An Economic Performance Analysis of the Beef Cow-herd Enterprise Using a Stochastic Frontier Function

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Abstract

Standardized Performance Analysis (SPA) data from Texas, Oklahoma, and New Mexico were used to examine the economic performance of beef cow herd operations in the Southern Plains region by measuring their technical efficiency index. Factors that make significant impacts on the production are herd size, machinery investment per breeding cow, and rainfall. Little technical inefficiency among the Southern beef cattle operations that participated in the SPA data was found.

Key word: beef, cattle, cost, cow-calf, production, stochastic production function.

Introduction

Beef cow calf operators need to properly manage and control factors incurred in the business and identify inefficient areas. Production measures targeted at increasing production have been commonly of interest among ranch operators because production is directly related to the profit of their enterprise. Under a competitive environment and being subject to common prices for inputs and outputs, productivity of individual farms is a major factor to contribute to the competitiveness of the cow herd enterprises.

The beef cow-calf Standardized Performance Analysis (SPA) is a tool developed by cattlemen, researchers, and extension specialists for cow herd operations to analyze their enterprise utilizing both financial and production records. The analysis focuses on the cow-calf production process through the weaned calf. SPA results used in this study came from individual beef cow calf herds analyses from Oklahoma, Texas, and New Mexico from 2004 to 2008. This SPA data is unique in that different production systems from extensive operations in the western part of region to intensive operations in the eastern part of region can be interpreted as the diversity of cow herd enterprises in the region with a wide range of characteristics (production and financial variables).

SPA, since its inception, has been used throughout Texas, Oklahoma, and New Mexico to analyze beef herds with the objective of each herd determining their strengths and weakness. Furthermore, the analysis aided the rancher in identifying where change was needed to help them reduce their overall cost of production. Results include ten production performances, 25 financial performances, and eleven miscellaneous performances. A secondary purpose of the SPA analysis is to develop regional SPA databases. Because the results are standardized, each herd is analyzed in a consistent basis. The database is then used to develop benchmarks for comparison of an individual herd to a like set of results. In addition, the database provides valuable information for research purposes.

There were several previous studies using SPA data. Using data from eight states including Montana, Wyoming, North and South Dakota, Nebraska, Kansas, Minnesota, and Iowa, Dunn (2000) found that lower investment, better production, lower expense, and higher market values for calves were factors characterizing herds in the higher profit groups. Miller et al (2001) identified specific factors affecting herd's profitability using 225 cow SPA data from Illinois' and Iowa. Important factors included feed costs, depreciation and operating costs, values of calves sold, and production. Falconer et al (1999) used SPA data from Texas cow-herds to estimate a cost function for the cow-calf operation and found that total cost of production is significantly affected by prices for feed and grazing, other operating costs, and total production.

A recent study by Ramsey et al (2005) identified management factors affecting cost of production, production, and profit of the cow-calf enterprise. Factors significantly related with the cost included investments in real estate, machinery, equipment, livestock, pounds of feed fed, and calf death loss, herd size, calving percentage, and length of the breeding season. Production is also significantly affected by investment in livestock, higher calving percentage, death losses, and longer breeding season. In terms of herds' profit, there were three factors such as calving percentage, and an increase in pounds of feed fed.

The main objective of this study is to examine the economic performance of beef cow herd operations in the Southern Plains region by measuring their technical efficiency index. Specific objectives are; first, to examine the effects of economic factors on output production in the beef cowherd; second, to measure the technical efficiency of farms by identifying the dispersion of production technology levels of the farms; and finally, to evaluate major contributing factors to the technical efficiency of cow herd operations.

Data and Method

From 2004 through 2008, 104 beef cow herds from Texas. Oklahoma, and New Mexico were analyzed using the SPA analysis. These analyses were conducted in either a workshop format conducted by Texas Extension Specialists or by individual ranch visits. A ranch management plan including the results of the analysis, weaknesses of the herd, and plans for improving the situations was developed, delivered and discussed with each herd manager. Included in the results is a ranch report card comparing the herd to a subset of like herds (i.e., size of herd, location, etc.).

Stochastic frontier production model, introduced (Aigner and Lovell 1977) and (Meeusen and van Den Broeck 1977), is applied to identify the existence of technical inefficiency in the beef cow-calf operations in the SPA data. In the model, the production function is viewed as a locus of maximum output levels from a given input set and thus the output of each firm is bounded above by a frontier (Kumbhakar 1987). The error term in the model consists of two independent components: one captures the exogenous shock and the other captures the technical inefficiency that causes production level of farms to be lower than production frontier, the maximum output levels from a given input set.

The log-linear form of stochastic frontier Cobb-Douglas production function for farm *i* can be expressed as

(1) $$\ln y_i = \beta_o + \sum\nolimits_n \beta_n \ln x_{ni} + \sum\nolimits_m \delta_m d_{mi} + v_i - u_i$$

where y_i is the output of a farm *i*, x_{ni} is the n-th input factor, d_{mi} is the m-th dummy variable, v_i is the two-sided symmetric random error term representing random shock, and u_i is the one-sided efficiency error term representing technical inefficiency. The random error term is assumed to be independently and identically distributed, $v_i \sim N(0, \sigma_v^2)$, while the efficiency error term is assumed to be distributed either half-normally or exponentially, and is modeled as a linear function of farm specific management factors.

The production factors used to estimate production technology in this study include pounds weaned per exposed female, herd size, pounds of feed per breeding cow, total labor per breeding cow, livestock investment per breeding cow, machinery investment per breeding cow, real estate investment per breeding cow, rainfall, and year dummies (Table 1). Although five years of SPA data was used in this study, the majority of farms participating in the data set submitted only one or two years of production information. Therefore, the data set was treated as cross-sectional data with year dummies rather than panel data.

Pounds weaned per exposed female is defined as the output representing production of beef cattle operations and others are defined as inputs. In particular, three investment factors represent capital intensity of a farm. On the other hand, farm specific management factors used to explain technical inefficiency level of farms in this study include calving percentage, calving death loss based on exposed females, and breeding-season length (Table 1). These factors are associated with reproduction skill of a farm, which is the most important management skill in production in beef cattle operations.

Most of the production and management factors used in this study were considered to be important factors affecting production in beef cattle operations in a previous study (Ramsey et al 2005) and a detailed discussion of these factors can be found there. The factors in Ramsey et al (2005) and those of this study differ in two ways. The former considers management factors as directly affecting output production of a farm. This study includes additional labor data to take into account labor variations in the SPA data and year dummies and rainfall data to take into account weather and other environmental variations in the SPA data. Rainfall also directly affects both the quality and quantity of own-growing roughage.

Result

The stochastic frontier production function is estimated[1] using the maximum likelihood technique under the assumption that the function has two separate error terms: a symmetric random error term (v_i), which captures the effects of traditional random variation, and a one-sided error term (u_i), which allows for technical inefficiency. The estimation results with either a one-sided exponential distributed error term or half-normally distributed error term[2] are almost identical to each other. Thus, only the estimation result with a one-sided exponential distributed error term is presented in Tables 2 and 3 for discussion.

The estimation results (Table 2) indicate that herd size, machinery investment per breeding cow, and rainfall have statistically significant effects on output production at the 0.05 level. Since machinery investment per breeding cow represents capital intensity of a farm, a positive coefficient on this is as generally expected, while negative coefficients

[1] The software STATA is used to estimate the model.
[2] The estimation results with a one-sided half-normally distributed error term are presented in the Appendix for comparison purposes with the estimation results with a one-sided exponentially distributed error term shown in Table 2.

on herd size and rainfall are different from general expectation. However, the negative coefficients on herd size might imply that the farm size in the SPA data (average of 528 breeding cows) is greater than the optimal farm size. Practically, larger ranches tend to lose productivity. They can get “too” big and then not be able to assist productivity. Similarly, the negative coefficients on rainfall might imply that the rainfall levels in the SPA data are greater than the optimal level of rainfall to growing forage. Otherwise, rainfall may also reflect other environmental factors which are not captured in either rainfall data or year dummies and affect production negatively.

There appears to be little technical inefficiency among the Southern beef cattle operations that participated in the SPA data (Figure 1 and Table 3). The average value of estimated technical efficiency is 92%, and more than 70% of farms have technical efficiency of more than the average of 92%. Only 13% of farms have technical efficiency less than 80%. The estimation results indicate calving percentage has statistically significant effect on technical inefficiency at the 0.05 level. A higher calving percentage represents better management skill and results in lower technical inefficiency. Therefore the coefficient on calving percentage is negative as expected.

Conclusion and Discussion

SPA data of 104 beef cow herds from Texas, Oklahoma, and New Mexico from 2004 through 2008 were used to examine the economic performance of beef cow herd operations in the Southern Plains region by measuring their technical efficiency index. Factors that make significant impacts on the production are herd size, machinery investment per breeding cow, and rainfall. Results also showed that little technical inefficiency among the Southern beef cattle operations that participated in the SPA data exits.

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Table 1. Variable Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max	Unit
Pounds weaned per exposed female	104	433	81	263	639	Pounds
Herd Size	104	528	929	32	5,561	Cows
Pounds of feed per breeding cow	104	1,869	1,452	55	6,051	Pounds
Total labor per breeding cow	104	102	66	1	346	Dollars
Rainfall	104	31	11	9	69	Inches
Livestock investment per breeding cow	104	819	281	254	1,969	Dollars
Machinery investment per breeding cow	104	232	430	1	3,844	Dollars
Real estate investment per breeding cow	104	2,010	3,325	1	25,552	Dollars
Calving Percent	104	85	9	59	100	Percent
Calving death based on exposed females	104	4	3	1	16	Percent
Length of breeding season	104	138	92	54	366	Days

Note: There are 18 observations in the year 2004 (base year), 28 observations in the year 2005, 25 observations in the year 2006, 19 observations in the year 2007, and 14 observations in the year 2008.

Table 2: Stochastic Frontier Production Function Estimates

ln(Pounds weaned per exposed female)	Coefficient	Std. Err.	z	P>z
ln(Herd size)	-0.0362	0.0154	-2.34	0.02
ln(Pounds of feed per breeding cow)	0.0270	0.0154	1.76	0.08
ln(Total labor per breeding cow)	-0.0032	0.0136	-0.24	0.81
ln(Rainfall)	-0.1064	0.0477	-2.23	0.03
ln(Livestock investment per breeding cow)	0.0182	0.0401	0.45	0.65
ln(Machinery investment per breeding cow)	0.0258	0.0084	3.08	0.00
ln(Real estate investment per breeding cow)	-0.0042	0.0042	-1.01	0.31
Year 2005	0.0631	0.0443	1.42	0.15
Year 2006	0.0343	0.0448	0.77	0.44
Year 2007	0.0970	0.0475	2.04	0.04
Year 2008	0.0711	0.0485	1.47	0.14
Constant	6.2550	0.3619	17.28	0.00
$\ln\sigma^2_v$				
Constant	-4.4354	0.1919	-23.11	0.00
$\ln\sigma^2_u$				
Calving Percent	-0.2445	0.0639	-3.83	0.00
Calving death loss based on exposed females	0.3326	0.1872	1.78	0.08
Length of breeding season	0.0028	0.0041	0.68	0.50
Constant	13.2081	4.6087	2.87	0.00
σ_v	0.1089	0.0104		
N = 104, Log Likelihood = 64.6864, Wald chi2(11) = 32.79, Prob≥chi2 = 0.0006				

Note: The random error term is assumed to be independently and identically distributed, $v_i \sim N(0, \sigma_v^2)$, while the efficiency error term is assumed to be exponentially distributed.

Table 3. Technical Efficiency Summary Statistics

Variable	N	Mean	Std. Dev.	Min	Max
Technical Efficiency	104	0.92	0.095	0.58	0.99

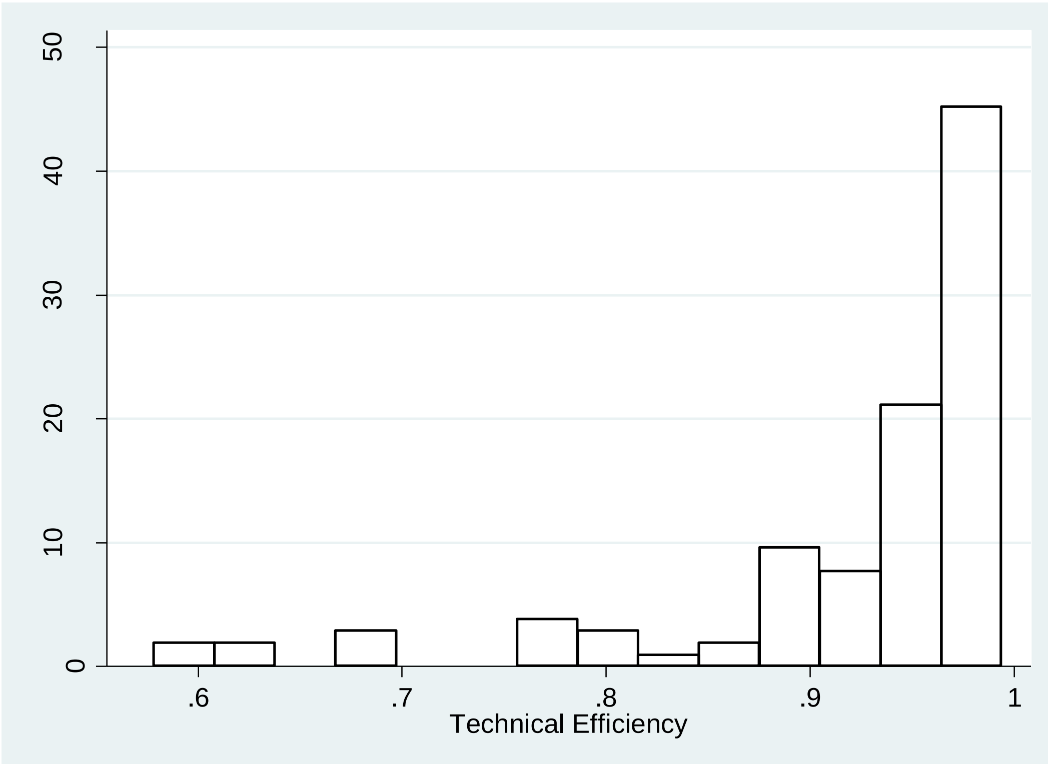

Figure 1. Technical Efficiency Scores of Farms

Appendix: Stochastic Frontier Production Function Estimates (Normal/Half-normal Model)[a]

ln(Pounds weaned per exposed female)	Coefficient	Std. Err.	z	P>z
ln(Herd size)	-0.0322	0.0155	-2.08	0.04
ln(Pounds of feed per breeding cow)	0.0265	0.0150	1.77	0.08
ln(Total labor per breeding cow)	-0.0054	0.0136	-0.40	0.69
ln(Rainfall)	-0.0971	0.0474	-2.05	0.04
ln(Livestock investment per breeding cow)	0.0165	0.0386	0.43	0.67
ln(Machinery investment per breeding cow)	0.0248	0.0082	3.03	0.00
ln(Real estate investment per breeding cow)	-0.0041	0.0041	-1.00	0.32
Year 2005	0.0628	0.0439	1.43	0.15
Year 2006	0.0329	0.0439	0.75	0.45
Year 2007	0.0979	0.0467	2.10	0.04
Year 2008	0.0675	0.0475	1.42	0.16
Constant	6.2528	0.3499	17.87	0.00
$\ln\sigma^2_v$				
Constant	-4.5351	0.2162	-20.98	0.00
$\ln\sigma^2_u$				
Calving Percent	-0.1942	0.0514	-3.78	0.00
Calving death loss based on exposed females	0.2523	0.1409	1.79	0.07
Length of breeding season	0.0025	0.0031	0.82	0.41
Constant	10.4512	3.6164	2.89	0.00
σ_v	0.1036	0.0112		
N = 104, Log Likelihood = 68.213, Wald chi2(11) = 29.96, Prob≥chi2 = 0.0016				

a. The random error term is assumed to be independently and identically distributed, $v_i \sim N(0, \sigma_v^2)$, while the efficiency error term is assumed to be half-normally distributed.