratios (at the 5 percent level). For the pure technical efficiency ratio, the mean in 1985 was found to be significantly higher than the means of 1983, 1986 and 1987, which were in turn found to be significantly higher than the means of 1982 and 1984 data. For the total efficiency ratio, the rankings are 1985 > 1983, 1986 and 1987 > 1982 > 1984, where ">" denotes significance of difference between means.

¹⁰For a more careful examination of this result, the "within" estimator (Schmidt and Sickles; Seale) was applied to the panel data. The results of this procedure indicate that the firms experienced \$90,250 of pure technical inefficiency on average over the six-year period. This result is very similar to the amount of pure technical inefficiency estimated in four (1983, 1985, 1986, 1987) of the six single-year estimations. This suggests that the use of a panel data estimation procedure alone may not be sufficient to account for some of the problems associated with using a single year's revenue and expenditure data to assess productive efficiency. Moreover, the firm efficiency estimates calculated using the within estimator are only consistent as $T \rightarrow \infty$, whereas in this analysis $T = 6$.

¹¹The Tukey multiple-comparison approach was used to test for significant differences in the means of the total efficiency ratio of farms classified by acreage. The results indicate that the mean total efficiency ratio of farms with less than 400 acres was significantly different (at the 5 percent level) from the mean efficiency ratios of all other size classes. No other significant differences in means were found.

When farm data are averaged over the 6-year period, the total efficiency ratio is found to be 0.65, higher than any individual year's estimate and also higher than any 3-year average estimate. When compared with 2-year average data estimates, it is found to be lower than only the estimate from the 1982-1983 period of 0.67. It appears that, on balance, averaging the data when calculating the efficiency of a sample of farms using a frontier technique increases efficiency measures by reducing the effects of specific annual occurrences. In addition, these results indicate that using averaged expenditure and revenue data to measure productive efficiency may provide a more effective evaluation by accounting for the effects of cash vs. accrual measurement errors and the benefits of crop rotation practices.¹⁰

Efficiency, Farm Size, and Scale Implications

The degree to which efficiency differs by farm size and total revenue is next examined. For the 6-year average data (the last line in Table 2), individual farm estimates of potential and constant returns to scale revenue are classified by number of tillable acres and level of actual revenue. Table 4 presents these results.

As farm size increases when measured either by acreage or actual revenue, total efficiency ratios initially increase and then appear to stabilize. In terms of farm size, the 400-700 acre range is the point where the total efficiency ratio levels off.¹¹ This size class contains the largest component of the sample and may be considered to represent single-family grain farms. Examination of the individual years and alternative aggregate groupings reveals a similar pattern. However, in two of the six years, the total efficiency measure declines once farm size exceeds 1000 acres.

The composition of the inefficiency changes systematically; as farm size increases, pure technical

Table 4. Summary of Average Revenue and Efficiency Measures by Acreage and Gross Revenue Class for Six-year Average Period for 170 Central Illinois Grain Farms

Farm Size	Obs.	R*	POTR	CRTSR	Inefficiency			Efficiency Ratio	
					Pure Tech.	Scale	Total	Pure Tech.	Total
acres	no.	dollars							
<400	44	103,418	172,111	177,107	68,693	4,996	73,689	0.60	0.58
400- 700	84	173,093	254,663	264,811	81,570	10,148	91,718	0.68	0.65
700-1000	30	262,046	333,399	389,275	71,353	55,876	127,229	0.79	0.67
≥1000	12	347,546	391,409	518,108	43,863	126,699	170,562	0.89	0.67
Actual Revenue (\$1,000)									
<100	16	79,607	136,064	148,274	56,457	12,210	68,667	0.59	0.54
100-200	92	147,527	228,539	233,293	81,012	4,754	85,766	0.65	0.63
200-300	49	239,806	314,032	355,145	74,226	41,113	115,339	0.76	0.68
≥300	13	348,112	390,247	514,994	42,135	124,747	166,882	0.89	0.68

* See Table 2 for definitions of R, POTR and CRTSR.

inefficiency decreases and scale inefficiency increases. This pattern is similar to the change in the decomposition of inefficiency noted by Moll. To provide further insight into this change, the optimal farm size and returns to scale measures are examined using the 6-year average data. Sets of the efficiency estimates are generated, one for each of three data sets: "total," "small," and "large." The "total" data set represents the entire 170 farms for the six-year average data. The "small" and "large" samples include only the 85 smallest and largest farms, respectively, in the "total" data set.

A ray-homothetic function is estimated for each of the samples. Based upon the estimated coefficients, the optimal output (OPTR), the returns to scale measure (u),¹² the levels of inefficiency, and the efficiency ratios are calculated (Table 5). Within each data set (total, small and large), the average values of these variables are also reported for the smallest and largest farms.

Several points emerge from Table 5. First, the total efficiency measures for both the small and large data sets are higher than for the total data set. Grouping the farms into similar size classes increases sample efficiency measurement. Second, regardless of the sample, decreasing returns to scale are evidenced. The average returns to scale measure, u , is always less than 1 for each of the complete samples (total, $u = 0.76$; small, $u = 0.64$; large, $u = 0.81$). Also, within each data set, the large farms exhibit greater pure technical efficiency and larger scale inefficiencies

than do the small farms. Furthermore, for all the data sets, u is greater than one (increasing returns) for some small farms and less than one for larger farms.

The scale inefficiency increases with farm size because of the form of the ray-homothetic function and because the optimal level of output (OPTR) does not change substantially within any of the data sets. For example, for the total data set, OPTR averaged \$201,951 with a standard deviation of only \$1,163. However, the actual revenue (R) of these farms ranged between \$48,556 and \$403,450. Further inspection of the factor shares for small and large farms revealed limited variability across size as the reason for a relatively constant OPTR.

It also appears that the ray-homothetic function classifies farms as being either scale efficient or scale inefficient depending upon the sample. For example, the smallest 85 farms in the total data set are found to be operating at approximately constant returns to scale ($u=1.01$). However, when only these farms are used (the small data set) in the estimation, substantial scale inefficiencies are identified ($u=0.64$: farms are operating at decreasing returns). This identifies the importance of the appropriate definition of the representative sample.

The findings here provide some insight into the Moll and Grabowski dialogue regarding the RHF. First, for the three samples (total, small, and large) the specification of the RHF appears to impose increasing returns to scale on the smallest farms and

¹² The returns to scale measure, or function coefficient, for this specification of the ray-homothetic function is:

$$u = (\alpha_r K_f + \alpha_p K_p + \alpha_s K_s + \alpha_c K_c + \alpha_b K_b + \alpha_n K_n + \alpha_l K_l) / R.$$

If $u=1$, constant returns to scale are exhibited. Increasing returns are indicated by $u>1$ and decreasing returns by $u<1$.

Table 5. Average Values of Actual Revenue (R), Optimum Revenue (OPTR), Returns to Scale Measure (u), Pure Technical and Scale Inefficiency and Efficiency Ratios for Selected Farm Samples

Data Set	Subset	Obs.	R*	OPTR	u	Inefficiency		Eff. Ratio	
						Pure Tech.	Scale	Pure Tech.	Total
		no.	----- dollars -----			----- dollars -----			
Total		170	183,072	201,951	0.76	73,772	25,111	0.71	0.65
	Small	85	124,581	202,089	1.01	76,057	4,071	0.62	0.61
	Large	85	241,563	201,812	0.58	71,487	46,151	0.77	0.67
Small		85	124,581	110,351	0.64	35,769	17,797	0.78	0.70
	Small	42	101,346	110,310	0.76	39,189	7,394	0.72	0.69
	Large	43	147,275	110,390	0.53	32,428	27,957	0.82	0.71
Large		85	241,563	243,097	0.81	52,200	13,459	0.82	0.79
	Small	42	196,663	243,337	0.97	53,357	1,075	0.79	0.78
	Large	43	285,418	242,862	0.68	51,071	25,555	0.85	0.79

decreasing returns on the larger farms. This effect is due to the form of the RHF in which the measure of returns to scale is inversely related to output and the fact that factor intensities do not differ appreciably across farms (see footnote 12). Second, in situations where factor intensities are relatively constant, the appeal of the RHF specification examined here may be diminished. High levels of scale inefficiencies may be due to the specification of the RHF rather than to the underlying nature of the production technology. In these circumstances, it may be more useful to consider alternative parametric specifications of the production technology with emphasis on statistical testing of the functional form prior to efficiency measurement. Finally, the results of this study do not indicate that mean farms always experience constant returns to scale; decreasing returns to scale are always indicated for the average output level.

SUMMARY AND CONCLUSIONS

This analysis examines several factors influencing farm efficiency measurement. Farm level data for 170 homogeneous grain farms was analyzed over a six-year period for various temporal and size aggregates. The effect of temporal aggregation on farm firm efficiency measurement was assessed using the ray-homothetic function. The change in the decomposition of inefficiency estimation was also explored.

The results provide some insight into the recent mixed assessments of farm firm efficiency. The measurement of farm efficiency appears to be time dependent. Year-to-year events statistically influ-

ence efficiency measures, suggesting that policy recommendations based on data from only one year must be made in a cautious manner. Multiple-year aggregation clearly has an upward effect on farm efficiency measurement. When efficiency is examined on a yearly basis, farms appear to be producing between 50 and 60 percent of their potential. At higher levels of temporal aggregation, average efficiency measures increase to between 60 and 65 percent of potential. Here, temporal aggregation of expenditure data permits a more accurate representation of the production frontier by accounting for irregularities caused by cash versus accrual measurement errors and the effects of beneficial crop rotation practices.

Overall, the results of the analysis reveal a surprisingly high level of farm inefficiency over the 1982-1987 period. Even when the study controls for sample homogeneity and calculates efficiency measures over larger temporal aggregates, the findings suggest that output could be increased by roughly 35 percent. The causes of this inefficiency are not readily apparent. While differences in the level of management are clearly affecting the findings, other factors may be influencing the results. Perhaps the majority of farmers are employing older, less effective technologies, while more innovative farmers have adopted more effective methods of production. Alternatively, farmers may possess different objectives that may result in achieving varying degrees of efficiency.

Alternative explanations of the high degree of inefficiency rest on the procedures used to estimate and calculate the efficiency measures and their de-

composition. First, the use of COLS approach, which categorizes all deviations from the frontier as inefficiency, may be too sensitive to outliers. Even after eliminating several observations that seemed dramatically different from the sample and using various temporal aggregates, the research found relatively large levels of inefficiency. Second, the specification of the RHF appears to be imposing rather high levels of decreasing returns to scale for the larger farms. This occurs because of the relative constancy of the factor shares and because the scale measure varies inversely with output. For the larger firms, higher levels of scale inefficiency tend to offset increases in pure technical efficiency. For the six-year average data, total farm efficiency initially rises but does not increase significantly for farms larger than 400 acres. Also, for several individual years, total efficiency declines for large size operations.

Clearly, additional research is needed to identify under what circumstances particular methods should be employed to measure farm efficiency. Perhaps more accurate measurements of the level of inefficiency should involve the use of stochastic frontier procedures that permit deviations from the

frontier to be due to random events as well as to technical inefficiency. Also, more care needs to be taken in the applications of specific functional forms. The use of the ray-homothetic function in the literature has not been based on statistical criteria. Instead, it has been used because it permits the optimal size of farm to vary with factor intensity, a unique characteristic of the function. For those technologies and samples where the factor intensities do not vary appreciably across firms, perhaps more emphasis needs to be placed on statistically determining the "best" functional form prior to generating measures of efficiency. This is especially significant in an environment where returns to scale are hypothesized to be important determinants of efficiency and the distribution of farms. Even when total efficiency is accurately assessed, errors in the measurement of the decomposition can lead to inappropriate recommendations, strategies, and policies to ameliorate its presence. Finally, direct comparisons with efficiency measures from procedures that incorporate multiple output technologies may provide additional insight into the assessment of firm behavior in the agricultural sector.

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