Determinants of Technical Efficiency in Louisiana Beef Cattle Production

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Abstract

Technical efficiency was estimated for a group of beef cattle producers. Producers using straight-bred Bos taurus bulls and mixed-bred Brahman cows were more technically efficient than producers who did not. Those who used a designated hay meadow, used registered cows, were older, and were more highly educated were the more technically efficient producers.

Introduction

U.S. beef cattle producers use a wide range of production practices; the climate, landscape, and soil types under which cattle are produced vary greatly geographically. Unlike its two main competitor industries, broilers and hogs, beef cattle production is primarily land-based, with little confinement used. Thus, it is subject to specific local environmental conditions, leading to highly varied production practices across regions. In addition to varied physical environments, clouded price signals received by cow-calf producers provide limited guidance as to the type of animal that is most desired by packers. Hence, even within regions and under relatively homogeneous conditions, a wide array of production practices is used to produce cattle.

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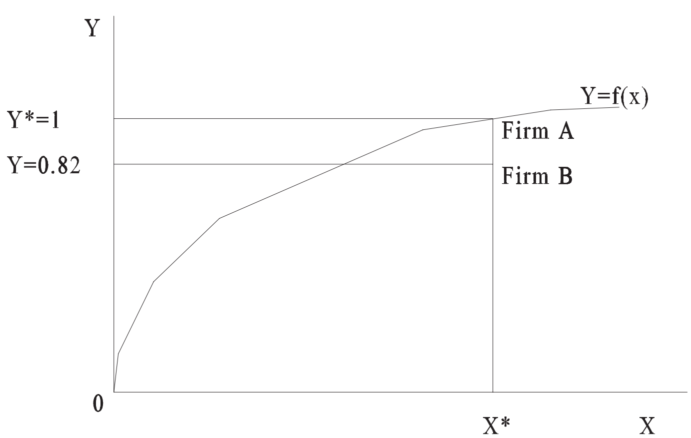
With the wide array of production practices employed in the beef industry, it is likely that some common production practices lead to inefficient operations. Estimates of net returns for commercial Louisiana cow-calf operations have periodically shown economic losses. Budgets for cow-calf production by Boucher (1995) and Boucher and Gillespie (1996-2002) have shown positive returns over specified expenses on semi-improved pastures in only two years, without labor expenses included. Coupling budgeted economic losses with the wide array of production practices leads to the question, "Which producers are likely to be successful in an industry segment that is plagued by low and often non-existent margins?" Technical efficiency, defined by Featherstone et al. (1997) is a measure of the distance a farm is off the production function under variable returns to scale, and is necessary for economic efficiency. Thus, it is appropriate to determine the types of operations that are likely to be technically efficient. Determination of the characteristics of the most efficient producers would provide insight into the types of operations that are likely to experience economic success in cattle production.

The objectives of this study are to (1) estimate the technical efficiency of a selected group of beef cattle producers in Louisiana and (2) determine the characteristics of cattle operations that are the most technically efficient.

Figure 1: Illustration of technical efficiency with production Function Y = f(x).



Methods

Suppose the production function for an input-output relationship is represented as Figure 1, where X is the aggregate input and Y is the output. The technically efficient firm, A, is able to get the maximum level of output, Y*, for a given input level, X*, due likely to superior management practices. Thus, on a scale from 0 to 1, this firm has a technical efficiency score of 1. Alternatively, Firm B also applies X* of input X, but is able to obtain only output Y^1=0.82, which is less than Y*. The distance $0Y^1$ is 82 percent of the distance $0Y^*$; thus, Firm B's technical efficiency score is 0.82. In other words, $Y^*/X^* > Y^1/X^*$, or 1 > 0.82. Two assumptions are typically made in measuring technical efficiency: (1) each firm in the industry follows the same production technology and (2) all inputs are homogeneous. Of course, this is a limiting assumption for the technical efficiency analysis since there are breed differences in cattle, different forage programs are used, and other inputs are also likely to vary. The follow-up tobit analysis to be discussed later addresses these differences in input quality.

Determining the level of output over the level of input (technical efficiency) is relatively easy when there is only one output and one input, such as the measure of calves produced per cow. However, in cases where there are multiple inputs used and multiple outputs produced on a farm, the determination of technical efficiency is more involved. In such a case, an alternative measure must be calculated. Data envelopment analysis is appropriate for use in estimating technical efficiency in cases when there are multiple outputs and multiple inputs, and there is not an objective way to use one efficiency index formula to determine a firm's efficiency. Using data envelopment analysis, linear programming methods provide a frontier for the most efficient firms. In the model, the producer is assumed to maximize weighted output subject to limited resources and subject to all other firms' weighted output minus weighted inputs being less than or equal to zero. The reader is referred to Sexton (1986) and Gillespie, Schupp, and Taylor (1997) for more detail on data envelopment analysis and the procedures for estimating technical efficiency. Using this model, the most efficient firms have technical efficiency scores equal to 1. Other less efficient firms fall within the envelope that is defined by this empirical frontier, and have efficiency scores less than one. A firm that produced no output would have an efficiency score of 0.

It is important to note that in practice those firms with technical efficiency scores equal to 1 have not necessarily reached the highest level of technical efficiency possible for a given production process. Instead, a technical efficiency score of 1 indicates that no other firm in the sample is more technically efficient given the combination of outputs and inputs used. Of course, it is possible for a firm outside the sample to be more technically efficient than the firms within the sample.

In this study, two outputs, numbers of weaned calves and stockers, and six inputs are used in the data envelopment analysis technical efficiency model. Inputs include the number of cows, the number of acres in the cattle operation, the number of breeding bulls, total hours of labor used per year in the cattle operation, amount of hay fed to cattle, and the total cost of operating tractors and machinery. These inputs represent the highest cost items in a cattle operation.

Determinants of Technical Efficiency

With technical efficiency measures estimated using data envelopment analysis for each of the surveyed farms, one may examine the farm and managerial characteristics that affect technical efficiency. A tobit regression model was estimated as TE=f(exogenous variables), where TE is the technical efficiency score of the producer, which is bounded above by 1 since 1 is the highest possible technical efficiency score. Exogenous variables include general production, breeding and forage management practices, demographic characteristics, farm type, and producers' future growth plans. The tobit model is a limited dependent variable model that is similar to the ordinary least squares model, except that the truncation of the dependent variable (in this case the technical efficiency score) is considered in the estimation. Details of the tobit model are presented in Maddala (1983), and also Greene (1997). Discussion of the exogenous variables follows.

The variable, *Presence of Stockers*, is a dummy variable indicating whether the cow-calf producer raised stockers. Producers raising both stockers and calves are expected to be more technically efficient due to vertical integration. Some inputs used in cow-calf production may be used in stocker production, allowing producers to produce more output per unit of input.

The weight at which a producer weans and sells calves is expected to be positively correlated with technical efficiency. Better management is likely to lead to a heavier *Weaning Weight of Calves Sold*, due to better environmental conditions for the cow.

The variable, *Farmer Pregnancy Tests*, is a dummy variable that takes the value of 1 if a farmer pregnancy tests cows, and 0 if otherwise. Pregnancy testing is likely to be conducted by farmers who are better managers, and may lead to higher technical efficiency. Also, culling of non-pregnant cows reduces maintenance costs on the herd and should improve efficiency. However, pregnancy testing requires more labor. If the necessary measures are taken after the test is conducted to get the non-pregnant cow pregnant, the breeding period is extended and may lower technical efficiency. Therefore, the effect of pregnancy testing on technical efficiency is indeterminate and will be investigated in the study.

Percentage of Improved Pasture measures the ratio of improved pasture acreage to the sum of the acreage of improved and unimproved pastures. With improved pasture, fertilizers and pesticides are applied, and the pastures are clipped as needed. Improved pasture typically provides higher quality and greater quantity of forage per acre than unimproved pasture for cattle. Koger et al. (1975) found higher annual production per cow with improved pasture than with native pasture. Thus, it is expected that this variable has a positive effect on technical efficiency.

The variable, *Straight-Bred Bos Taurus Bull*, is a dummy variable taking a value of 1 if the farmer uses only Continental or British breeds of bulls, and 0, if otherwise. Bos taurus bulls may impregnate a higher percentage of cows in a limited breeding season than either Brahman or mixed-bred Brahman bulls (Franke, personal communication). This is supported by Chenoweth et al. (1996), suggesting breed influenced semen traits of Bos taurus bulls are generally superior to Bos indicus breeds. Hence, it is hypothesized that this variable positively affects technical efficiency.

The variable, *Mixed-Bred Brahman Cows*, is the percentage of mixed-bred Brahman cows in the herd. These cows include British or Continental breeds crossed with Brahman. According to DeRouen and Franke (1989) and Williams et al. (1990), mixed-bred cows are generally more productive than straight-bred. Williams et al. (1990) found a calving rate of 73 percent for straight-bred cows, 83 percent for two-breed rotation cows, 87 percent for three-breed rotation cows and 85 percent for four-breed rotation cows. DeRouen and Franke (1989) found that crossbred heifers were more fertile than straight-bred heifers. Crossbred heifers had an average calving rate of 78 percent, while straight-bred cows had a calving rate of only 63 percent. Therefore, this variable is hypothesized to be positively correlated with technical efficiency.

The variable, *Registered Cows*, is the percentage of cows registered. Only purebred cows can be registered, and as discussed previously, purebred cows may have lower calving rates than mixed-bred cows. In addition, registered cattle producers have different objectives than commercial producers. They are likely to breed for the higher-value bull markets or for the show ring, rather than for slaughter, thus allowing more intensive input usage than by a commercial producer. These factors would suggest that producers of registered cows would have lower technical efficiency if output is not increased sufficiently to offset the increased input usage. Alternatively, registered producers are assumed to work with the highest quality cattle of their respective breeds. While a technical efficiency analysis assumes constant quality inputs, facilities may be of higher quality, allowing more efficient use of labor. Registered breeders are likely to manage their herds more closely, since high quality purebred animals command a premium price. These factors would suggest that producers of registered cows would have higher technical efficiency. Thus, the expected sign for Registered Cows is indeterminate.

The variable, *Age*, is the age of the operator in years. Boehlje (1992) discussed the stages of the family farm life cycle as the Sociological Model. During the exit stage, many entrepreneurs attempt to reduce their commitment to the business and profit maximization is less of a priority for them. Thus, one could argue that older farmers in the exit stage would likely have lower technical efficiency. Alternatively, older farmers typically have more experience in farming; Amara et al. (1999) found that greater experience in farming was associated with increased technical efficiency of potato farmers in Quebec. Thus, the effect of this variable on the technical efficiency of cattle producers is examined.

The variable, *Formal Education*, is the number of years of formal education of the producer. Education is expected to have a positive effect on technical efficiency, as more highly educated producers are more likely to remain up-to-date on the most appropriate production practices and to be better managers. Romain and Lambert (1995) found that education was positively correlated with technical efficiency in Ontario and Quebec milk production.

The variable, *Time Worked in an Off-Farm Job*, is the number of hours worked per week by the producer in an off-farm job. On the one hand, it can be expected that the more off-farm hours a producer works, the less time is devoted to the cattle operation, resulting in lower efficiency. Alternatively, an off-farm job may force a producer to become a better manager, and become more efficient in the use of resources to compensate for the time spent off-farm. Two previous studies (Bagi, 1984; Chavas and Aliber, 1993) did not find that an off-farm job significantly affected technical efficiency. The expected effect of this variable on technical efficiency is indeterminate and will be investigated in the study.

The variable, *Operation is Highly Important*, is a dummy variable that takes the value of 1 if the cattle operation is rated as highly important to the producer, and zero if the operation is somewhat or less important. This variable measures the producer's attitude toward the cattle operation. If the operation is rated as highly important, it is hypothesized that the producer is striving to maximize profits and, thus, efficiency; for those whom the operation is less important are likely to have competing goals that do not necessarily serve to maximize efficiency. This variable is hypothesized to be positively related with technical efficiency.

The variable, *Percentage of Cattle Land Rented*, is calculated by dividing the acres of rented cattle land by the sum of owned and rented cattle land on the farm. The expected sign for this variable is positive. The incentive to use more sustainable practices that insure long run economic viability on rented land is low, given the short time horizon and associated high discount rate of most tenants. Thus, management and labor effort expended to maintain land and buildings for future production is likely to be low, while maximization of short-run technical efficiency is likely to be high. Though Featherstone, Langemeier, and Ismet (1997) did not find a significant relationship between tenure and efficiency, it is hypothesized that a farmer who rents land has less incentive to use sustainable practices, potentially increasing short-run technical efficiency.

The variable, *Total Farm Acreage*, is used to determine the effect of farm size, expressed in acres, on technical efficiency. Featherstone, Langemeier, and Ismet (1997) found that larger cattle operations were more technically efficient than smaller ones. It is hypothesized that larger operations will be more technically efficient, leading to greater economies of size. Therefore, the expected sign is positive.

The variable, *Farm Located in South Louisiana*, is a dummy variable that takes the value of 1 if an observation was taken from either Calcasieu or Lafourche parishes, and 0 if otherwise. The Southern marsh and bayou areas of Louisiana differ from the rest of the state in environment and production practices. The environment is harsher, given the greater heat and humidity and wetter soils. It is expected that this variable is negatively correlated with technical efficiency.

Data

Twelve Louisiana parish extension agents were requested to assemble groups of five to ten cattle producers each to be surveyed as to production practices used. These parishes represented the top cattle producing parishes in the state. The producers were to be those who operated well-managed farms,

Table 1. Descriptive statistics of variables used in the Tobit Analysis.

Variable	Unit	Mean	Std Dev	Minimum	Maximum
General Production Practices					
Presence of Stockers	0-1	0.229	0.424	0	1
Weaning Weight of Calves	lb	516.333	90.986	300	825
Percentage of Improved Pasture	Percent	52.19	43.354	0	100
Breeding Practices					
Straight-Bred Bos Taurus Bull	0-1	0.458	0.504	0	1
Registered Cows	Percent	29.646	41.048	0	100
Mixed-Bred Brahman Cows	Percent	55.338	45.512	0	100
Farmer Pregnancy Tests	0-1	0.688	0.468	0	1
Demographic Characteristics of the Producer					
Age	Yr	54.854	12.634	28	83
Formal Education	Yr	14.125	3.457	4	23
Time Worked in an Off-Farm Job	Hrs/Wk	21.146	22.872	0	60
Operation is Highly Important	0-1	0.646	0.483	0	1
Farm Characteristics					
Percentage of Cattle Land Rented	Percent	39.659	40.13	0	100
Acres Devoted to Cattle Operation	Ac	1398.438	3771.505	25	20,100
Farm Located in South Louisiana	0-1	0.208	0.41	0	1

maintained good records, and represented the array of commercial operations found in their parishes. This sampling method was used to obtain responses from producers who were considered to be good managers and obtained a significant amount of their livelihood from the beef cattle operation, rather than those who were "hobby" farmers. The positive aspect of this procedure is that sideline operations with less than twenty cows (which constitute about 80 percent of Louisiana cow-calf producers) were not involved. The downside is that the sample cannot be considered truly random. Table 1 presents descriptive statistics of the sample.

Two persons conducted each two-to-three hour session, guiding producers through the survey forms with producers asking questions as needed. While data were collected for sixty-two farms, due to incomplete forms for six producers, fifty-six producers' technical efficiency coefficients were estimated.

Results

Descriptive statistics on the estimated technical efficiency coefficients of the DEA models are presented in Table 2. The average baseline technical efficiency is 0.92 and the lowest is 0.36. Twenty-six producers were technically efficient and had technical efficiency scores of 1. Fifteen producers had scores in the range, 0.90 - 0.99, and nine producers were in the range, 0.80 - 0.89. Only six farmers had technical efficiency scores lower than 0.80. Among these, two were in the range, 0.70 - 0.79, one was in the range, 0.60 - 0.69, two were in the range, 0.40 - 0.49, and one was in the range, 0.30 - 0.39.

Table 2. Descriptive statistics on technical efficiency coefficients for Louisiana beef cattle producers.

Measure	Technical Efficiency
Average	0.9205
Maximum	1.0000
Minimum	0.3592
Number of Technically Efficient Farms	26

The analysis showed no evidence of multicollinearity in the data, based upon examination of correlation coefficients, variance inflation factors, and condition indexes. All condition indexes were less than 30. For the baseline technical efficiency model, the likelihood ratio test (Greene, 1997) did not reveal heteroskedasticity.

The effects of Louisiana producers' characteristics and management and production practices on technical efficiency, estimated with the baseline model, are presented in Table 3. The variables, *Straight-Bred Bos Taurus Bull, Mixed-Bred Brahman Cows, Registered Cows, Age, Formal Education*, and *Improved Pasture* were significant at the five percent level or greater. In this model, the marginal effects are equal to the betas, indicating that the independent variables serve as good predictors that the dependent variable, technical efficiency, is less than or equal to 1.

Both *Straight-Bred Bos Taurus Bull* and *Mixed-Bred Brahman Cows* are of the expected signs. Among the surveyed producers, use of straight-bred *Bos taurus* bulls, rather than Bos indicus breed and Bos indicus crossbreeds, led to higher technical efficiency, supporting the previous work of animal scientists. An increase in the percentage of mixed-bred cows in the herd was correlated with an increase in technical efficiency, also consistent with previous studies.

Registered Cows is significant and positive, suggesting greater technical efficiency of the purebred, registered cow-calf operations. The incentive of producers to more closely manage their operations, the use of high quality breeding stock, and the use of high quality inputs likely explains this greater level of technical efficiency. This result may at first appear to conflict with the results of the *Mixed-Bred Brahman Cow* variable. However, the base group against which both are compared includes not only the "other" group (i.e., registered cows for the *Mixed-Bred Brahman Cow* variable), but also all straight-bred, non-registered cows and crossbred cows with no Brahman influence. Thus, it is plausible that *Registered Cows* and *Mixed-Bred Brahman Cows* could both have positive influences on technical efficiency.

Age is highly significant in the model, suggesting a strong positive correlation with technical efficiency. The older the producer, the more likely he or she has greater experience. The positive sign on this variable is consistent with the argument that, in an industry where technological innovations that require large idiosyncratic investments have been relatively slow to develop and economies of size are limited, experience may be a dominant factor in determining technical efficiency.

Education has the expected sign, suggesting that more highly educated producers are more technically efficient. Though formal education received by a producer may not be directly related to agriculture, it improves the ability to understand the importance of new developments in the industry. Educated producers are thus likely to adopt more efficient managerial practices.

Producers utilizing improved pasture had higher technical efficiencies, indicating that, in spite of the additional labor and machinery inputs required to improve pasture, technical efficiency was increased.

Three factors had probabilities, (0.05 < Pr # 0.10), indicating their impacts on technical efficiency. *Time Worked in an Off-*

Table 3. Results of the Tobit Analysis.

Constant	-0.72165 *	0.38797	0.06288
General Production Practices			
Presence of Stockers	-0.11582	0.07232	0.10925
Weaning Weight of Calves	0.00032	0.00032	0.32002
Percentage of Improved Pasture	0.00267***	0.00083	0.00124
Breeding Practices			
Straight-Bred Bos Taurus Bull	0.13772**	0.05991	0.02152
Registered Cows	0.00208**	0.00103	0.04412
Mixed-Bred Brahma Cows	0.00351***	0.00103	0.00007
Farmer Pregnancy Tests	-0.06395	0.06068	0.29195
Demographic Characteristics of the Producer			
Age	0.01250***	0.00307	0.00005
Formal Education	0.01886**	0.00878	0.03175
Time Worked in an Off-Farm Job	0.00268*	0.00143	0.06020
Operation is Highly Important	0.12446*	0.06514	0.05606
Farm Characteristics			
Percentage of Cattle Land Rented	0.00090	0.00072	0.21082
Acres Devoted to Cattle Operation	0.00001	0.00001	0.16176
Farm Located in South Louisiana	0.14928*	0.08841	0.09131

*** indicates the factor is highly significant ($P \leq 0.01$).
** indicates the factor is significant ($P \leq 0.05$).
* indicates $P \leq 0.10$.
Log-Likelihood Function: 5.096

Farm Job is positively related with technical efficiency. This result is consistent with the hypothesis that those producers with an off-farm job must compensate for the time they spend off-farm, making more efficient use of their own management and labor. Therefore, they become better managers and are more efficient in their use of resources. Producers who rated their cattle operations as highly important were more technically efficient than those who did not. This factor indicates the farmer's attitude toward the operation. Producers located in South Louisiana were more technically efficient than those in North Louisiana. This is likely due to the reduced input usage typically characterizing cow-calf operations under marsh pasture conditions.

Surprisingly, acres devoted to the cattle operation was not significant, nor was number of cows in an alternative model that was run. There were a number of large farms in the sample that were relatively low-input and produced lower calving rates, while there were a number of smaller farms in the fifty cow range that were high-input and had higher calving rates. The technical efficiencies of these types of farms were very similar in magnitude. The South Louisiana variable likely addressed the size factor indirectly, since there are a number of very large farms in the South, and the estimate was statistically significant and positive.

Implications

This study closely examines the efficiency of fifty-six beef cattle producers in Louisiana. Results suggest that the most efficient producers in the group used Bos taurus bulls, used mixed-bred Brahman cows, had a higher percentage of registered cows in their operation, used improved pasture, were older, were more highly educated, worked more hours in an off-farm job, and considered their operations as "highly important." The interpretation of these results is that producers of the above descriptions produced more output per unit of input utilized in their operations and were, thus, more technically efficient. Results with respect to the breeds of animals used tend to support previous studies conducted by animal scientists. Also of interest is that the older producers were more technically efficient than the younger ones. Compared with many other agricultural industries where younger producers are the more efficient ones, this result is of interest. Perhaps the influence of experience overshadows the influence of using the latest technology (typically used by younger producers) on efficiency of cow-calf and stocker production. This could be the case in an industry where new technology rarely requires major investment in expensive technology that must be paid for over an extended period.

The positive influence of education on farm efficiency underscores the importance of education on the ability of a producer to obtain the highest amount of output per unit of input. While our study does not lead to the conclusion that farmers who spend more time in off-farm work produce more animals than those who work less time off-farm, it does indicate that the forced increased efficiency of labor under time constraints can increase the ratio of output to input, simply because the amount of input used decreases. In an industry characterized by increased reliance on off-farm income accompanied with increased farm size, this should not be too surprising.

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