Kansas cow-calf production efficiency

by

Hannah Elizabeth Shear

B.S., University of Kentucky, 2012
M.S., University of Arkansas, 2015

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
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Abstract

The beef cattle sector has been, and continues to be, the single largest sector in the Kansas agriculture industry, with cattle and calves generating $8.27 billion in cash receipts in 2017 (KDA 2018). In 2017, Kansas produced nearly 5.69 billion pounds of red meat, or nearly 11 percent of the nation's total (KDA 2018). According to estimates prepared by the Kansas Department of Agriculture, beef cattle farming and ranching has a direct output of approximately $6.3 billion. The cow-calf sector is the beginning of the beef industry; therefore, understanding the factors influencing profitability, efficiency, and structure is very important. The objective of this study is to examine the efficiency of beef cow-calf production in Kansas. Technical, allocative, and scale efficiencies of cow-calf operations are estimated, as well as, analysis on the relationship between input costs and efficiency and profitability and efficiency.

Beef cow-calf operations vary considerably in size, available resources, profitability, and the use of technology. The variability in profitability suggests room to improve both production and financial management practices. In addition to estimating efficiency measures of cow-calf operations, the study identifies how marketing strategies (selling calves vs. selling feeders) impacts efficiency. This study contributes to the existing literature by estimating efficiencies for cow-calf producers and identifying production characteristics that impact efficiencies, in addition to, introducing the use of super-efficiency in the cow-calf industry segment.

The nonparametric Data Envelopment Analysis approach, along with regression analysis, is used to determine how marketing strategies and production characteristics are correlated with efficiency and profitability. The Kansas Farm Management Association data are used in this analysis with cow-calf producers analyzed in two groups based on their marketing strategy (sells calves or sells feeders). Three years of whole-farm and enterprise data are included in the study,

with a total of 240 producers selling calves and 264 producers selling feeders between 2018 and 2020. An input orientation is applied including feed, labor, utilities, and veterinary costs. Output is defined as the gross farm income (in dollars).

Producers selling feeders were more technically efficient than those selling calves in both 2018 and 2019; however, in 2020, those that sold calves were slightly more technically efficient on average (0.840) than those that sell feeders (0.830). Technical efficiency was relatively more important than scale and allocative efficiency for both marketing strategies across almost all years (one exception in 2020, with producers marketing calves, where the allocative efficiency correlation coefficient was higher than technical). Technical efficiency was relatively more important in explaining profitability than either allocative or scale efficiency. Regressions indicated that a 0.10 increase in pure technical efficiency increases net income per cow by $96. A 0.10 increase in allocative and scale efficiencies increases net income per cow by $48 and $97, respectively. This suggests that producers that are experiencing low (or negative) levels of profitability should concentrate on adjusting the size of their herd relative to reducing input use per unit of output. Labor costs had the most impact on technical and allocative efficiency, while feed costs had the greatest impact on scale efficiency. Suggesting that producers wanting to impact their efficiency should focus on feed and labor costs.

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Table of Contents

List of Figures

List of Tables

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Dedication

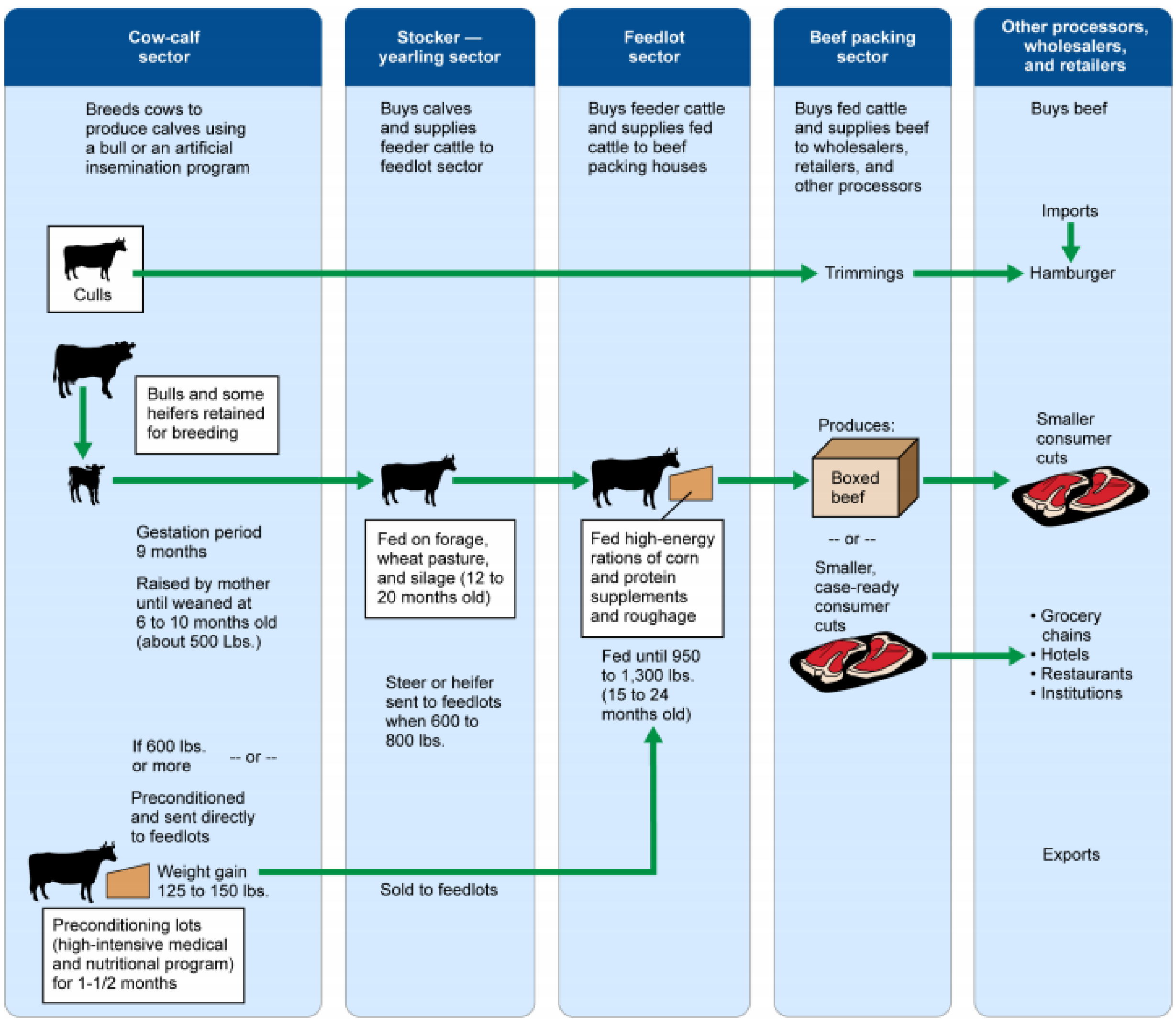
To my father, who values education, but never at the expense of being a kind and gracious person. To my mother, who always finds a way to bring out the beauty in something. To my older sister, who forged the way. To my younger sister, who always makes me laugh and cares deeply for our family. This is because of your support and unconditional love. This is for you. Thank you.

Chapter 1 - Introduction

There are over 94 million head of cattle in the United States, with 320,000 head and 2.1 billion pounds of beef exported in 2020 (USDA 2020; U.S. Meat Export Federation 2020). The beef cattle sector is the single largest sector in the Kansas agriculture industry, with cattle and calves generating $8.27 billion in cash receipts in 2017 (KDA 2018). In 2017, Kansas produced nearly 5.69 billion pounds of red meat, or nearly 11 percent of the nation's total (KDA 2018). According to estimates prepared by the Kansas Department of Agriculture, beef cattle farming and ranching has a direct output of approximately $6.3 billion to the Kansas economy.

Beef production in the United States is highly segmented, which causes the ownership and location of an animal to change several times between when an animal is weaned and slaughtered. Figure 1.1 illustrates the typical production path for U.S. cattle. Beginning at the cow-calf sector, the primary product of cow-calf operations is weaned calves, which are sold to stocker operators, backgrounding lots, or feedlots. Calves from cow-calf operations are generally transferred directly to feedlots at or around the time of weaning (referred to as "calf-feds") or they are placed in a stocker operation to be grown for a period of time (USDA 2001). Cattle then also typically pass through a feedlot at some point before reaching the beef packing sector and then on to final processors, wholesalers, and retailers.

Cow-calf production, as the starting point for the U.S. beef, is an import segment of the beef industry. Producers in this segment are price takers, meaning they are subject to the set market price. While producers can utilize value-added programs, alternative marketing agreements, and genetics to improve margins, producers must focus on reducing their costs and ensuring efficient production of calves to remain profitable and competitive in the industry. Producers must make decisions on how to allocate land, labor, capital, and more. Producers also must decide if they wish to retain their calves and feed them (precondition) prior to selling straight to a feedlot, or if they wish to market them to a stocker. Some producers may retain ownership through the feedlot sector. These marketing decisions impact feed and labor costs and profitability. Ideally, if cow-calf producers knew which decisions had the largest impact on profitability and efficiency, they could in turn make better management decisions and be more profitable.



Source: GAO analysis of U.S. Department of Agriculture and industry information. | GAO-18-296

Figure 1.1 U.S. Cattle Industry Overview

Producers that can efficiently allocate their resources relative to other producers will be relatively more profitable. Chapter 2 analyzes the production efficiency of Kansas cow-calf producers.

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. The main objective of this study is to examine the efficiency of beef cow-calf production in Kansas. This study will 1) estimate technical, allocative, scale, and overall efficiency for cow-calf producers, 2) estimate super-efficiency, and 3) look to understand drivers of efficiency and profitability. Chapter 2 utilizes that Kansas Farm Management Association (KFMA) data to analyze efficiency. The data includes producers that are identified as cow-calf producers that sell calves, meaning these producers market their calves at weaning, and those that sell feeders meaning the producers retain the calves and feed them to a higher weight prior to marketing. This allows for better understanding of how producers' marketing strategies impact efficiency and profitability. Chapter 2 includes a more in-depth description of the KFMA data and explanation of the data envelopment analysis (DEA) utilized to estimate production efficiency for Kansas cow-calf producers. The results, also discussed in Chapter 2, suggest further research in understanding the drivers of efficiency and profitability is needed for producers.

Chapter 2 - Production Efficiency of Kansas Cow-Calf Producers

Introduction

Beef cow-calf production occurs in all states of the United States. A cow-calf operation is focused on raising beef cattle utilizing a herd of cows, that are generally retained, to produce calves for sale later (typically after weaning). 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. Beef cow-calf production is relatively widespread and economically important in the United States. Figure 2.1 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 inventories numbers, while beef cattle operation numbers dropped by about 105,000.

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 1994). Cattle production is another livestock sector that is experiencing specialization and industrialization, as the cattle industry is highly segmented (Feuz and Ward 1995).

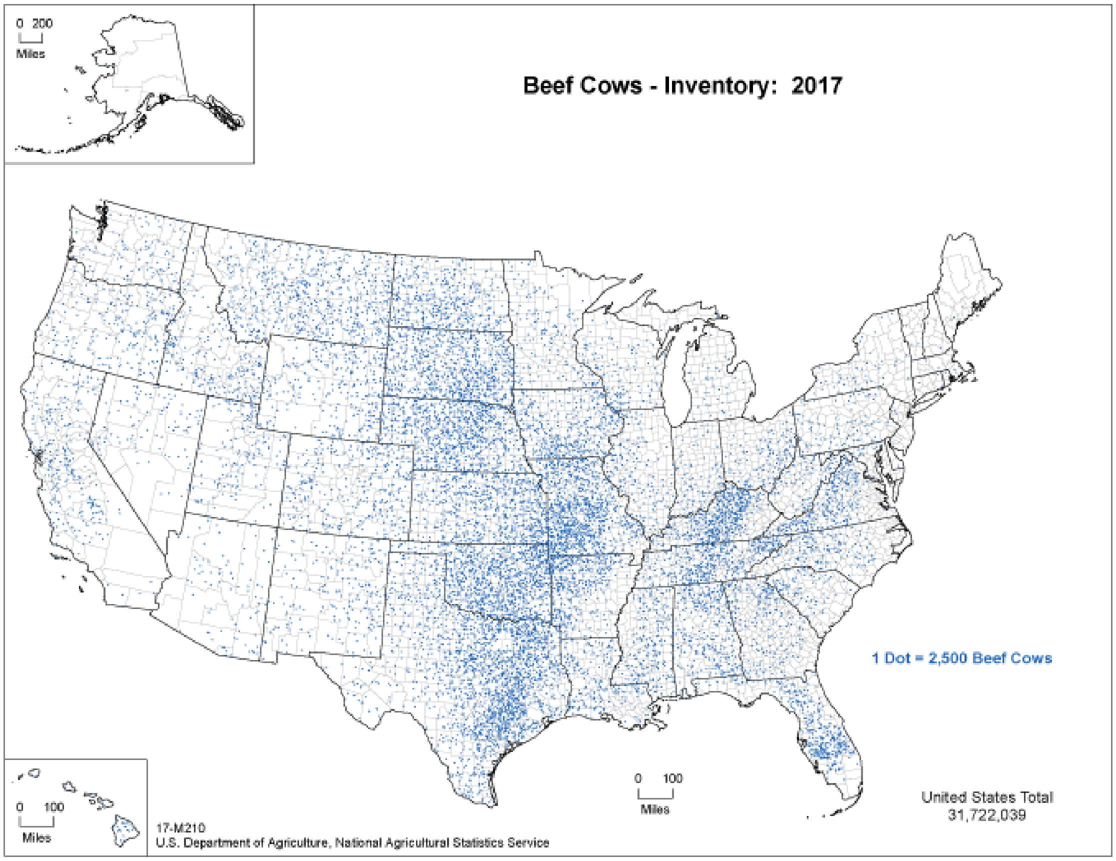


Figure 2.1 U.S. Beef Cow Inventory 2017

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 Manual). The Beef Cattle Manual outlined several important trends occurring in the U.S. beef cattle industry that either directly or indirectly affect cow-calf operations: 1) consolidation accelerating, 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.

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

In 2019, the average beef cow herd was 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 2020).

Industrialization, or the increased use of capital and mechanization over labor, 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/NASS 2018). According to the Census of Agriculture, between 1974 and 1992, the average 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 main objective of this study is to examine the efficiency of beef cow-calf production in Kansas. This study will 1) estimate technical, allocative, scale, and overall efficiency for cow-calf producers, 2) estimate super-efficiency, and 3) utilize a tobit regression to understand drivers of efficiency and profitability.

Literature Review

This study contributes to the existing literature by both estimating efficiencies for cow-calf producers and identifying production characteristics that impact efficiencies as well as providing an analysis using super-efficiency DEA analysis to better understand the characteristics of efficient firms. 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. Super-efficiency, as a means to better understand the differences between the efficient firms in an agricultural setting is lacking in the literature. Providing producers with a better understanding of what makes them relatively more efficient than their 'competitors' would be beneficial to making production management decisions.

Efficiency

Two main methods are used to empirically measure technical efficiency: 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. DEA 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. 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. It must be remembered that the estimates are relative estimations. This means firms may be identified as efficient in one data set, but if the data set were expanded to include additional firms, they may no longer fall on the efficient frontier.

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 the 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 Färe et al. (1985) and Seiford and Thrall (1990). DEA involves the identification and measurement of relevant inputs and outputs, which are common in all units.

Using the linear programming technique, various forms of DEA models intend to provide efficiency score (Coelli et al. 2005). In this setting, the production frontier curve is structured based on some points being determined by using mathematical programming. In order to indicate points, two assumptions of variable return to scale and constant return to scale are considered. The linear optimization will show whether a DMU is located on the efficient curve or off the curve. It distinguishes between efficient and non-efficient units.

Super-Efficiency

The procedure of conventional models in DEA is based on evaluating the efficiency of an observed sample relative to a reference set comprising of all sample observations, including the observed sample as well (Banker and Chang 2006). In primary CCR approaches, efficient units cannot be ranked based on their efficiency scores (Andersen and Petersen 1993). However, it seems to be unreasonable to assume that efficient units are the same in terms of efficiency scores. While DEA has been commonly used to explore and identify efficient firms, the inability to rank or identify the most efficient DMU's from within the efficient designation is a shortcoming. This led to the development of super-efficiency DEA.

To better understand the differences in the efficient firms, various approaches have been suggested in the literature; for instance, the hybrid of the analytic hierarchy process (AHP) and DEA, bootstrap DEA and super-efficiency (Boyle 2004; Yoo et al. 2013). Accordingly, super-efficiency models are introduced to overcome this drawback by evaluating the efficiency rate of efficient units (Chen et al. 2013). The formal super-efficiency model in DEA was suggested by Banker and Grifford (1988) to exclude each observation from its own reference set such that it is possible to get efficiency scores exceeding one. Consequently, there would be only one efficient firm with the highest efficiency score among other similar firms.

Various methods have been suggested for super-efficiency DEA, methods proposed by Banker and Grifford (1988) and Andersen and Petersen (1993) being the most used approaches. The methods suggested in these studies are quite similar. Andersen and Petersen (1993) proposed two constant returns to scale (CRS) and variable returns to scale (VRS) models by making modifications on the CCR model. Banker and Chang (2006) used simulation and showed that the model of Andersen–Petersen does not perform satisfactorily in terms of ranking efficient units. Different applications have been mentioned in the literature for super-efficiency DEA, such as identifying and ranking the extreme efficient DMUs (Banker and Chang 2006; Johnson and McGinnis 2009); measuring technology and productivity changes (Fare et al. 1994); analyzing the sensitivity of efficiency classifications (Charnes et al. 1992; Zhu 2003); and making acceptance decision rules (Seiford and Zhu 1998).

Several previous studies have applied DEA in cattle, swine, and dairy production; however, they did not utilize super-efficiency. While the DEA literature is broad, and encompasses many industries, incorporating super-efficiency into an agricultural industry adds to the literature by providing an opportunity to better understand efficiency and drivers of efficiency for our most efficient cow-calf producers. This analysis begins an opportunity to build the literature of super efficiency in livestock production in addition to identifying current drivers of efficiency for cow-calf producers.

Methods

Efficiency Estimation

To address the main objective of this paper, a DEA is implemented to evaluate the efficiency of farm technologies based on their marketing strategy (calves vs. feeders). The non-parametric DEA approach proposed by Charnes, Cooper, and Rhodes and the super-efficiency model proposed by Banker and Grifford (1988) and Banker and Chang (2006) are utilized in this study. This analysis is based on 2018 through 2020 data from the Kansas Farm Management Association, which collects information on many farms and farmer characteristics, including the number of beef cows per farm, costs, and returns to management. The following analysis was applied to 174 farms in 2018, 147 in 2019, and 183 farms in 2020. Within the KFMA data, producers are identified as cow-calf producers that either sell calves at weaning or those that sell calves after some feeding. These two marketing strategies create two separate groups for analysis within the DEA approach.

The nonparametric DEA approach proposed by Charnes, Cooper, and Rhodes is applied in an input orientation within a cost minimization approach (instead of profit maximizing). The output is measured by gross farm income (in dollars), while the input expenses include feed, labor (paid and unpaid), utilities and fuel, and veterinary expenses.

Technical Efficiency

Technical efficiency is a measure of the distance a farm is from the production function under variable returns to scale. Technical efficiency in an input orientation measures the proportional decrease in input variable necessary to produce the same output bundle. Technical efficiency using an input approach is determined by solving the following linear program for each farm:

$$Min\ \lambda_i \tag{1}$$

Subject to:

$$X'Z \leq \lambda_i x_i$$

$$Y'Z \geq y_i$$

$$z_1 + z_2 + \cdots + z_k = 1$$

$$z_i \in \Re^+$$

Where λ_i is the measure for pure technical efficiency for firm i, X' is a matrix of input levels for each producer, x_i is a vector representing the amount of inputs used by firm i, Z is a column vector of variable weights, Y' is a column vector of fixed output mounts, and y_i is the output of firm *i*. Firm *i*, is said to be technically efficient if $\lambda_i = 1$ and inefficient if $\lambda_i < 1$.

A frontier is fitted with the initial data. Then a distant metric correlated with the weight is used to fit the distance of each ordered pair from the initial frontier. This is called a projection of the points on the frontier to each for all ordered pairs. The linear program maximizes efficiency subject to the constraints. The weights are then iterated on to adjust the distance of the ordered pairs from the frontier to maximize the efficiency coefficient. The third constraint in equation 1 restricts the intensity vector to sum to one, which allows the technology to have variable returns to scale. The farm is technically efficient if λ_i=1, and inefficient is less than 1.

Allocative Efficiency

Allocative efficiency (γ_i) determines if a farm is using the optimal input mix. Allocative efficiency can be calculated by dividing the minimum cost under variable returns to scale by the actual cost adjusted for technical efficiency (λ_i).

$$\gamma_i = \frac{C_i(w,y,T_v)}{w_i' \lambda_i x_i} \qquad (2)$$

The minimum cost under variable returns to scale can be found by solving the following linear programming problem for each farm:

$$C_i^{\ v} = \ Min\, w_i' \widetilde{x_i} \tag{3}$$

Subject to:

$$X'Z \leq \ \widetilde{x_i}$$

$$Y'Z \geq \ y_i$$

$$z_1 + z_2 + \cdots + z_k = 1$$

$$z_i \in \ \Re^+$$

Allocative efficiency is calculated by dividing the minimum cost from the above linear programming problem (Equation 3) by the actual cost multiplied by technical efficiency.

Scale Efficiency

Scale efficiency measures whether a farm is at the most efficient size. Scale efficiency (Θ_i) is determined by:

$$\Theta_i = \ \frac{C_i^{\ c}}{C_i^{\ v}} \tag{4}$$

Scale efficiency is calculated by dividing the minimum cost under constant returns to scale by the minimum cost under variable returns to scale (Equation 3). The minimum cost under constant returns to scale ($C_i^{\ c}$) can be calculated using the same linear program in Equation 3, but without requiring the sum of variable weights to equal one.

Overall Efficiency

Overall efficiency is the product of scale, allocative, and technical efficiency, and can also be calculated as the minimum cost under constant returns to scale to produce the actual level of output by the actual cost to produce that level output.

$$\rho_i = \frac{C_i{}^c}{w_i' x_i} = \Theta_i \times \gamma_i \times \lambda_i \tag{5}$$

Super-Efficiency Estimation

Super-efficiency estimations require the same formulas as described above (Equations 1-5); however, when the reference set is used to determine the frontier, the firm itself will be excluded in the super efficiency estimation (Banker and Gifford 1988). This will allow us to consider if we are able to rank the efficient firms as well as identify outliers that may be skewing the efficiency results (Banker et al. 1989; Andersen and Peterson 1993).

Bootstrapping Analysis

Traditional nonparametric approaches hinge on data sampling variation (Latruffe et al. 2005). Issues regarding sample bias are heightened because deviations from the observed frontier are interpreted entirely as production inefficiency (Simar and Wilson, 1998). If the truly most efficient farms are omitted from the available dataset, then efficiency estimates of farms in the dataset will be biased upward as the production frontier is underestimated. This occurs as efficiency is evaluated relative to the sample frontier, rather than the true population frontier (Latruffe et al. 2005; Davidova and Latruffe 2007). This impact of sampling variation on efficiency estimates has been discussed in the literature (Latruffe et al. 2005; Brummer 2001; Simar and Wilson, 1998, 2000), where bootstrapping has been commonly employed to address this issue. Empirical bootstrapping is used to investigate the sample variability of efficiency point estimates by repeatedly estimating efficiency scores, simulating the true data-generating process (Simar and Wilson, 1998). Our data's means and standard deviations are used to repeatedly draw at random (1000 times) to create a bootstrapped sample. After many simulations

(1,000 in our analysis), a distribution of efficiency scores is obtained and represents an estimate of the true distribution (Brummer 2001).

Efficiency Explanation Models

To better understand what characteristics and farm management decisions impact or are most closely related to efficiency performance, a tobit regression model is estimated. A tobit model will assist in identifying sources of inefficiencies by regressing efficiency estimates on a chosen set of farm characteristics.

Many previous DEA analyses utilize tobit regressions, as each efficiency measure is bound between zero and one, and a tobit model allows for the examination of the relationships that exist between estimated efficiency measures and observed firm characteristics (Rowland et al. 1998).

The tobit models are estimated as follows:

$$E_i^* = \beta' X + e_i, e_i \sim N[0, \sigma^2] \quad if\ 0 < E_i^* < 1 \qquad (6)$$

$$E_i = 0 \quad if\ 0 = E_i^*$$

$$E_i = 1 \quad if\ 1 = E_i^*$$

where E_i^* is the DEA point estimate of firm efficiency, β represents a vector of parameters to be estimated, X is a vector of explanatory variables, and e_i is a normally distributed error term (Greene 2003). The explanatory variables were carefully selected to avoid overlap with the variables used in the efficiency estimations models. Characteristics to include are leverage (debt to equity), number of beef cows, percentage of income from beef cow production, and percentage of land owned, and off-farm income.

Data

The Kansas Farm Management Association (KFMA) collects information from participating members each year including whole farm and enterprise data. Table 2.1 summarizes the number of producers reporting and their cow-calf marketing strategy (selling calves or selling feeders). Producers that sell calves, sell them after weaning, where producers that sell feeders will retain the calves after weaning and will feed them to a higher weight before selling. This analysis estimates the efficiencies based on group and year so as to be accurate in their comparison (i.e., six frontier estimations – two groups and three years).

Table 2.2.1 KFMA Cow-Calf Farms Reporting

Year	Sells Calves	Sells Feeders	Total Firms
2018	95	79	174
2019	73	74	147
2020	72	111	183

Large amounts of data are collected from producers; however, this analysis will focus on the main input costs for cow-calf producers, including feed, labor, utilities, and veterinary costs. Summary statistics from the KFMA enterprise database can be seen in Tables 2.2 and 2.3. Due to the differences in their average costs of inputs producers that sell calves are compared only to those selling calves and those that sell feeders are only compared to those that sell feeders. All input cost averages across all years are higher for producers that sell feeders than for those that sell calves (which is to be expected as they provide additional feed to the calves). Additionally, those that sell feeders tend to be larger and report a higher average herd size across all years in comparison to those that sell calves. Gross income per cow is also higher for those that sell feeders, which is expected since calves are sold at a higher weight. However, net income per cow is slightly more inconsistent across groups and time, which encourages us to look further into what might make firms more efficient.

Table 2.2.2 Summary Statistics for Kansas Farm Management Association Cow-Calf Operations, Sells Calves 2018-2020

	2018, n= 95		2019, n= 73		2020, n= 72	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Number of Cows per Farm	122.0	96.8	129.4	104.3	132.8	94.1
Gross Income per Cow[a]	744.2	164.1	667.5	143.1	791.4	156.7
Feed Costs per Cow[a]	487.1	122.9	559.4	156.7	499.6	133.1
Labor Costs per Cow[a]	18.1	28.9	21.7	37.5	22.4	35.3
Utilities and Fuel per Cow[a]	33.8	21.4	33.4	19.9	29.2	17.8
Veterinary Expenses per Cow[a]	34.0	21.9	36.4	24.6	37.6	23.1
Net Income per Cow[a]	-152.6	227.1	-315.7	249.4	-129.1	213.0

[a] variable is in unit of dollars per cow

Table 2.2.3 Summary Statistics for Kansas Farm Management Association Cow-Calf, Sells Feeders 2018-2020

	2018, n= 79		2019, n= 74		2020, n=111	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Number of Cows per Farm	160.3	91.0	152.0	102.3	155.1	125.9
Gross Income per Cow[a]	873.6	191.5	820.1	172.5	937.6	151.8
Feed Costs per Cow[a]	572.1	143.8	611.9	139.7	639.2	129.8
Labor Costs per Cow[a]	24.0	30.5	18.4	24.6	25.2	33.2
Utilities and Fuel per Cow[a]	34.2	18.8	32.5	20.2	31.3	21.2
Veterinary Expenses per Cow[a]	46.2	22.4	46.4	25.3	55.0	29.9
Net Income per Cow[a]	-159.4	228.4	-268.8	256.6	-192.6	282.7

[a] variable is in unit of dollars per cow

Results

Efficiency Results

Efficiencies were estimated using the DEA approach for each farm based on their marketing strategy (i.e., sells calves and sells feeders) for each year (2018-2020). The average efficiency results are reported in Table 2.4, and tables providing the distribution of the efficiency scores are reported in tables A.1 – A.6 in the appendix. Producers selling feeders were more technically efficient than those selling calves in both 2018 and 2019; however, in 2020 those that sold calves were slightly more technically efficient on average (0.840) than those that sell feeders (0.830). However, a larger percentage of firms were technically efficient for those that sell calves in both 2019 and 2020 than for those that sell feeders.

Producers that sell feeders were allocatively more efficient on average, across all years, than those that sell calves. However, interestingly in 2020 despite producers that sell calves having a higher average allocative efficiency, a lower percentage of producers selling feeders were efficient (1.8%) in comparison to those that sell feeders (4.2%). When considering scale efficiency, producers selling calves were on average more scale efficient than those selling feeders across all years. The percentage of firms being scale efficient were similar between the two groups across all years (around 1.4%), excluding 2020 feeders that has a slightly smaller percentage of scale efficient producers (0.9%). Overall, producers that sell feeders were on average more efficient than those that sell calves in 2018 and 2019; however, in 2020 those selling calves were on average more efficient than those selling feeders.

Table 2.2.4 Summary Statistics of Efficiency Point Estimates

Efficiency Measure		2018 N = 95 Calves	2018 N = 79 Feeders	2019 N = 73 Calves	2019 N = 74 Feeders	2020 N = 72 Calves	2020 N = 111 Feeders
Technical	Mean	0.757	0.827	0.801	0.842	0.840	0.830
	SD	0.164	0.142	0.180	0.137	0.145	0.135
	Efficient Firms %	18.9%	27.8%	30.1%	25.7%	29.2%	16.2%
	Efficient Firms #	18	22	22	19	21	28
Allocative	Mean	0.805	0.817	0.757	0.815	0.828	0.849
	SD	0.104	0.112	0.126	0.181	0.118	0.184
	Efficient Firms %	3.2%	3.8%	4.1%	4.1%	4.2%	1.8%
	Efficient Firms #	3	3	3	3	3	4
Scale	Mean	0.761	0.728	0.897	0.822	0.841	0.814
	SD	0.155	0.122	0.127	0.139	0.122	0.115
	Efficient Firms %	1.1%	1.3%	1.4%	1.4%	1.4%	0.9%
	Efficient Firms #	1	1	1	1	1	1
Overall	Mean	0.458	0.490	0.541	0.561	0.581	0.571
	SD	0.139	0.137	0.166	0.147	0.147	0.139
	Efficient Firms %	1.05%	1.27%	1.37%	1.35%	1.39%	0.90%
	Efficient Firms #	1	1	1	1	1	1

Looking at the distribution of the efficiency scores between the two groups and across time illustrates some difference between the producers that sell calves and those that sell feeders. While point estimates are important and are analyzed in the remainder of this analysis, the bootstrap results providing the confidence interval and their widths is needed to better understand the accuracy of the point estimates. DEA literature has suggested that point estimates tend to overstate efficiency and, therefore, bootstrapping typically suggests that the firms are less efficient than the point estimates suggest (Davidova and Latruffe 2007; Gocht and Balcombe 2006; Latruffe et al. 2005). However, when comparing the bootstrap results in Table 2.5 with the point estimates averages in Table 2.4, the point estimates fall within the bootstrap confidence intervals. This suggests that our point estimates may not overstate efficiency as the literature suggests.

Looking at Figures 2.2 - 2.4, the distribution of efficiency scores for producers that sell calves appears to change more drastically across time, where the efficiency score distribution of those that sell feeders is more consistent across time. Figure 2.2 illustrates the technical efficiency cumulative distribution for all groups across all years. Figures 2.3 and 2.4 separate the groups, those that sell feeders and those that sell calves, to illustrate the difference across time within each group.

Table 2.2.5 Summary Statistics of Bootstrapped Efficiency Estimates

Efficiency Measure	Statistics	2018 N = 95 Sells Calves	2018 N = 79 Sells Feeders	2019 N = 73 Sells Calves	2019 N = 74 Sells Feeders	2020 N = 72 Sells Calves	2020 N = 111 Sells Feeders
Technical	Mean	0.792	0.856	0.830	0.873	0.866	0.858
	Mean Lower Bound	0.715	0.810	0.764	0.819	0.808	0.806
	Mean Upper Bound	0.876	0.923	0.911	0.929	0.926	0.916
	Mean Width	0.161	0.113	0.147	0.110	0.118	0.110
Allocative	Mean	0.815	0.807	0.776	0.811	0.832	0.846
	Mean Lower Bound	0.714	0.747	0.670	0.727	0.764	0.789
	Mean Upper Bound	0.909	0.898	0.895	0.916	0.897	0.913
	Mean Width	0.195	0.150	0.224	0.189	0.133	0.124
Scale	Mean	0.789	0.780	0.870	0.828	0.834	0.828
	Mean Lower Bound	0.714	0.644	0.719	0.751	0.724	0.771
	Mean Upper Bound	0.923	0.940	0.956	0.923	0.962	0.920
	Mean Width	0.208	0.296	0.237	0.172	0.238	0.149
Overall	Mean	0.506	0.539	0.558	0.583	0.597	0.600
	Mean Lower Bound	0.426	0.448	0.493	0.522	0.506	0.539
	Mean Upper Bound	0.670	0.681	0.682	0.699	0.761	0.721
	Mean Width	0.245	0.233	0.190	0.177	0.254	0.181

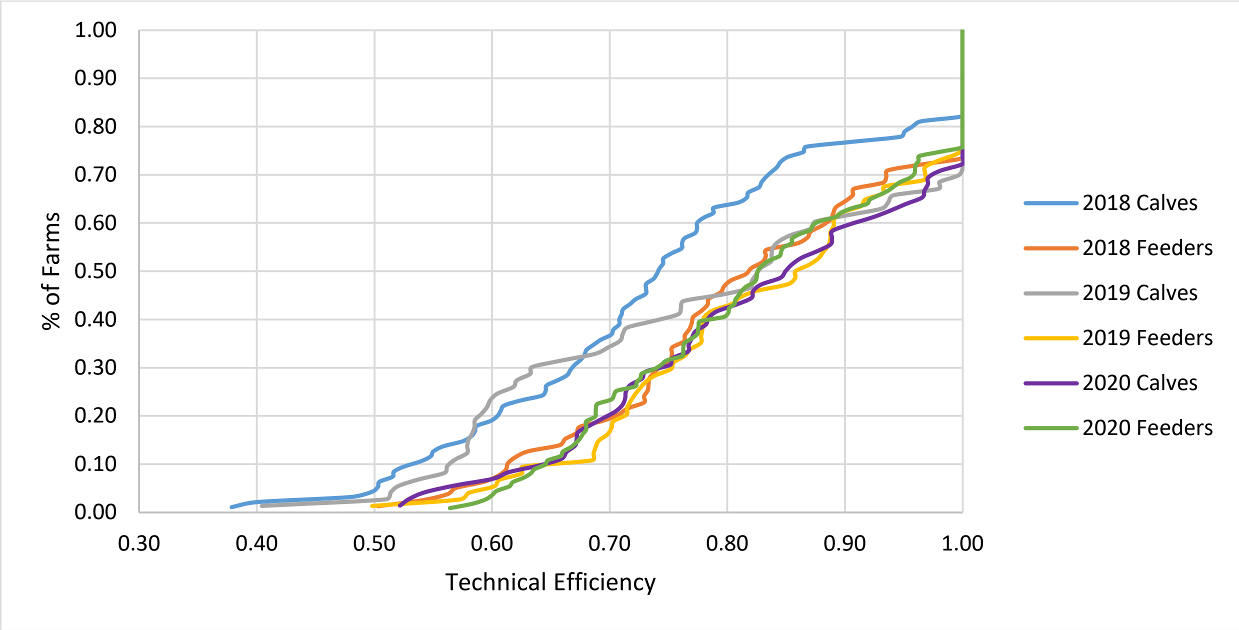


Figure 2.2 Cumulative Distribution: Technical Efficiency 2018-2020

As seen in Figure 2.2, 2018 Calves and 2019 Calves cumulative distributions are quite different from one another. In Figure 2.3, the cumulative distribution changes across time is more visible for those that produce calves, whereas in Figure 2.4 the cumulative distribution for producers selling feeders across time is more similar.

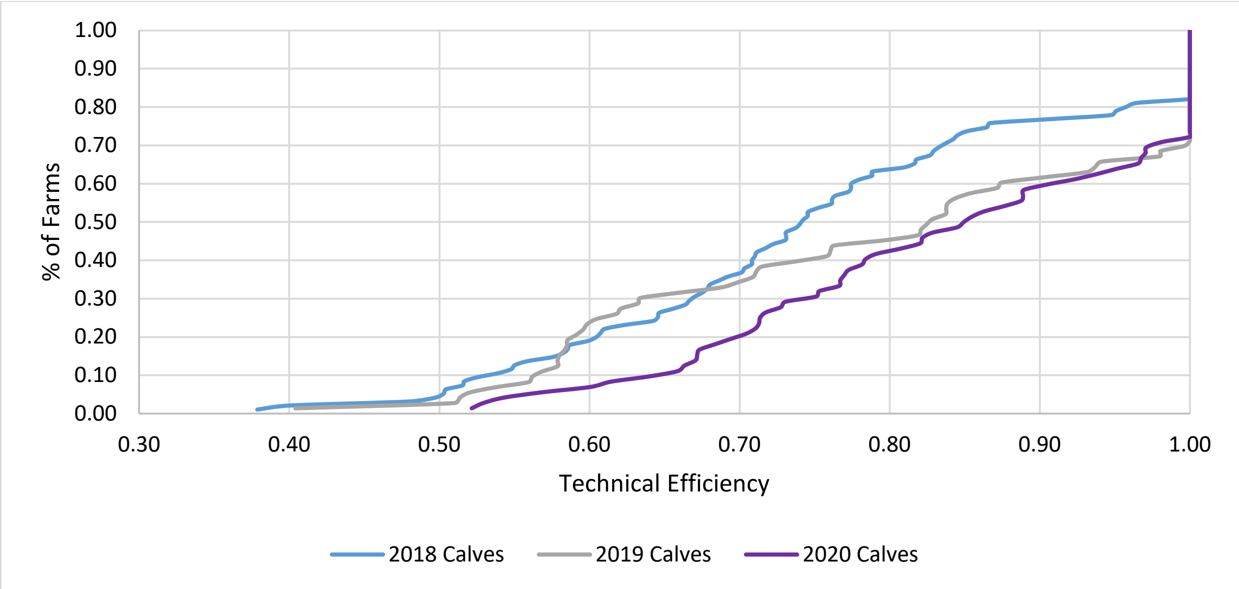


Figure 2.3 Cumulative Distribution: Calves Technical Efficiency 2018-2020

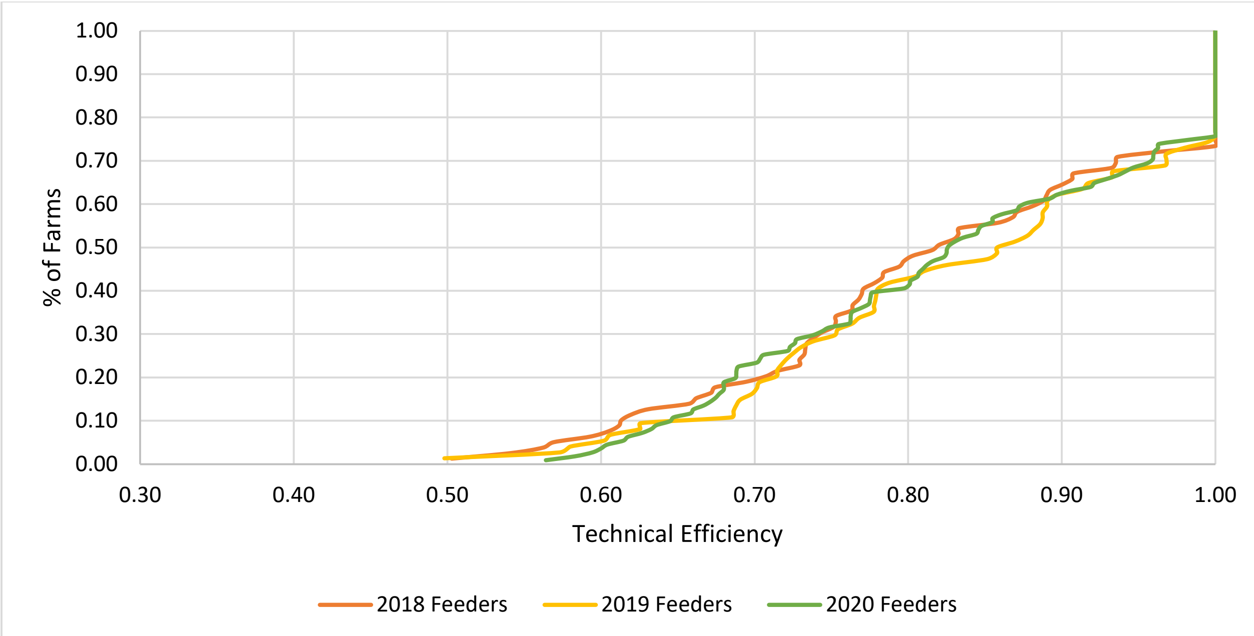


Figure 2.4 Cumulative Distribution: Feeders Technical Efficiency 2018-2020

When considering the cumulative distribution of the allocative efficiency results, there is a more similar distribution across groups and time, with 2019 calves and 2020 feeders having slightly different distributions. Figures 2.5 - 2.7 reports the distributions across time and group.

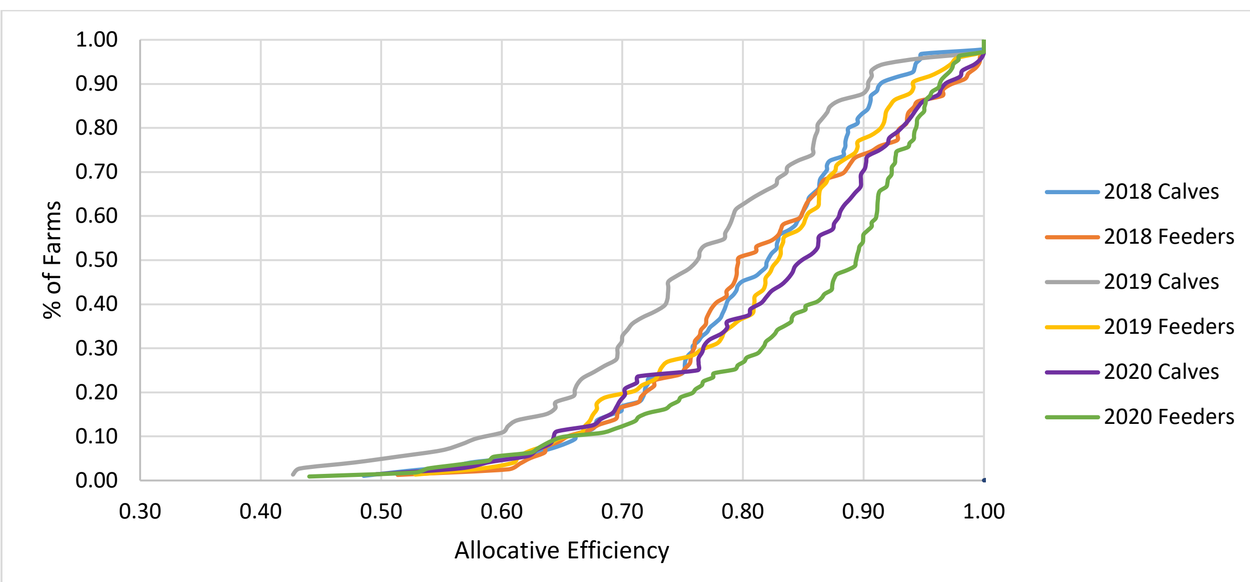


Figure 2.5 Cumulative Distribution: Allocative 2018-2020

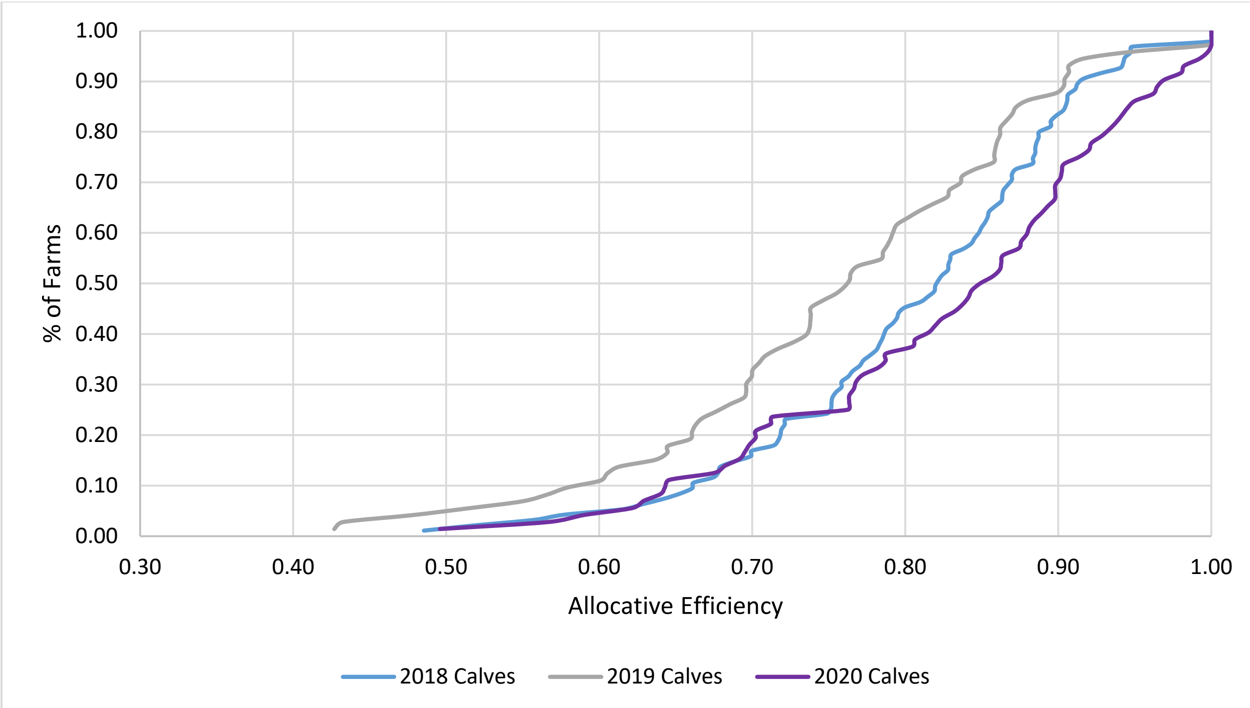


Figure 2.6 Cumulative Distribution: Calves Allocative 2018-2020

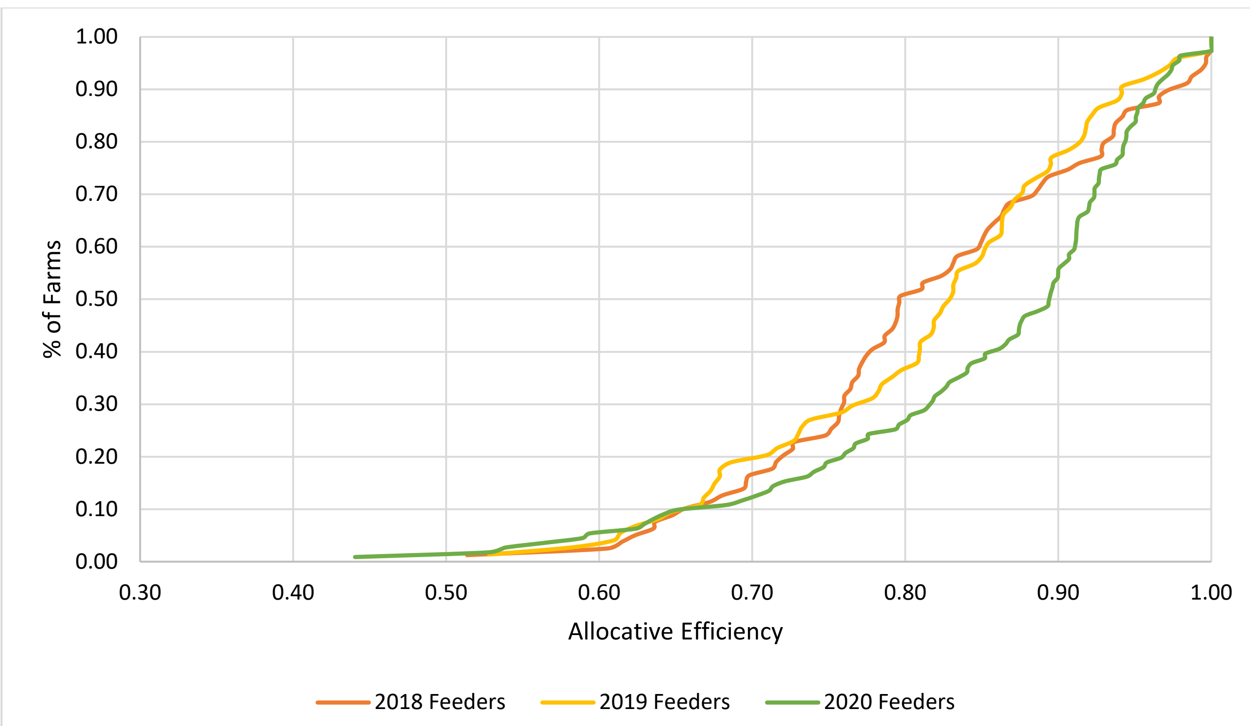


Figure 2.7 Cumulative Distribution: Feeders Allocative 2018-2020

Scale efficiency cumulative distribution is different from year-to-year and across marketing strategy groups. Herd size on average increased for those selling calves each year from 2018 to 2020, while the average herd size for those selling feeders fluctuated from 160 head in 2018, to 152 head in 2019, and then back to 155 head in 2020.

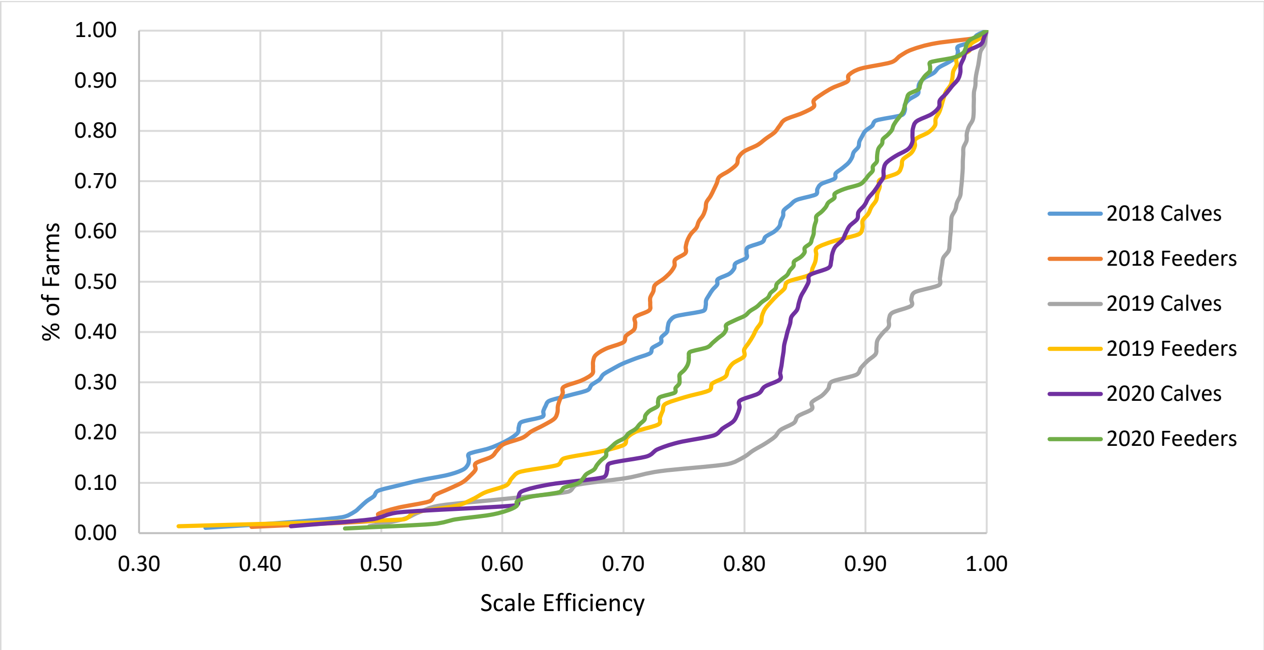


Figure 2.8 Cumulative Distribution: Scale Efficiency 2018-2020

Figure 2.8 illustrates the cumulative distribution of scale efficiency across groups and time. Producers selling calves in 2019 were the most efficient on average (0.897), while those producing feeders in 2018 were the least scale efficient on average (0.728). The cumulative distributions of the two groups can be seen in Figures 2.9 and 2.10.

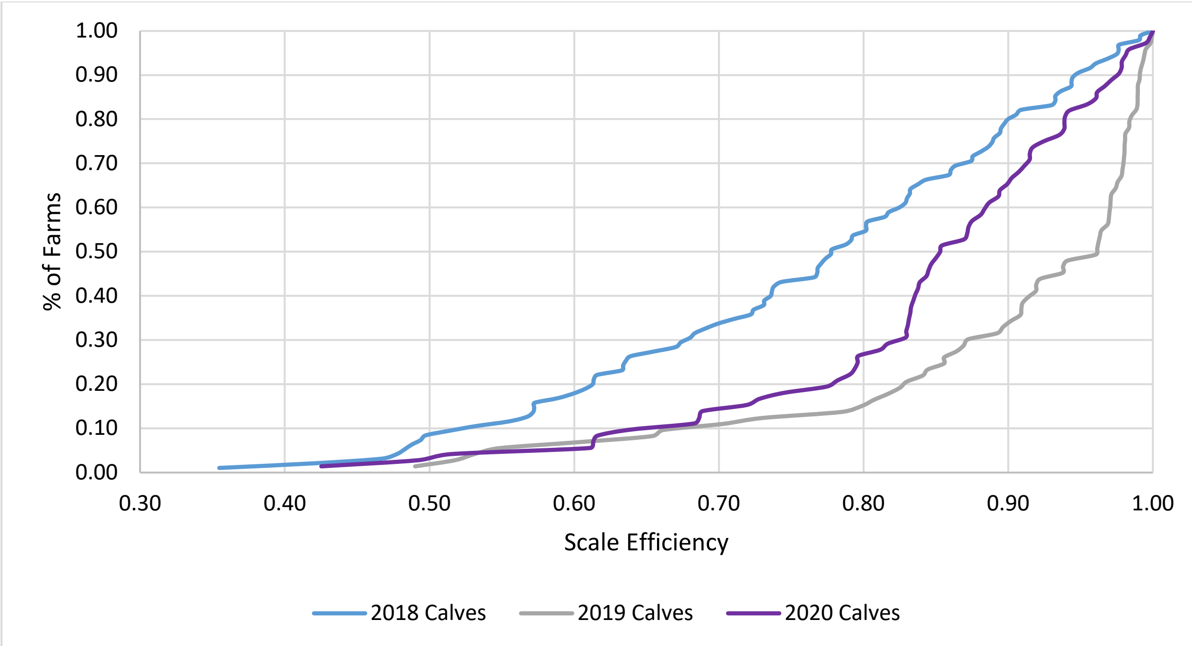


Figure 2.9 Cumulative Distribution: Calves Scale Efficiency 2018-2020

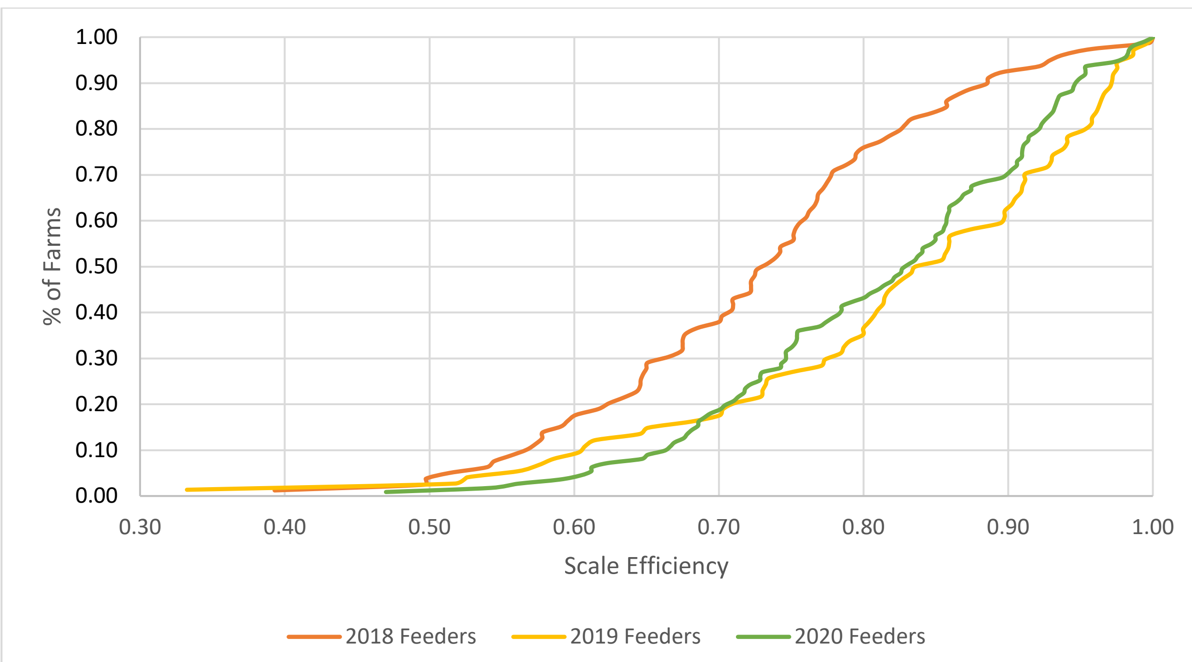


Figure 2.10 Cumulative Distribution: Feeders Scale Efficiency 2018-2020

Figure 2.11 illustrates the cumulative distribution of overall efficiency. All groups across time follow a similar distribution, with groups (calves and feeders) seeming to move their distribution upward across time, which follows the point estimates for each groups overall efficiency increasing over time. Figures 2.12 and 2.13 illustrate the shift of the cumulative distribution across time for each group separately.

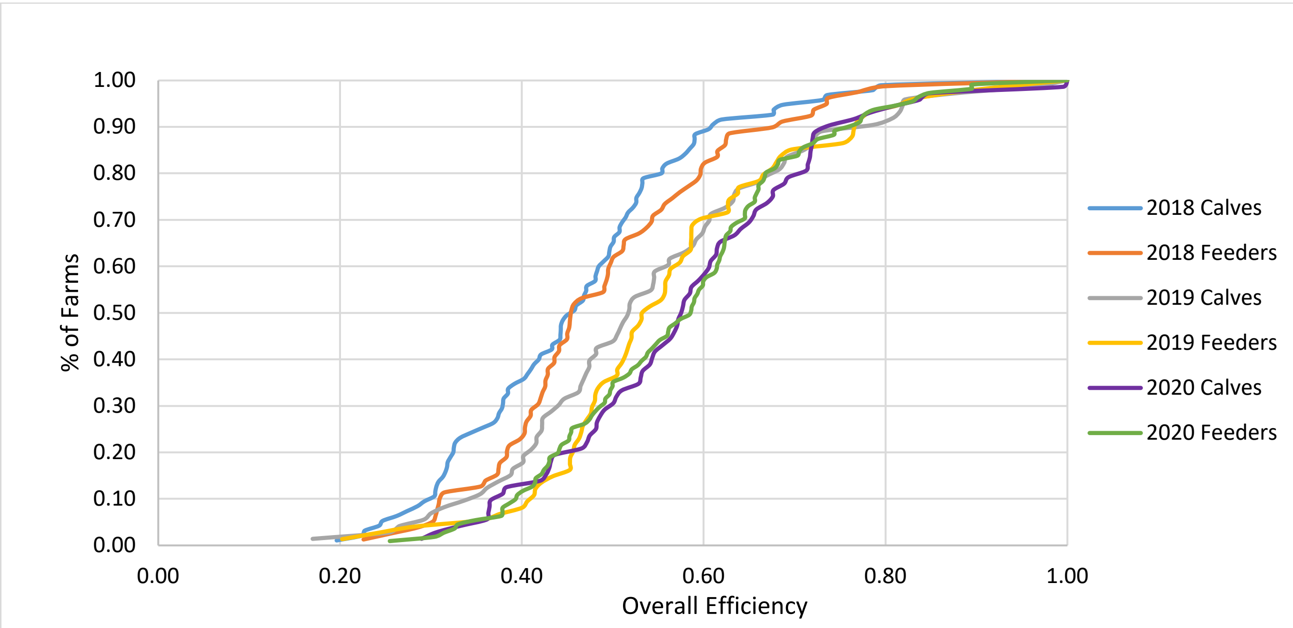


Figure 2.11 Cumulative Distribution: Overall Efficiency 2018-2020

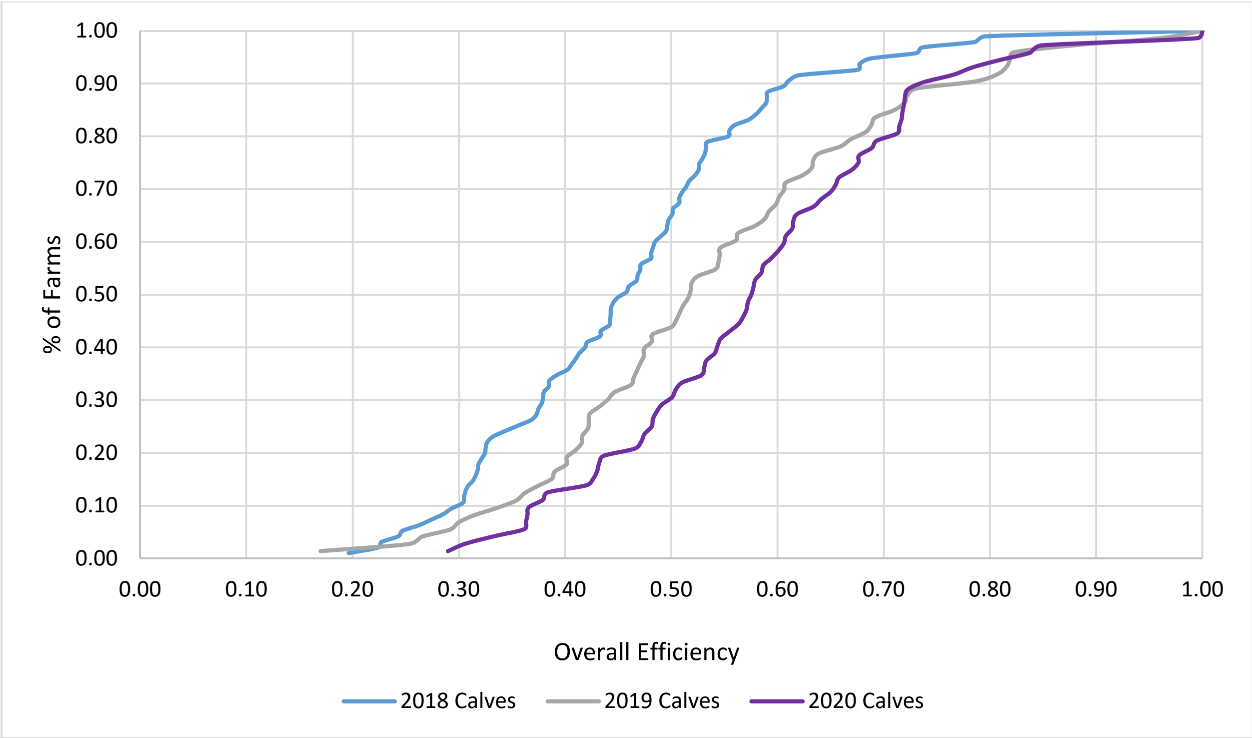


Figure 2.12 Cumulative Distribution: Calves Overall Efficiency 2018-2020

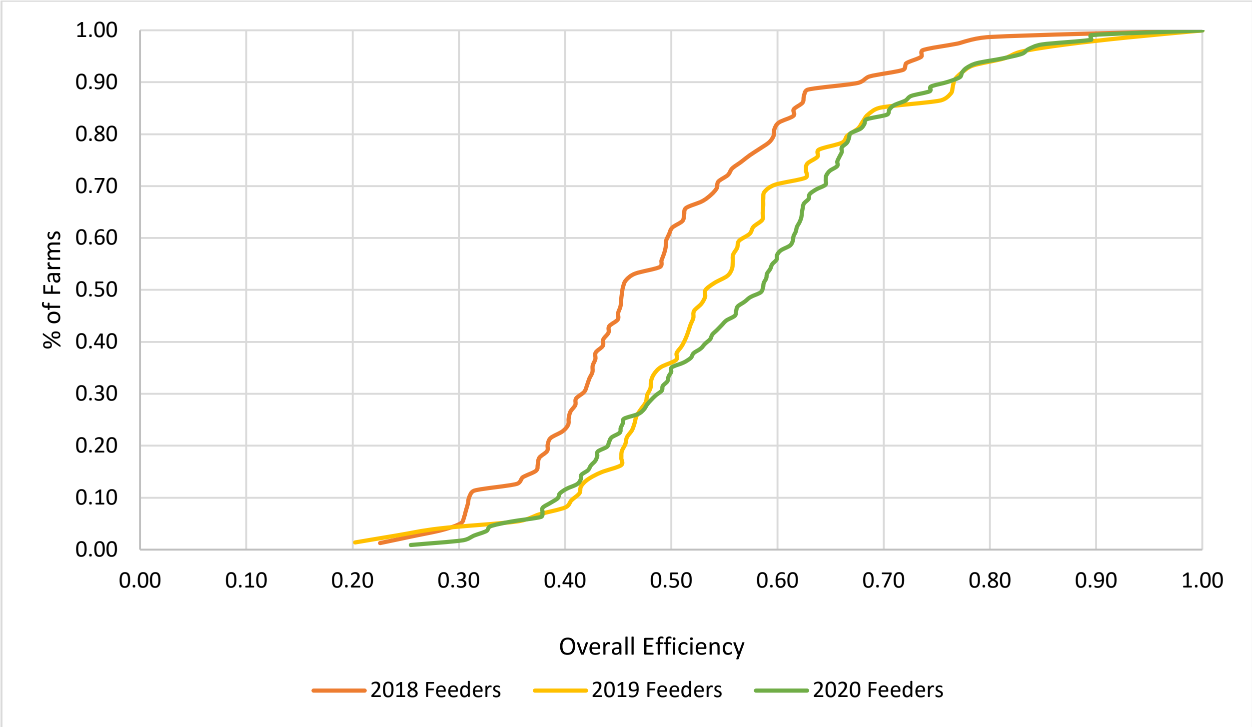


Figure 2.13 Cumulative Distribution: Feeders Overall Efficiency 2018-2020

Tobit Model Results

After merging the KFMA enterprise data with the whole farm data, some observations were dropped due to some producers only provide enterprise data. Table 2.6 provides a summary of the number of observations used in the tobit regression per marketing strategy per year.

Table 2.2.6 KFMA Cow-Calf Farms Reporting Whole Farm & Enterprise Data

Year	Sells Calves	Sells Feeders	Total Firms
2018	88	77	165
2019	68	74	142
2020	71	109	180

In addition to the tobit regression, a simple summary table reporting the mean values for our variables of interest is reported for the Top 20 and Bottom 20 producers based on their technical efficiency (Table A.7). The producers' technical efficiency scores were sorted highest to lowest and the highest twenty producers were compared (as the Top 20) to the twenty producers with the lowest technical efficiency scores (Bottom 20). The summary table can be seen in the appendix and provides a side-by-side comparison across groups and across time. The Top 20 producers across all years had, on average, more cows in addition to having more total farm assets than those producers in the Bottom 20. As expected, all costs (on a per cow basis) were lower for the Top 20 producers and the leverage (debt to equity) is lower for the Top 20 producers.

Of interest, are the differences between off farm income and percentage of land owned, along with the percentage of income from beef cow production. Off-farm income for both marketing strategies was similar, and was also similar between the top and bottom producers. However, in 2019 off-farm income was drastically higher for the Bottom 20 producers that sell calves in comparison to the Top 20 that sell calves ($123,383 for Bottom 20 and $33,145 for Top 20). Producers that sell feeders also had significantly higher off-farm income in 2019 in comparison to 2018 for both the Top and Bottom 20 producers. Off-farm income nearly returned to 2018 levels in 2020, excluding that of the Bottom 20 producer of calves, whose off-farm income remained high ($94,681). Fluctuations in the percentage of land owned from year to year may suggest more turn over in rental agreements and it may be beneficial to consider if these were changes in rented cropland or pasture.

Table 2.2.7 Tobit Results: Overall Efficiency ~ Variables of Interest

	Overall Efficiency		
Variable	**2018**	**2019**	**2020**
Intercept	0.4426*** (0.0349)	0.5722*** (0.4249)	0.5181*** (0.027)
Number of Cows	0.0002 (0.0001)	0.0000 (0.0001)	0.0003 (0.0001)
Leverage	0.0020 (0.0041)	0.0152 (0.0096)	0.0077 (0.0082)
% of Land Owned	0.0000 (0.00000)	0.0000 (0.00000)	0.000002*** (0.00000)
Off Farm Income	-0.0000 (0.00000)	0.00000 (0.00000)	-0.000000 (0.00000)
Log likelihood	-1.9902 (0.0815)	-2.0055 (0.0832)	-2.0039 (0.0677)

Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% level, respectively

Similar to previous studies (Featherstone et al. 1997, Tonsor and Featherstone 2009), many of the variables of interest lacked statistical significance based on analysis from the tobit regression seen in Table 2.7. Correlation coefficients were calculated to understand the importance of efficiency measures and their ability to explain profitability. Net income per cow was correlated positively with overall efficiency (as it should, considering we included net income per head in the efficiency estimations) across all group in all years with coefficients of 0.92, 0.90, and 0.85 for calves in in 2018, 2019, and 2020, respectively. Feeders followed in the same pattern with overall efficiency correlation coefficients of 0.87, 0.88, and 0.83 for 2018, 2019, and 2020, respectively. The complete correlation matrices are reported in the Appendix Table A.8 (all the coefficients are significant at the 1% level). Technical efficiency was relatively more important than scale and allocative efficiency for both marketing strategies across almost all years (one exception in 2020 calves, where allocative efficiency correlation coefficient was higher). Technical efficiency was relatively more important in explaining profitability than either allocative or scale efficiency. Table A.9 reports the super-efficiency results. However, due to an insufficient number of efficient firms (i.e., XX), no further analysis…

Simple regressions were estimated for each marketing strategy in each year, looking at how efficiency impacts net income per cow. The simple regression results are reported in Table 2.8, with net income per cow (per head) as the dependent variable. Regression indicated that a 0.10 increase in pure technical efficiency increases net income per cow by $96 (both marketing strategies in 2018). A 0.10 increase in allocative and scale efficiencies increases net income per cow by $48 and $97, respectively (both marketing strategies in 2018). A 0.10 increase in overall efficiency increases net income per cow by $163 (both marketing strategies in 2018). For both marketing strategies across all years, overall efficiency was estimated to have the greatest impact on net income per cow. Scale efficiency had a greater impact on net income per cow for producers marketing feeders than those marketing calves across all years. This suggests that producers who are experiencing low (or negative) levels of profitability should concentrate on adjusting the size of their herd relative to reducing input use per unit of output.

Table 2.2.8 Simple Regression Results of Profitability and Efficiency Measures

	2018			2019			2020		
	Calves	Feeders	Together	Calves	Feeders	Together	Calves	Feeders	Together
TE	95***	112***	96***	105***	128***	113***	82***	128***	108***
SE	92***	109***	97***	82***	107***	84***	65***	116***	96***
AE	31	65**	48***	70***	58**	66***	105***	109***	105***
OE	169***	162***	163***	144***	167***	154***	140***	188***	168***

Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% level, respectively

Tobit regressions were run for each marketing group in each year by regressing log of the inputs (feed, labor, utilities and fuel, and veterinary costs) on the each of the four efficiency measures in log form (technical, allocative, scale, and overall). Tables A.10-A.12 report the tobit results describing the relationship between inputs and efficiency scores. Significant factors impacting technical efficiency include all inputs (feed, labor, utilities and fuel, and veterinary costs), with labor costs having the most impact on technical efficiency. Labor costs were the most significant factor impacting technical efficiency in 2018 and 2020 for both marketing strategies, with labor falling second to feed costs in 2019 as the second most significant factor influencing technical efficiency for producers selling calves. Labor costs were the most significant factor impacting allocative efficiency across all years for both marketing strategies. Feed costs had the greatest impact on scale efficiency, suggesting that producers wanting to impact their scale efficiency should focus on feed costs. Overall efficiency was consistently most impacted by feed and labor costs across all years and marketing groups.

Conclusions

The beef industry has continued to shift towards consolidation of farms in addition to more cow-calf producers utilizing backgrounding and retaining ownership longer. Increased competition, or increased demand, for competing proteins (and alternative meat) has continued to place pressure on prices, forcing producers to be increasingly vigilant about minimizing production costs. Additionally, inefficiency of scale may continue to cause consolidation of the industry as scale inefficient firms exit the industry.

This analysis applied data envelopment analysis (DEA) to understand the efficiency of Kansas cow-calf producers. Technical, allocative, scale, and overall efficiency were estimated for cow-calf producers from 2018-2020 using Kansas Farm Management Association (KFMA) data. The data allowed for the analysis to compare two marketing strategies for cow-calf producers, those that sell calves and those that sell feeders.

Using a nonparametric approach, this study determined that cow-calf producers that sell calves were almost always less technically and allocatively efficient than producers who sold feeders. However, those that sold calves were more scale efficient than those that sold feeders across all years (2018-2020). In 2018 nearly 30% of producers selling feeders were technically efficient, compared to only 19% of producers selling calves. However, in 2019, 30% of produces selling calves were technically efficient, while only 25% of producers selling feeders were technically efficient. This trend continued into 2020, with 29% producers selling calves being efficient and only 16% of producers selling feeders being technically efficient. While there was a larger difference in technical efficiency averages between the two marketing strategies, the overall efficiency averages for the two groups were more similar. Producers selling calves in 2018 had an average overall efficiency of 0.46, while those that sold feeders having an average efficiency of 0.49. This trend continued for 2019 (0.54 and 0.56) and 2020 (0.58 and 0.57). The DEA bootstrap method suggests that our results may not be overestimated as the point estimate all fell within the confidence interval. Additionally, while the super efficiency results allowed us to rank the efficient firms, with limited data, the results could only be compared using the top and bottom 20 firms.

Comparing the highest (top) twenty technically efficient producers to the lowest (bottom) twenty technically efficient producers, the average herd size for the top twenty producers was much higher. The largest herd size difference between the top and bottom producers was seen in the 2019 feeder group, with the top 20 producers having an average herd size of 159.8 and the bottom 20 producers having an average herd size of 98.8. The gross income per head was, on average, nearly one hundred dollars higher across all marketing strategies, and time, for the top twenty efficient producers compared to the bottom twenty producers.

Using the DEA approach with limited data has some limitations. Given the relatively low number of observations in the KFMA data set for cow-calf producers in each marketing strategy, it can be difficult to truly estimate the drivers of efficiency. Additionally, limitations of DEA include the discussions around selecting/identifying outliers in addition to the typical overestimation of efficiency. While our bootstrapping method suggests our estimates are reasonable, a larger data set may introduce the need to discuss this further.

While the tobit regression provided minimal statistically significant results, further analysis including a supplemental survey data would be beneficial. The study will be improved through the use of supplemental survey data from KFMA that collects additional information from producers, including management decisions and technology utilized in production. Management decisions about fall and spring calving, pasture and feed management, nutritional plans, and breeding technology (i.e. hormones or artificial insemination) will provide a better understanding of what decisions may be impacting producer's efficiency and profitability. Future work should utilize a larger data set to better understand what is driving efficient firms to be super-efficient. This study brings a better understating of production efficiency to the present-day cow-calf sector and provides insight into the areas that producers may continue to focus their efforts to improve efficiency and profitability.

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Chapter 3 - Conclusion

The main objective of this study is to examine the efficiency of beef cow-calf production in Kansas. This study 1) estimates technical, allocative, scale, and overall efficiency for cow-calf producers, 2) estimates super-efficiency, and 3) utilizes a tobit regression to understand drivers of efficiency and profitability. While limited data did not allow for further analysis of the super-efficiency scores, the results met the objectives and provide guidance as to where future research should focus. The collection of results across marketing groups, and time, suggest that further analysis of feed and labor costs is needed.

While consolidation of the U.S. beef industry has continued over time, the herd size has not changed dramatically, and the results indicating that scale efficiency is not as important relative to allocative or technical efficiency to impacting profitability supports this. Producers should focus on decisions surrounding feed and labor to better impact their efficiency and profitability. More detailed data regarding feeding practices, feedstuffs used, rented pasture and owned pasture, calving season, and more could provide a base on which to continue this research and provide insights as to what is impacting feed costs.

Producers must continue to reduce production costs and efficiency allocate the resources they have to remain profitable and in the industry. Increased competition from other protein sources and demand changes will continue to pressure beef producers to be more efficient. Continued efforts to understand the decisions impacting production efficiency and profitability is integral to the cow-calf producers, the beginning of the U.S. beef industry.

Appendix A - Supplemental and Supporting Data

Table A.1 Efficiency Score Distribution, 2018 Calves

	2018 Calves			
	Technical	**Scale**	**Allocative**	**Overall**
Summary:				
Mean	0.757	0.761	0.805	0.458
Standard Deviation	0.164	0.155	0.104	0.139
Minimum	0.379	0.355	0.485	0.196
Maximum	1.000	1.000	1.000	1.000
Distribution:				
Less than 0.40	2	1	0	33
0.40 to 0.50	2	7	1	28
0.50 to 0.60	14	9	3	23
0.60 to 0.70	16	15	12	6
0.70 to 0.80	26	19	27	4
0.80 to 0.90	12	25	36	0
0.90 to 1.00	5	18	13	0
1.00	18	1	3	1

Table A.2 Efficiency Score Distribution, 2019 Calves

	2019 Calves			
	Technical	**Scale**	**Allocative**	**Overall**
Summary:				
Mean	0.801	0.897	0.757	0.541
Standard Deviation	0.180	0.127	0.126	0.166
Minimum	0.404	0.490	0.427	0.170
Maximum	1.000	1.000	1.000	1.000
Distribution:				
Less than 0.40	0	0	0	12
0.40 to 0.50	1	1	3	20
0.50 to 0.60	16	3	4	17
0.60 to 0.70	8	3	16	12
0.70 to 0.80	8	4	22	5
0.80 to 0.90	11	13	19	5
0.90 to 1.00	7	48	6	1
1.00	22	1	3	1

Table A.3 Efficiency Score Distribution, 2020 Calves

	2020 Calves			
	Technical	**Scale**	**Allocative**	**Overall**
Summary:				
Mean	0.840	0.841	0.828	0.581
Standard Deviation	0.145	0.122	0.118	0.147
Minimum	0.522	0.425	0.496	0.290
Maximum	1.000	1.000	1.000	1.000
Distribution:				
Less than 0.40	0	0	0	9
0.40 to 0.50	0	2	1	12
0.50 to 0.60	4	1	2	20
0.60 to 0.70	10	7	10	16
0.70 to 0.80	16	9	13	10
0.80 to 0.90	12	28	24	3
0.90 to 1.00	9	24	19	1
1.00	21	1	3	1

Table A.4 Efficiency Score Distribution, 2018 Feeders

	2018 Feeders			
	Technical	**Scale**	**Allocative**	**Overall**
Summary:				
Mean	0.827	0.728	0.817	0.490
Standard Deviation	0.142	0.122	0.112	0.137
Minimum	0.503	0.393	0.514	0.226
Maximum	1.000	1.000	1.000	1.000
Distribution:				
Less than 0.40	0	1	0	18
0.40 to 0.50	0	2	0	30
0.50 to 0.60	5	10	1	16
0.60 to 0.70	10	17	12	8
0.70 to 0.80	22	30	27	6
0.80 to 0.90	13	13	18	0
0.90 to 1.00	7	5	18	0
1.00	22	1	3	1

Table A.5 Efficiency Score Distribution, 2019 Feeders

	2019 Feeders			
	Technical	**Scale**	**Allocative**	**Overall**
Summary:				
Mean	0.842	0.822	0.815	0.561
Standard Deviation	0.137	0.139	0.109	0.147
Minimum	0.498	0.332	0.528	0.203
Maximum	1.000	1.000	1.000	1.000
Distribution:				
Less than 0.40	0	1	0	5
0.40 to 0.50	1	0	0	21
0.50 to 0.60	2	5	2	26
0.60 to 0.70	9	6	12	11
0.70 to 0.80	19	15	13	6
0.80 to 0.90	15	19	30	3
0.90 to 1.00	9	27	14	1
1.00	19	1	3	1

Table A.6 Efficiency Score Distribution, 2020 Feeders

	2020 Feeders			
	Technical	**Scale**	**Allocative**	**Overall**
Summary:				
Mean	0.833	0.812	0.854	0.583
Standard Deviation	0.136	0.114	0.109	0.142
Minimum	0.564	0.470	0.539	0.255
Maximum	1.000	1.000	1.000	1.000
Distribution:				
Less than 0.40	0	0	0	12
0.40 to 0.50	0	1	1	26
0.50 to 0.60	3	3	5	25
0.60 to 0.70	22	16	7	29
0.70 to 0.80	20	27	16	12
0.80 to 0.90	24	31	32	6
0.90 to 1.00	14	32	46	0
1.00	28	1	4	1

Table A.7 Means Summary of Top and Bottom 20 Producers

	2018				2019				2020			
	Calves		Feeders		Calves		Feeders		Calves		Feeders	
Variable	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**	**Top**	**Bottom**
Number of Cows	146.65	86.74	144.13	116.2	149.29	94.7	177.15	120.73	143.1	92.95	159.88	98.79
Gross Income	800.5	716.76	903.65	841.51	719.99	613.64	878.75	760.26	793.59	782.23	970.38	877.28
Feed Cost	423.97	582.26	490.47	676.12	478.52	663.02	522.19	669.34	470	575.34	596.12	777.62
Labor Cost	139.76	241.12	152.11	228.28	146.86	208.99	175.26	203.99	165.26	246.44	231.09	248.16
Utilities and Fuel Cost	21.83	40.02	28.36	39.88	24.8	38.26	31.25	45.99	20.73	34.62	22.96	43.94
Veterinary Cost	20.5	43.06	35.54	57.77	31.88	48.59	37.28	62.51	29.01	48.51	40.18	65.6
Net Income	1.8	-306.19	-40.87	-347.02	-135.73	-495.53	-80.28	-469.18	-41.28	-260.04	-20.29	-483.44
Leverage	0.02	0.75	0.57	1.09	0.26	0.53	0.45	1.13	0.24	0.52	0.29	0.56
% of Income from Beef Cow Production	15%	22%	18%	19%	21%	14%	27%	18%	15%	16%	24%	14%
% of Land Owned	49.1%	23.0%	27.1%	26.3%	33.3%	34.0%	21.8%	23.7%	28.5%	38.3%	33.0%	24.4%
Off Farm Income	41,876	31,453	42,887	37,009	33,145	123,383	111,647	129,903	42,243	94,681	41,158	42,059
Total Farm Assets (1000s)	4,392	1,4940	3,662	2,259	3,150	2,678	2,296	2,479	3,377	2,311	3,685	2,394
Technical Efficiency	1	0.54	1	0.65	1	0.57	1	0.66	1	0.65	1	0.64

Table A.8 Profitability and Efficiency Correlations

	Calves					Feeders					
2018											
	Net Inc.	Technical	Scale	Allocative	Overall		Net Inc.	Technical	Scale	Allocative	Overall
Net Inc.	1					Net Inc.	1				
Technical	0.612	1				Technical	0.626	1			
Scale	0.559	0.005	1			Scale	0.520	0.047	1		
Allocative	0.128	-0.265	-0.165	1		Allocative	0.287	-0.190	0.001	1	
Overall	0.915	0.614	0.615	0.178	1	Overall	0.866	0.559	0.655	0.409	1
2019											
	Net Inc.	Technical	Scale	Allocative	Overall		Net Inc.	Technical	Scale	Allocative	Overall
Net Inc.	1					Net Inc.	1				
Technical	0.711	1				Technical	0.629	1			
Scale	0.390	0.267	1			Scale	0.532	0.142	1		
Allocative	0.334	-0.229	-0.232	1		Allocative	0.228	-0.191	-0.218	1	
Overall	0.896	0.721	0.519	0.327	1	Overall	0.879	0.619	0.626	0.305	1
2020											
	Net Inc.	Technical	Scale	Allocative	Overall		Net Inc.	Technical	Scale	Allocative	Overall
Net Inc.	1					Net Inc.	1				
Technical	0.491	1				Technical	0.540	1			
Scale	0.326	-0.231	1			Scale	0.415	0.002	1		
Allocative	0.514	-0.221	0.197	1		Allocative	0.398	-0.237	0.042	1	
Overall	0.850	0.440	0.543	0.572	1	Overall	0.825	0.521	0.595	0.483	1

Table A.9 Super-Efficiency Results

2018				2019				2020			
Firm	**Calves**	**Firm**	**Feeders**	**Firm**	**Calves**	**Firm**	**Feeders**	**Firm**	**Calves**	**Firm**	**Feeders**
53	15.605	19	4.044	23	2.987	4	5.027	71	5.172	81	4.797
58	14.614	51	2.036	27	2.256	2	2.466	38	3.049	87	4.163
52	1.931	26	1.534	55	1.818	71	1.835	16	1.654	53	2.126
44	1.523	78	1.440	47	1.756	43	1.777	72	1.510	56	1.678
32	1.420	74	1.251	21	1.558	51	1.735	24	1.439	39	1.393
31	1.326	41	1.211	41	1.385	47	1.425	18	1.315	76	1.265
3	1.174	4	1.200	26	1.320	24	1.322	5	1.268	64	1.240
54	1.166	17	1.158	45	1.297	27	1.293	25	1.215	82	1.220
28	1.148	8	1.139	28	1.254	33	1.186	4	1.182	23	1.216
66	1.109	18	1.111	46	1.193	48	1.167	12	1.161	47	1.190
51	1.102	38	1.100	16	1.142	50	1.139	36	1.155	11	1.176
82	1.063	54	1.094	2	1.140	32	1.109	17	1.082	74	1.144
49	1.054	69	1.084	42	1.130	28	1.103	34	1.072	84	1.134
48	1.007	66	1.084	50	1.088	30	1.095	43	1.067	96	1.125
83	1.004	56	1.076	20	1.069	45	1.059	29	1.054	103	1.114
74	1.000	77	1.075	31	1.028	7	1.054	26	1.036	72	1.113
		30	1.052	73	1.026	21	1.002	7	1.027	51	1.109
		37	1.046	58	1.026			8	1.008	31	1.105
		75	1.026	43	1.025			46	1.005	98	1.064
		52	1.017	64	1.003					7	1.051
										95	1.049
										108	1.044
										73	1.044
										90	1.025
										3	1.004
										66	1.001

Table A.10 Efficiency and Inputs Tobit Results, 2018

	Technical		**Allocative**		**Scale**		**Overall**	
	Calves	Feeders	Calves	Feeders	Calves	Feeders	Calves	Feeders
Intercept	3.5600***	3.6132***	1.3273***	2.1448	-2.7651***	-3.0540***	0.2491*	-0.0491
	(0.4662)	(0.5135)	(0.3436)	(0.3270)	(0.2838)	(0.0296)	(0.1368)	(0.1440)
Feed Costs	0.1966***	0.1679**	0.0390	0.0564	0.7476***	0.7733***	0.9249***	0.9984***
	(0.0727)	(0.07170)	(0.0507)	(0.0478)	(0.0438)	(0.0048)	(0.0349)	(0.0347)
Labor Costs	-0.5311***	-0.4245***	-0.2260***	-0.3755	-0.0159	0.0023	-0.7407***	-0.7366***
	(0.0677)	(0.0615)	(0.0459)	(0.0395)	(0.03979)	(0.0040)	(0.0315)	(0.0286)
Utility & Fuel Costs	-0.2495***	-0.2214***	0.0724***	-0.0040	-0.0421*	-0.0035	-0.1834***	-0.1699***
	(0.0394)	"(0.0422)	(0.0260)	(0.0280)	(0.0225)	(0.0029)	(0.0179)	(0.0206)
Veterinary Costs	-0.1189***	-0.1905***	0.0344***	0.1135	0.0026	0.0001	-0.0452***	-0.0355**
	(0.0261)	(0.0293)	(0.0141)	(0.0190)	(0.0122)	(0.0019)	(0.0097)	(0.0140)

Numbers in parentheses are standard errors. Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% level, respectively

Table A.11 Efficiency and Inputs Tobit Results, 2019

	Technical		Allocative		Scale		Overall	
	Calves	Feeders	Calves	Feeders	Calves	Feeders	Calves	Feeders
Intercept	2.0170**	3.0370***	2.0571***	1.9526***	-1.7394***	-2.3013***	0.4883**	0.3350***
	(0.7931)	(0.5890)	(0.5234)	(0.3586)	(0.2734)	(0.2959)	(0.1950)	(0.1746)
Feed Costs	0.4852***	0.2933***	-0.0083	0.0647	0.4734***	0.6076***	0.8441***	0.9026***
	(0.1142)	(0.0747)	(0.0830)	(0.0477)	(0.0364)	(0.0388)	(0.0425)	(0.0336)
Labor Costs	-0.4750***	-0.4901***	-0.2478***	-0.3709***	0.0013	0.0287	-0.6516***	-0.7084***
	(0.0919)	(0.0797)	(0.0646)	(0.04710)	(0.0283)	(0.0376)	(0.0331)	(0.0327)
Utility & Fuel Costs	-0.2496***	-0.2046***	-0.0241	0.0491	-0.0422**	-0.0580**	-0.2336***	-0.1871***
	(0.06847)	(0.0521)	(0.0469)	(0.0326)	(0.0206)	(0.0267)	(0.0240)	(0.0231)
Veterinary Costs	-0.0956**	-0.1055***	0.0068	0.0876***	0.0186	-0.0432***	-0.0216	-0.0404***
	(0.0443)	(0.0294)	(0.03082)	(0.0186)	(0.0135)	(0.0153)	(0.0158)	(0.0132)

Numbers in parentheses are standard errors. Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% level, respectively

Table A.12 Efficiency and Inputs Tobit Results, 2020

	Technical		**Allocative**		**Scale**		**Overall**	
	Calves	Feeders	Calves	Feeders	Calves	Feeders	Calves	Feeders
Intercept	3.2119***	3.3898***	1.3853***	2.2673***	-2.2126***	-3.1538***	0.2254*	0.3897**
	(0.6283)	(0.7475)	(0.3859)	(0.5525)	(0.2296)	(0.3064)	(0.1244)	(0.1951)
Feed Costs	0.0985	0.1253	0.2477***	0.0657	0.5955***	0.7279***	0.9479***	0.8822***
	(0.1072)	(0.0981)	(0.0662)	(0.0715)	(0.0389)	(0.0413)	(0.0305)	(0.0373)
Labor Costs	-0.2948***	-0.4528***	-0.3453***	-0.2546***	-0.0337	-0.0188	-0.6911***	-0.6999***
	(0.0934)	(0.0756)	(0.0576)	(0.0541)	(0.0339)	(0.0314)	(0.0265)	(0.02829)
Utility & Fuel Costs	-0.2366***	-0.1261***	-0.0554	-0.1057***	-0.0250	-0.0028	-0.2494***	-0.2108***
	(0.0598)	(0.0377)	(0.0357)	(0.0271)	(0.0210)	(0.0157)	(0.0165)	(0.0142)
Veterinary Costs	-0.1167***	-0.0994***	0.0327*	0.0229	0.0033	0.0093	-0.0360***	-0.0322***
	(0.0338)	(0.0228)	(0.0185)	(0.0161)	(0.0109)	(0.0093)	(0.0086)	(0.0084)

Numbers in parentheses are standard errors. Single, double, and triple asterisks (*) denote significance at the 10%, 5%, and 1% level, respectively