MEASURING SCOPE EFFICIENCY FOR CROP AND BEEF FARMS

Michael Langemeier

Kansas State University

Abstract

This paper examines scope efficiency for a sample of crop and beef farms in Kansas. Scope and economic efficiency were estimated for each individual farm using the nonparametric approach. Average scope efficiency was 0.25 indicating that joint production of crop and beef cow enterprises on the same farm reduced total cost by 25%. Scope efficiency was significantly higher for smaller farms. Despite the relatively higher scope efficiency levels, economic efficiency was significantly lower for smaller farms.

Key Words: Economic and Scope Efficiency

Sub Theme: Farm Management

Introduction

Both the percent of income from livestock and the percent of farms with livestock income in Kansas have declined over the last 30 years (Langemeier, 2009). Though this decline has occurred for beef, swine, and dairy, the percentage decline is not near as large for beef as it is for swine and dairy. Moreover, the majority of farms still have a beef enterprise. In 2008, approximately 63 percent of Kansas Farm Management Association (KFMA) farms had a beef enterprise. The existence of economies of scope or scope efficiency for a combination of crop and beef enterprises would help explain the persistence of this farm type. Scope efficiency exists when the total cost of producing two or more enterprises together on the same farm is less than the total cost of producing the enterprises on separate farms (Baumol, Panzar, and Willig, 1982).

Research that examines scope efficiency or economies of scope for agricultural enterprises is sparse. Chavas and Aliber (1993), using a sample of Wisconsin farms, found substantial economies of scope associated with the joint production of crops and livestock. However, average economies of scope declined as farm size increased. Wu and Prato (2006) examined scope efficiency for a sample of Missouri farms. Scope efficiency was inversely related to farm size. Mayen, Balagtas, and Alexander (2009) examined economies of scope in dairy farming in the United States. The authors found significant economies of scope for organic dairy producers.

Unlike previous studies, this study focuses on economies of scope between crop and beef enterprises, a common farm type in the Central Plains of the United States. There are three potential sources of economies of scope between these enterprises. First, a farm may be able to more effectively utilize labour in winter months if they have both crops and beef. Second, a farm may be able to more effectively utilize capital, especially machinery and equipment, if they have both crop and beef enterprises. Third, beef enterprises can often utilize crop aftermath or wheat pasture with little or no loss in crop revenue. Though crop-only farms could conceivably rent these resources out to other producers, there are often large transaction costs associated with doing so. Therefore, these resources are frequently unused on crop-only farms. The use of crop aftermath or wheat pasture could lower the total cost of producing both crop and livestock enterprises and would thus be associated with economies of scope.
The primary objective of study was to examine scope efficiency for a sample of Kansas crop and beef cow farms using nonparametric analysis. The relationship between scope efficiency, economic

efficiency, and farm size were also explored. Farm size was measured using value of farm production, total hectares, and beef income.

Methods

Scope efficiency can be estimated by examining the cost of producing individual outputs and the cost of producing outputs jointly (Baumol, Panzar, and Willig, 1982; Chavas and Aliber, 1993). Specifically the following index of scope efficiency can be utilized:

$$SC(r, y, T_v) = ((\sum_j C_j(r, y_j, T_v)) / C(r, y, T_v)) \qquad (1)$$

where SC is scope efficiency, r is an input price vector, y is a vector of outputs, T_v refers to technology under variable returns to scale, Cj represents the cost of producing the j^{th} output, y_j represents the j^{th} output, and C is the cost of producing outputs jointly. Scope economies can be measured for numerous permutations of the output vector. This study focuses on economies of scope associated with jointly producing both crop and beef enterprises[17]. Thus, the vector of outputs in equation (1) includes crop and beef enterprises. Economies of scope resulting from the joint production of crop and beef enterprises exist if SC > 0. Diseconomies of scope exist if SC < 0.

In this study, scope efficiency was estimated using the nonparametric approach. The advantages associated with using the nonparametric approach rather than econometrically estimating scale and scope economies are threefold. First, by using the nonparametric approach, cost efficiency rather than estimated cost (which is typically not adjusted for efficiency differences among production units) was used to compute scope efficiency. Clearly, cost efficiency is the more relevant measure for decision making at the individual farm level. Second, the nonparametric approach imposes curvature on the cost function as part of the estimation. Thus, it is not necessary to test for curvature or impose curvature on the estimated coefficients. Third, the nonparametric approach does not assume a specific functional form for the cost function.

The computation of scope efficiency involves the estimation of cost efficiency under variable returns to scale (Chavas and Aliber, 1993). The following linear program was used to estimate cost efficiency under variable returns to scale for each farm:

$$\begin{aligned} C_i(r, y, T_v) &= \text{Min } r_i' x_i \\ \text{subject to} \quad & x_{11} z_1 + x_{12} z_2 + \cdots + x_{1k} z_k \le x_{1i} \qquad (2) \\ & x_{21} z_1 + x_{22} z_2 + \cdots + x_{2k} z_k \le x_{2i} \\ & x_{31} z_1 + x_{32} z_2 + \cdots + x_{3k} z_k \le x_{3i} \\ & x_{41} z_1 + x_{42} z_2 + \cdots + x_{4k} z_k \le x_{4i} \\ & x_{51} z_1 + x_{52} z_2 + \cdots + x_{5k} z_k \le x_{5i} \\ & y_{11} z_1 + y_{12} z_2 + \cdots + y_{1k} z_k - y_{1i} \ge 0 \\ & y_{21} z_1 + y_{22} z_2 + \cdots + y_{2k} z_k - y_{2i} \ge 0 \\ & z_1 + z_2 + \cdots + z_k = 1 \end{aligned}$$

where C is cost, r is a vector of input prices, y represents output levels, T_v refers to technology under variable returns to scale, x represents a vector of inputs, and z is an input intensity vector. The subscript k represents the number of farms, and the subscript i represents the individual farm of interest. There is a constraint for each input and output in equation (2). Each input or output constraint compares the input or output levels of the individual farm of interest to the input and output levels of all of the other farms in the sample. As illustrated in equation (2), five inputs and two outputs were utilized in this study.

[17] Scope efficiency could also be estimated for various crop combinations. Estimating scope efficiency for various crop combinations is an important topic, but is outside the scope of this paper.

March2011 - ISBN 978-92-990056-6-8 www.ifmaonline.org - Congress Proceedings

Three permutations of equation (2) were used to compute scope efficiency for each farm. First, equation (2) was estimated for each farm with all of the outputs included. The resulting estimate represents the denominator of equation (1). Second, equation (2) was estimated without the beef output. Third, equation (2) was estimated with just the beef output. The second and third permutations represent the numerator of equation (1).

Economic efficiency was also estimated for each farm using the nonparametric approach. Economic efficiency was computed by multiplying technical efficiency by allocative efficiency[18]. Economic efficiency measures a farm's ability to produce on the cost frontier. Scope efficiency could lead to improvements in economic efficiency, providing the primary impetus for estimating economic efficiency in this study.

Scope and economic efficiency were correlated with income ratios, expense ratios, and farm size measures. This enabled us to determine whether scope efficiency is related to the use of specific inputs or the production of specific outputs. Examining scope efficiency differences across inputs and outputs is particularly relevant for gaining a better understanding of farms that utilize crop aftermath or wheat grazing. Income ratios were computed by dividing each enterprise income item by value of farm production. Similarly, input ratios were computed by dividing each expense item by value of farm production. Three measures of farm size were utilized: value of farm production, total hectares, and beef income. Value of farm production categories included farms with a value of farm production less than \$100,000, farms with a value of farm production between \$100,000 and \$250,000, farms with a value of farm production between \$250,000 and \$500,000, and farms with a value of farm production above \$500,000. The mean and standard deviation of total hectares were used to categorize farms into three categories: farms with total hectares more than one standard deviation below the mean, farms with total hectares between one standard deviation below the mean and one standard deviation above the mean, and farms with total hectares more than one standard deviation above the mean. The mean and standard deviation of beef income were also used to categorize farms by size. The standard deviation of beef income was larger than the average beef income so there were only two categories: farms with beef income up to one standard deviation above the mean and farms with beef income greater than one standard deviation above the mean.

To determine whether scope efficiency and economic efficiency were significantly different across income and expense ratios, and/or farm size categories, t-tests were utilized. Based on previous research, average scope efficiency was expected to be significantly different from zero, scope efficiency was expected to be inversely related to farm size, and economic efficiency was expected to be positively related to farm size. Previous research does not address gains in efficiency resulting from the use of crop aftermath and/or wheat pasture. If utilizing crop aftermath and/or wheat pasture reduces total cost, there will be a positive correlation between beef income and scope efficiency.

Data

Information for farms with crop and beef cow enterprises was obtained from farms participating in the Kansas Farm Management Association (KFMA) with continuous data from 2004 to 2008. Given the focus on crop and beef farms, farms typed as swine, dairy, or turkey were not included in the analysis. Though annual data were available for each farm, five-year average data were used in this study to reduce the impact of weather in a particular year on efficiency estimates.

Efficiency estimates required data on total cost, outputs, inputs, and input prices. Two outputs, crop and livestock, were used in the estimation. The crop output was computed using crop income share

[18] Detailed information on the estimation of technical, allocative and economic efficiency can be found in Färe, Grosskopf & Lovell (1985) and Coelli, Rao & Battese (2005).

weights and output prices for crops in Kansas (USDA). The livestock output was computed using livestock income share weights and output prices for livestock in Kansas (USDA). Dairy and swine are minor enterprises for the sample farms so for all intensive purposes the livestock output represents the output resulting from beef production.

Inputs were divided into five categories: labour, crop inputs, fuel and utilities, livestock inputs, and other. Labour included hired as well as family and operator labour. Crop inputs included seed, fertilizer and lime, crop marketing and storage, herbicide and insecticide, and crop insurance. Livestock inputs included dairy expense, feed purchased, veterinarian expense, and livestock marketing and breeding. The "other input" represented capital and miscellaneous expenses and included repairs, machine hire, conservation, interest, cash farm rent, real estate and personal property taxes, general farm insurance, organization fees, dues, and publications, and depreciation. All of the inputs were computed by dividing the input costs by input price indices (USDA).

Though output and input data was used to compute the efficiency indices, presenting income and expense data is often helpful when describing farm characteristics of the sample of farms. Table 1 summarizes income and expense information for the sample of farms. The standard deviation for each variable can be found in parentheses. Information is summarized for all farms with crop and/or beef enterprises, and for beef farms or farms that produced at least some beef. It is important to note that most of the beef farms also produced crop enterprises and received income from government payments, crop insurance, custom work, and/or patronage dividends. Using value of farm production as a measure of size, the beef farms were relatively smaller than the full sample of farms, but, due to the importance of pasture to these farms, the beef farms had more total hectares.

Results

Data for the full sample of farms were used to estimate scope and economic efficiency. To effectively measure scope efficiency, farms with various enterprise combinations were needed. Given the focus of this study, scope and economic efficiency results discussed below are presented only for the farms with a beef enterprise (i.e., beef farms).

The average scope efficiency index was 0.2527 indicating that joint production of beef and crop enterprises on the same farm reduced cost approximately 25 percent. The average economic efficiency index was 0.6753 indicating that, on average, farms could reduce cost by approximately 32 percent by producing at the lowest possible cost for a given level of output or on the cost frontier.

Table 2 presents correlation between efficiency, and income, expense, and farm size variables. The income and expense ratios were computed by dividing the income or expense item by value of farm production. Correlation is a statistical measure of how variables move together and is bounded by -1.0 and 1.0. A value of -1.0 indicates two variables move together perfectly, but in opposite directions, while a value of 1.0 indicates two variables move up and down together proportionally. Values close to zero indicate the two variables have little relationship to each other. Note that scope efficiency is significant and negatively correlated with feed grain and oilseed income, and significant and positively correlated with beef income. This indicates that farms with relatively larger amounts of feed grain and oilseed income have lower scope efficiency indices while farms with a relatively larger amount of beef income have higher scope efficiency indices. The positive correlation between beef income and scope efficiency suggests that producing both crops and beef on the same farm results in cost advantages. These cost advantages could be due to more efficient utilization of labour and capital, see discussion below, and/or the use of crop aftermath or wheat pasture.

March2011 - ISBN 978-92-990056-6-8 www.ifmaonline.org - Congress Proceedings

Table 1. Summary Statistics for a Sample of Crop and Beef Farms.

Variable	All Farms	Beef Farms
Number of Farms	817	563
<u>Efficiency</u>		
Scope (Index)	N/A	0.2527 (0.1765)
Economic (Index)	0.6698 (0.1244)	0.6753 (0.1219)
<u>Income</u>		
Feed Grains ($)	98,077 (140,363)	87,818 (127,865)
Hay and Forage ($)	13,141 (37,992)	13,913 (39,307)
Oilseeds ($)	68,265 (89,838)	65,596 (88,500)
Small Grains ($)	64,124 (69,613)	60,385 (65,887)
Beef ($)	53,162 (164,458)	77,146 (193,434)
<u>Expenses</u>		
Labor ($)	58,582 (35,445)	59,001 (36,044)
Crop Inputs ($)	101,185 (99,291)	96,963 (95,142)
Fuel and Utilities ($)	29,489 (31,202)	28,696 (24,738)
Livestock Inputs ($)	23,801 (173,665)	33,962 (208,410)
Other ($)	177,002 (130,559)	182,484 (131,796)
<u>Farm Size</u>		
Value of Farm Production ($)	343,444 (310,908)	341,890 (307,731)
Total Hectares	771 (516)	828 (535)

March2011 - ISBN 978-92-990056-6-8 www.ifmaonline.org - Congress Proceedings

Table 2. Correlation Between Efficiency, and Income, Expense, and Farm Size.

Variable	Scope Efficiency	Economic Efficiency
Income Ratios		
Feed Grains	-0.3727*	0.1619*
Hay and Forage	0.0449	-0.1631*
Oilseeds	-0.1152*	-0.0290
Small Grains	0.0355	-0.0938*
Beef	0.2201*	0.1246*
Expense Ratios		
Labor	0.7870*	-0.3176*
Crop Inputs	-0.1983*	-0.1815*
Fuel and Utilities	0.4812*	-0.2696*
Livestock Inputs	0.0221	0.2028*
Other	0.5802*	-0.5397*
Farm Size		
Value of Farm Production	-0.6165*	0.4568*
Total Hectares	-0.5820*	0.3109*
Beef Income	-0.1510*	0.2398*

Note:

An asterisk indicates that the efficiency index was significantly different from zero at the 5% level.

March2011 - ISBN 978-92-990056-6-8 www.ifmaonline.org - Congress Proceedings

Examining the correlation between scope efficiency and the expense ratios, it is evident that farms with relatively larger labour, fuel and utility, and other expense ratios have higher scope efficiency indices. This result suggests that farms with higher scope efficiency indices use joint production to lower these input ratios. This result is very intuitive. Controlling labour expense and capital expense, an important component of the other expense ratio, are often cited as reasons for producing both crop and beef enterprises.

Finally, scope efficiency is significant and negatively correlated with farm size while economic efficiency is significant and positively correlated with farm size. In other words, larger farms have lower scope efficiency indices and higher economic efficiency indices. Table 3 presents scope and economic efficiency indices by farm size category. Regardless of the farm size measure used, the largest farm size category had significantly lower scope efficiency indices and significantly higher economic efficiency indices. It is important to note, however, that even though the scope efficiency index for the largest farm size categories is significantly lower, it is still significantly greater than zero indicating that scope efficiency is still important on larger farms.

Summary and Conclusions

The objective of this paper was to examine scope efficiency for a sample of crop and beef farms. Scope efficiency associated with the joint production of crops and beef could result from the improved utilization of labour and capital, and/or a more effective use of resources such as crop aftermath and wheat pasture. Scope efficiency was estimated for each farm, and was related to income and expense shares as well as farm size.

The average scope efficiency index was 0.2527 indicating that joint production of crop and beef enterprises on the same farm reduced total cost approximately 25%. Though scope efficiency was significantly different from zero for all farm size categories, scope efficiency was significantly higher for smaller farms. Despite the relatively higher scope efficiency indices, economic efficiency was significantly lower for smaller farms suggesting that scope efficiency levels for the small farms were not large enough to offset other cost disadvantages relative to the large farms.

Table 3. Scope and Economic Efficiency by Farm Size Category.

Farm Category	Number of Farms	Scope Efficiency	Economic Efficiency
Value of Farm Production			
Less than $100,000	70	0.5999*[a]	0.6199[a]
$100,000 to $250,000	204	0.3079*[b]	0.6390[a]
$250,000 to $500,000	182	0.1557*[c]	0.6812[b]
Greater than $500,000	107	0.0850*[d]	0.7705[c]
Total Hectares			
Less than 293	54	0.5721*[a]	0.6367[a]
293 to 1,363	446	0.2328*[b]	0.6699[a]
Greater than 1,363	63	0.1194*[c]	0.7463[b]
Beef Income			
Less than $270,580	543	0.2576*[a]	0.6703[a]
Greater than $270,580	20	0.1184*[b]	0.8094[b]

Notes:

An asterisk indicates that the scope efficiency index was significantly different from zero at the 5% level.

An unlike superscript in the scope efficiency or economic efficiency column indicates that the indices are significantly different across size categories.

Given the results presented in this article, the crop/beef farm type is likely to remain a common farm type in Kansas. There are significant cost advantages associated with producing both crop and beef enterprises on the same farm. These cost advantages are particularly strong for smaller farms which use diversification to reduce per unit labour and capital costs.

References

Baumol, W.J., J.C. Panzar, and R.D. Willig. 1982. Contestable Markets and the Theory of Industry Structure. New York: Harcourt, Brace, and Javanovich.

Chavas, J.P. and M. Aliber. 1993. "An Analysis of Economic Efficiency in Agriculture: A Nonparametric Approach." Journal of Agricultural and Resource Economics. Volume 18, pages 1-18.

Coelli, T., D.S.P. Rao, C.J. O'Donnell, and G.E. Battese. 2005. An Introduction to Efficiency and Productivity Analysis, Second Edition. Boston: Kluwer Academic Publishers.

Färe, R., S. Grosskopf, and C.A.K. Lovell. 1985. The Measurement of Efficiency of Production. Boston: Kluwer-Nijhoff.

Langemeier, M. 2009. "Relative Importance of Livestock Income to KFMA Farms." KFMA Newsletter, Department of Agricultural Economics, Kansas State University, January.

Mayen, C.D., J.V. Balagtas, and C.E. Alexander. 2009. "Vertical Economies of Scope in Dairy Farming." Journal of Agricultural and Food Industrial Organization. Volume 7, pages 1-15.

United States Department of Agriculture. Agricultural Prices. Various issues, 2004-2008. Washington DC: U.S. Government Printing Office.

Wu, S. and T. Prato. 2006. "Cost Efficiency and Scope Economies of Crop and Livestock Farms in Missouri." Journal of Agricultural and Applied Economics. Volume 38, December, pages 539-553.