Assessing Efficiency of U.S. Cow-Calf Operations

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Abstract

Beef cow-calf production in the United States is widespread, occurring in every state. Approximately 36% (729,046) of the 2.02 million farms in the United States had a beef cow inventory in 2017. Most of these were small, part-time operations. Nearly 80 percent had fewer than 50 cows. Given that the cow-calf sector is the beginning of the beef industry structure, understanding the factors influencing profitability, efficiency, and changes in structure is very important. This study uses data from the Kansas Farm Management Association, specifically 2018 Cow-calf Enterprise data to show that both herd size and off-farm income impact cow-calf production efficiency. This study describes and compares cow-calf operations and assesses their relative competitiveness using Data Envelopment Analysis. Inefficiency was related to herd size and degree of specialization (those selling feeders vs those selling calves). The results also show that increased reliance on off-farm income increases inefficiency variance for producers that produce calves. Herd size increased inefficiency for both producers selling calves and feeders. Producers that sell calves are less efficient overall compared to those that sell feeders, but are more technologically efficient than those selling feeders.

Introduction

Industry structure and agricultural production changes over time, allowing producers and industries to become more efficient. The agricultural sector, specifically livestock, has seen an increase in specialization. A shift towards highly specialized and industrialized production can be seen in the poultry and most notably in the hog industry (Drabenstott and Rhodes 1994). Cattle production is another livestock sector that is experiencing specialization and industrialization, as the cattle industry is highly segmented (Feuz and Ward 1995).

Beef cow-calf operations vary considerably in size, available resources, profitability, and the use of technology. Opportunities remain to improve management practices, both production and financial, in many cow-calf operations in major cow-calf states (Beef Cattle Manuel). In 2012, the USDA outlined several important trends occurring in the U.S. beef cattle industry that either directly or indirectly affect cow-calf operations: 1) consolidation accelerating due to excess capacity, 2) more direct cattle ownership in feedlots and less custom feeding, 3) feedlot backgrounding[1] opportunities, and 4) feedlot locations moving toward corn production locations.

Beef cow-calf production is relatively widespread and economically important in the United States. Figure 1 identifies the number of beef cows in important Agricultural Statistics Districts (ASDs) and characterizes the relative importance of these ASDs in cow-calf production. Beef cow inventories are steady compared to 1997 while beef cattle operation numbers dropped by about 105,000, suggesting consolidation trends.

In 2019, the average beef cow herd is 43.5 head, but operations with 100 or more beef cows comprise nearly 10 percent of all beef operations and 56 percent of the beef cow inventory, (compared to 49 percent in 1997). Operations with 50 or fewer head are largely part of multi-enterprises or are supplemented by off-farm employment (USDA/ERS 2017). Operations with 50 or fewer head are largely part of multi-enterprises or are supplemental to off-farm employment—i.e. hobby farms (USDA/ERS 2012).

Industrialization within the cattle industry is mostly concentrated at the finishing level, which is predominantly the feedlot and backgrounding sectors. However, at the cow-calf level, the largest 25 firms hold less than 1% of beef cow inventories (USDA/ERS 2017). According to the Census

1 providing high energy rations to bigger calves on cow-calf sites in preparation for shipping higher weight calves to feedlots.

of Agriculture, between 1974 and 1992, the size of beef cow herds changed by less than 1%, from 40.3 (1974) cows to 40.5 (1992) cows. In 2018, the average herd size was 43.5, which is only an 8% change over 44 years.

While the average beef cow herd has not changed dramatically, profitability remains widely variable among producers. A report compiled by Bowman, Pendell, and Herbel (2018) observed that the difference in profitability between the top quartile and bottom quartile of Kansas cow-calf producers is $433 per cow. Determining if the difference in profitability is due to economies of scale or to production inefficiency within the industry is not clear. Factors that may explain this difference in profitability include input usage, sale weights, death loss, and marketing and financing differences.

The objective of this study is to examine the efficiency of beef cow-calf production in Kansas. This study will estimate technical, allocative, cost efficiency of cow-calf operations, as well as, identify how production characteristics and certain management decisions may impact production efficiency. This study will estimate efficiency measures of cow-calf operations, identify how production characteristics (selling calves vs. selling feeders) impacts efficiency, and identify if herd size affects efficiency. This study contributes to the existing literature by both estimating efficiencies for cow-calf producers and identifying production characteristics that impact efficiencies. There is little recently published research concerning the efficiency of cow-calf operations. A study conducted by Featherstone, Langemeier, and Ismet (1997) used data from 195 cow-calf operations in the state of Kansas, and a report compiled by the ERS looked at efficiencies across the United States, but was based on 2008 ARMS data. In addition to using updated data, an evaluation of efficiency for cow-calf operations at the regional and national levels is needed. Efficiency will fluctuate across regions due to differences in input costs and production practices stemming from geography and climate differences.

Methods

This analysis is based on 2018 data from the Kansas Farm Management Association, which collects information on many farm and farmer characteristics, including the number of beef cows per farm, costs, and returns to management. The following analysis was applied to 173 farms in the Kansas Farm Management Association program that reported enterprise records in 2018; 79 that sell feeders, and 94 that sell calves.

Two main methods are used to empirically measure technical inefficiency; Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). The DEA and SFA can both be implemented from an output or input orientation; however, the main difference between the two approaches concerns how deviations outside the control of producers (i.e. white noise) are handled. Data Envelopment Analysis ignores white noise while SFA accounts for it in the production process (Belotti et al. 2013). Utilizing an output method compares observed output to its potential, given the input sets and the technology, while the input orientation compares observed input levels to its minimum potential, necessary to produce a given output level.

DEA is a non-parametric approach that has been extensively used for determining efficiency frontiers and deals with the nature, existence, and departures from them. This approach defines a non-parametric frontier and measures the efficiency of each unit relative to that frontier. In other words, the DEA approach provides an analytical tool for determining effective and ineffective performance as the starting point for inducing theories about best-practice behavior (Charnes et al. 1994). DEA uses linear programming to construct a frontier that envelops all observations and computes the relative Technical Efficiency of each farm included in the sample.

The DEA methodology uses a set of production units of a sample to construct an efficiency frontier consisting of all possible linear combinations of efficient production units. The frontier technology consists of convex input and output sets enveloping the data points with linear facets. Consequently, the efficient units lie, by definition, on that frontier while the inefficiency of units that are not on the frontier is indicated in direct proportion to their distance from the frontier. Individual units are considered as Decision Making Units (DMUs) and efficiency can be measured relative to the highest observed performance. The proposed measure of efficiency of any DMU is obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity. The fundamental version of the DEA model, which is also known as the CCR model (it was initially proposed by Charnes, Cooper and Rhodes) can be found in Charnes et al. (1978, 1979, 1981). Additional work, including production function estimation and other model modifications can be found in Fare et al. (1985) and in Seiford and Thrall (1990). DEA involves the identification and measurement of relevant inputs and outputs, which are common in all units. The output utilized in this analysis is gross farm income (in dollars), while the input expenses include: feed, labor (paid and unpaid), capital, utilities and fuel, veterinary expenses, and miscellaneous costs.

In effort to address the main objective of this paper, a DEA is implemented to capture the efficiency of farmers' technologies based on their production method (calves vs. feeders). The nonparametric DEA approach proposed by Charnes, Cooper, and Rhodes is utilized in an output orientation, meaning output is maximized for a specific input level. Each DMU's technical efficiency was estimated with an output orientation under both constant returns to scale and variable returns to scale. Technical efficiency under constant returns to scale is estimated as following

$$maximize\ h_0 = \frac{\sum_{j=1}^{s} W_j Y_{jn}}{\sum_{i=1}^{r} V_i x_{in}}$$

$$\text{Subject to } \frac{\sum_{j=1}^{s} W_j Y_{jm}}{\sum_{i=1}^{r} V_i x_{im}} \leq 1 \quad m = 1,2,\dots,n$$

$$W_j \geq 0 \ ; \quad j = 1, 2, \dots, s$$

$$V_i \geq 0 \ ; \quad i = 1, 2, \dots, r.$$

Y_{jn} is output (gross income) of DMU *n*, x_{in} are the inputs of DMU n, W_j is the weight for output j, V_i is the weight for input j, *n* is the number of DMUs, *s* is the number of inputs, and *r* is the number of outputs.

Additionally, regression analysis is conducted to determine how producer demographics, operation characteristics, location, production practices, and financial characteristics are correlated with each producer classification. This approach assumes that a homogeneous production method (calves, feeders)--specific production technology, coupled with best animal husbandry practices, allow maximum potential output for an input set and therefore puts all farmers on the production frontier. However, due to technical inefficiency and/or production risks, some farmers may deviate from the potential output attainable in their respective production method (Bokusheva and Hockmann 2005).

Data

The Kansas Farm Management Association collects information from participating members each year. In 2018, 173 members reported their cow calf operation information, including financial information and some production management information. Of the total 173 producers, 94 sold their calves at weaning and 79 sold the calves as feeders. The average herd size for those reporting was 137 head, where herd size is in reference to the number of cows in the herd. The average gross income in 2018 was $112,700. Table 1 provides a summary of the descriptive statistics for the operations, including important variables utilized in the DEA analysis.

Table 1. Descriptive Statistics – Kansas Farm Management Association: 2018 Cow Calf Production

	Producers Selling Calves (N=94)			**Producers Selling Feeders** (N=79)			**Total** (N=173)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Herd Size (hd)	120	12	560	157	21	399	137	12	560
Pasture Acres	1,162	30	6,600	1,362	49	4,258	1,253	30	6,600
Gross Income ($)	89,789	7,812	357,469	139,961	15,984	402,166	112,700	7,812	402,166
Labor ($)	19,437	1,835	143,422	25,562	2,598	70,446	22,234	1,835	143,422
Capital ($)	16,879	259	98,574	24,909	570	91,080	20,546	259	98,574
Feed ($)	56,844	3,565	247,669	88,602	8,068	297,520	71,346	3,565	297,520
Utilities/Fuel ($)	3,928	48	17,647	5,220	0	22,370	4,518	0	22,370
Veterinary ($)	4,036	0	36,002	7,172	0	25,522	5,468	0	36,002
Miscellaneous ($)	7,559	376	36,971	7,366	268	26,815	7,471	268	36,971

Results

Out of the 173 DMUs, thirty-nine were technically efficient under variable returns to scale, which is approximately 23% of the DMUs. Only 17% (29 DMUs) were categorized as scale efficient. Producers that sell calves are on average, less efficient overall compared to those that sell feeders. Table 2 provides a summary of the efficiency results by production group (those that sell feeder vs those that sell calves) as well as in total, and Table 3 provides a breakdown of the distribution of the technical inefficiency scores by group.

Table 2. KFMA 2018 Cow-Calf Producers: Data Envelopment Analysis Summary

Average Efficiency Scores by Group - KFMA 2018			
Group	CRS	VRS	Scale
Producers Selling Calves	0.650	0.696	0.933
Producers Selling Feeders	0.697	0.773	0.909
Total	0.671	0.731	0.922

Table 3. Distribution of DMUs Technical Efficiency (Number of DMUs in each range)

	Efficiency (under VRS)										
	0.0-0.09	0.10-0.19	0.20-0.29	0.30-0.39	0.40-0.49	0.50-0.59	0.60-0.69	0.70-0.79	0.80-0.89	0.9-0.99	1
Sell Calves	0	0	1	6	13	14	16	20	11	3	17
Sell Feeders	0	0	0	3	5	11	13	8	13	7	22
Total	0	0	1	9	18	25	29	28	24	10	39

A regression analysis was also used to understand how input variables are correlated with the output variable, gross income. Separate OLS regressions were estimated for the two production groups (those selling calves and those selling feeders) in additional to a composite regression where all cow calf producers parameter estimates were regressed together. These results can be seen in Table 4. An additional regression was estimated to understand how herd size and off-farm income is correlated with efficiency scores. Separate OLS regressions were estimated for the two production groups in additional to a composite regression where all cow calf producers parameter estimates were regressed together. These regression results are reported in Table 4.

Table 4. Parameter Estimates for Cow-Calf Producers

OLS Production Parameter Estimates for Cow-Calf Producers in Kansas 2018			
	Selling Calves	**Selling Feeders**	**Composite**
Farm Income			
Herd Size	0.866**	0.907**	0.895**
Labor	0.014**	-0.150	-0.014
Feed	0.017**	0.132	0.046**
Utilities	-0.005**	0.050	-0.002
Vet	-0.048**	0.024	-0.054**
Misc.	0.174**	0.095	0.166**
Constant	5.667**	5.567**	5.709**
Inefficiency Variables			
0 to 120 cows			
121 cows to 300 cows	-0.142	23.267*	0.044
301 cows to 500 cows	-0.704	27.543**	-1.185*
501 cows to 1,000 cows	0.578**		-2.235**
Off Farm Income	4.794**	13.097	0.078
Significance: * p<0.05,** p<0.01			

Increasing herd size, labor use and feed positively impacts farm income for cow-calf producers selling calves. Increasing herd size was correlated with an increase in farm income, as well as labor and feed. As expected, the estimation revealed that increasing the use of utilities and veterinary use would negatively impact farm income.

Off-farm income increases inefficiency variance for producers that produce calves. When considering the impacts of off-farm income, only the inefficiency of producers selling calves was impacted by off-farm income. Producers selling feeders indicated a positive relationship as well; however, it was not statistically significant. Herd size increased inefficiency for both producers selling calves and feeders. For producers selling calves, increasing herd size had no impact on inefficiency until the herd size was 500 or more. For producers selling calves, increasing herd size increased inefficiency across on herd sizes.

Discussion

When so many other livestock industries, and segments within the beef industry, are increasing in size or head, the cow-calf industry has remained relatively stagnant in herd size. These results coincide with the fact that increasing herd size may not be the best decision for a cow-calf producer, as increasing herd size increases inefficiency.

As expected, off-farm income increased inefficiency for producers selling calves, however these producers were more technically efficient, suggesting they operated with more efficient technologies. This could be due to the need to utilize more technology (i.e. rotational grazing, AI, etc.) in order to compensate for time spent off the farm. However, this cannot be explicitly inferred from these results without additional data regarding labor and income for owners and operators. Those selling feeders were overall more efficient; however, they were less technically efficient suggesting they are not utilizing available technologies as efficiently as those producers selling calves.

To improve this research, ARMS 2018 data will be utilized incorporating more DMU observations from five different regions (focusing on states with large cow-calf production); this data will include financial, production, and management information for cow-calf producers from across thirteen states. A DEA approach will be utilized in addition to more extensive testing to determine the appropriate structure of the production function and estimates of factors impacting producer efficiency such as producer characteristics (age, location, education, gender) and management decisions (pasture management, breeding, etc.).

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Appendix

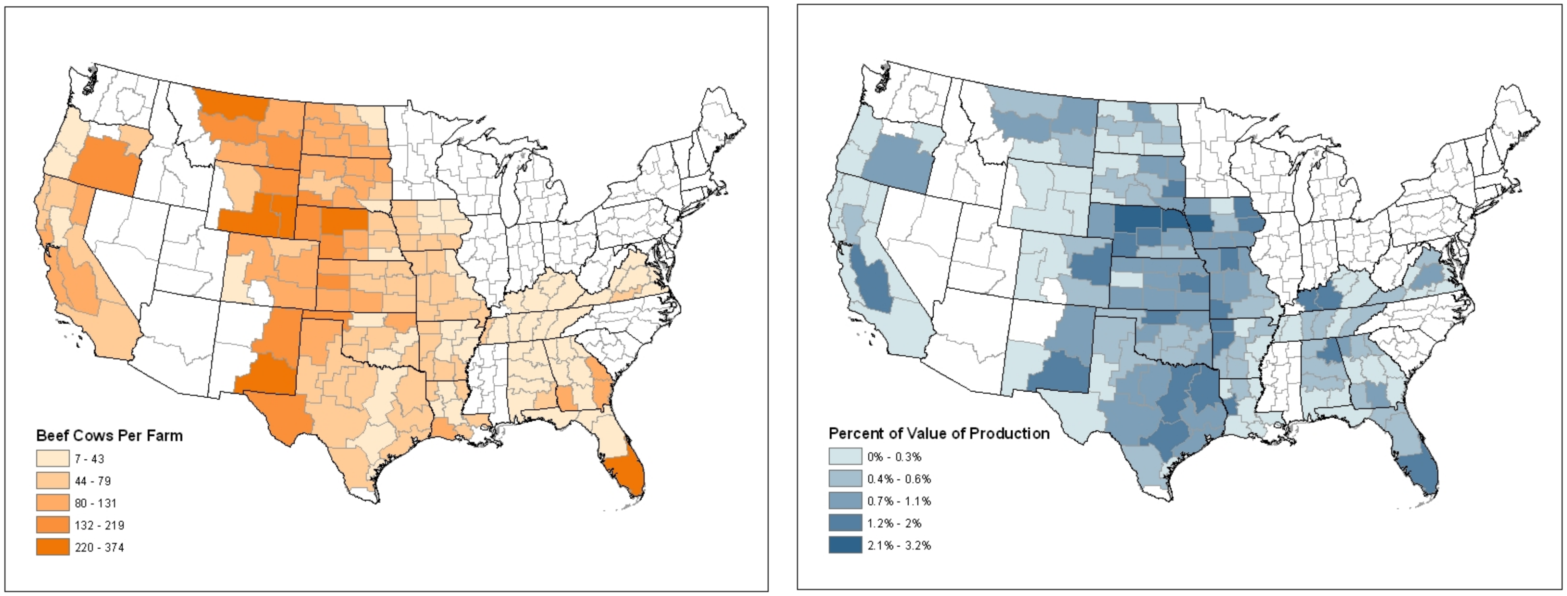

Figure 1. Left: Average Number of Beef Cows per Farm by ASD (Agricultural Statistics District), 2018 estimates

Figure 1. Right: Percent value of Production by ASD relative to the entire sample (value of all farm outputs on all cow-calf operations in an ASD—relative to all production in the sample
U.S. Department of Agriculture, Economic Research Service (USDA/ERS). 2018.