Simulating Calving Season Length Impact on Beef Cattle Profitability

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Abstract

We determined the impacts of calving season length on net returns and variability in net returns for spring- and fall-calving herds in Tennessee. Weaning weight as a function of calving date was estimated using 19 years of data and simulation models were developed to find a distribution of net returns for 30, 60, and 90-day calving periods. Two scenarios were included that assume the adoption of improved reproductive management (IRM). The fall-calving season was most profitable, and shortening the calving period from 90 days increased expected net returns in the spring- and fall-calving herds. The 30-day fall-calving period with IRM maximized profits, but an extremely-risk averse producer would select a 30-day fall-calving period without IRM.

Keywords: Beef Cattle, Profitability, Simulation, Stochastic Dominance

JEL Classifications: Q12

Introduction

About 33% of all United States beef cattle operations have a defined calving season, which is the time of the year when calves are born (United States Department of Agriculture (USDA), 2009). Even though a controlled calving season (e.g., in the spring or fall) for beef cattle production is more profitable than year-round calving (Doye, Popp, and West, 2008). Selecting a calving season may appear complicated to producers utilizing year-round calving due to the calving season influencing seasonal variation in nutritional demands for brood cows, calf weaning weight, calving rate, and cattle and feed prices (Bagley et al., 1987; Caldwell et al., 2013; Campbell et al., 2013; Leesburg, Tess, and Griffith, 2007; Smith et al., 2012). Additionally, the calving season has major implications on net returns (i.e., profitability) and risk exposure for producers (Henry et al., 2016). Therefore, a producer has to consider nutrition, reproduction, calf performance, and economic markets when selecting a calving season that maximizes net returns.

Henry et al. (2016) compared the profitability and risk of spring- and fall-calving herds in Tennessee. They found that fall-calving to have higher net returns and had less variability in net returns (i.e., risk exposure) than spring-calving when marketing calves at weaning. Despite fall-born calves having lighter weaning weights and cows having a higher winter feed cost than the spring-calving herd, the cattle prices at weaning for fall-born calves were higher than spring born calves, resulting in fall-calving being more profitable. Other studies conducted in the Mid-South United States such as Bagley et al. (1987) and Smith et al. (2012) also found fall-calving to be more profitable than the spring-calving.

Far less knowledge, however, exists on the implication calving season length has on herd profitability for both spring- and fall-calving herds. Calving season length could be described as the number of days from the start of calving to the end of calving and corresponds with the number of days cows are exposed to a bull (or sometimes called breeding season). For instance, if a producer follows a 60-day calving season starting at the end of January and finishing at the end of March, the breeding season (i.e., bull with cows) will run for 60 days from mid- to late-April to mid- to late-June. Most cow-calf producers in the United States sell calves at weaning (USDA, 2009) and weaning often occurs when it is convenient regardless of calf age or weight. Calves born late in the calving season (i.e., younger calves) will be weaned at a lighter weight than early born calves (Deutscher, Stotts, and Nielson, 1991; Funston et al., 2012; Mousel et al., 2012; Ramsey et al., 2005). Furthermore, a longer calving season could cause some cows to have less time for uterine repair (involution) to occur before the beginning of the next breeding season, negatively influencing reproductive performance (Johnson, 2005; Mousel et al., 2012). These studies indicate that a longer calving season could decrease revenue.

On the other hand, a longer calving season length provides more opportunities for cows to get bred and wean a calf. For example, if a producer decides to shorten their 60-day breeding season from mid-April through mid-June to 30 days from mid-April through mid-May, cows will most likely have only one estrous cycle to become pregnant. While cows in a 60-day breeding season would have at least two estrous cycles to become pregnant, increasing the likelihood of pregnancy and weaning a calf (Deutscher, Stotts, and Nielson, 1991; Mousel et al., 2012).

A potential reproductive management practice that could be implemented to address these challenges is defining a rigid culling program that replaces open and later calving cows with heifers that show signs of early breeding along with implementing estrus synchronization (ES) with timed artificial insemination (TAI) (Johnson, 2005; Johnson and Jones, 2008; Lamb and Mercadante, 2016). This practice can shorten the calving season length, produce more uniform calves and heavier calves while maintaining a pregnancy rate similar to the longer breeding season (Johnson, 2005; Johnson and Jones, 2008; Lamb and Mercadante, 2016). Furthermore, ES with TAI could increase net returns by improving herd genetics relative to natural service breeding (Lamb and Mercadante, 2016; Rodgers et al., 2012). A few studies have reported that these benefits result in higher net returns than natural service breeding, despite the higher cost of using ES with TAI (Johnson and Jones, 2008; Lamb and Mercadante, 2016; Parcell et al., 2011; Rodgers et al., 2012).

Producers have a tradeoff between shortening the calving season length to increase weaning weight, calf uniformity, and reproductive advantages at the risk of decreasing the percentage of cows bred and weaning a calf. While these studies are insightful, an analysis is needed to indicate the profit-maximizing calving season length for cow-calf producers as well as determine the calving season length that reduces production risk. These results build on the economics literature of calving season and provide unique insight into the economics of calving season length. It would also be useful to examine how implementing an improved reproductive management (IRM) practice such as ES with TAI could impact the profitability of a herd.

Therefore, the objective of this research was to determine the implication of calving season length on net returns and variability in net returns for spring- and fall-calving herds in Tennessee. Data were used from a 19-year study in Tennessee of spring- and fall-calving herds. We estimate a response function for calf weaning weight as a function of calving date and determine the profit-maximizing calving date for a spring- and fall-calving herd. Monte Carlo simulation models were established considering production risk when calving season lengths were 30, 60, and 90 days. We also included two scenarios for 30- and 60-day calving season length that assumed the producer used an IRM practice to increase calving rate. Beef cattle production in the Mid-South is centered on pasture-based, cow-calf production (McBride and

Mathews, 2011). Thus, results will benefit a large audience of producers by demonstrating the importance of reproductive management on the profitability of the herd.

Economic Framework

Net Returns

A risk neutral, profit maximizing cow-calf producer would select the *i*th calving season (*i* = fall, spring) with calving season length *j* (*j* = 30, 60, 90 days) that provides the highest net returns. These net returns are found by subtracting expenses from revenue. Revenue from a cow-calf operation is received from selling steers, heifers, and culled cows. Fall-calving herds produce lighter calves than spring-calving herds at weaning (Campbell et al., 2013; Henry et al., 2016), and a shorter calving season length can increase calf weaning weight (Deutscher, Stotts, and Nielson, 1991; Funston et al., 2012; Mousel et al., 2012). Moreover, cattle prices are typically lower in the fall than in the spring (Julien and Tess, 2002). This means fall-born calves, weaned in the spring (April and May), may bring higher prices than identical weight spring-born calves weaned in the fall (September and October) (Henry et al., 2016).

Production expenses for a cow-calf operation include land, labor, pasture, feed, animal health, trucking, and marketing fees. Most of these production expenses do not vary significantly across calving season and calving season length with the exception of supplemental feed costs during the months pasture is dormant. Feed costs are higher for fall-calving cows than for spring-calving cows since fall-calving cows have a higher nutritional demand in the winter months than spring-calving cows (Henry et al., 2016).

The producer's objective of selecting the calving season and calving season length that maximizes expected net returns is defined as

$$(1)\ \max_{i,j}\ \mathrm{E}\left[\pi_{ij}\right] = p_i^s y_{ij}^s\left(CD_{ij}\right)\left(\frac{CR_{ij}}{2}\right) + p_i^h y_{ij}^h\left(CD_{it}\right)\left(\frac{CR_{ij}}{2} - RR_i\right) + p_i^c y_i^c\left(RR_{ij}\right) - FC_i - PC$$

where π_{ij} is the expected annual net returns ($/head) for the *i*th calving season with calving season length *j*; $p_i^s$is the price of steer calves ($/lb); y_{ij}^s is the weight of the steer calves (lb/head) and is function of calving date CD_{ij}; CR_{ij} is the calving rate $0 \leq CR_{ij} \leq 1$; p_i^h is the price of the heifer calves ($/lb); y_{ij}^h is the weight of heifer calves (lb/head); RR_{it} is the replacement rate of the cow herd $0 \leq RR_{ij} \leq 1$; p_i^c is the price of culled cows ($/lb); y_i^c is the weight of cull cows (lb/head); FC_i is the supplemental or harvested feed costs ($/head) for each calving season; and PC includes all other production expenses ($/head). Following Henry et al. (2016), we assumed only the feed costs would vary by calving season and all other production expenses to be constant across calving season. We also assumed that production expenses do not vary across calving season length, although it is likely that a longer calving season could increase labor expense. Additional labor expense was not a function of calving season length since labor constraints for each farm is different.

Risk

Another important component to consider when selecting an optimal calving season and calving season length is how these decisions can impact the variability of net returns (i.e., risk exposure). Extending the calving season could increase the variability in weaning weights or production risk since a longer calving season length can result in less uniform and smaller calves (Funston et al., 2012; Mousel et al., 2012). On the other hand, the shorter calving season length could result in fewer cows being bred and weaning a calf. Depending on a producer’s risk aversion level, the shorter calving season length could be preferred to longer calving season length, despite the possibility of producing fewer calves.

A producer's decision-making framework to select the optimal calving season and calving season length while considering risk changes from profit maximization to utility maximization, defined as $U\left(\pi_{ij}, r\right)$ where *r* is the producer's risk preference level (Hardaker et al., 2004). A rational, risk averse producer would choose calving season and calving season length that maximizes utility.

Methods

Statistical Analysis

To implement the economic framework, we first estimate calf weaning weight as a function of calving day (Julian day - starting at 1 January of each year) and sex of the calf for spring- and fall-calving herds. A quadratic functional form for calving date was selected based on the pattern of the data. We hypothesize that weaning weights increase to a certain calving date and then begin decreasing. Sex of the calf was an indicator variable that shifts the average weight for steer or heifer calves. Random effects were included for year and sire as well as for the cow being a commercial cow or a registered Angus cow (or herd random effect). These random effects will control for unobserved heterogeneity. The response function was specified as

(2) $y_{itkl} = \beta_{0i} + \beta_{1i}CD_i + \beta_{2i}CD_i^2 + \beta_3 S + v_t + u_k + w_l + \varepsilon_{itkl}$

where y_{itkl} is calf weaning weight (lb/head) for calving season *i* in year *t* from sire *k* and breed *l*; CD_i is Julian day when the calf was born; *S* is an indicator variable for sex (*S* = 1, steer; *S* = 0, heifer); $\beta_0, \ldots, \beta_3$ are coefficients to be estimated; $v_t \sim N(0, \sigma_v^2)$ is the year random effect; $u_k \sim N(0, \sigma_u^2)$ is the sire random effect; $w_l \sim N(0, \sigma_w^2)$ is the random effect for commercial and purebred Angus cattle; and $\varepsilon_{itkl} \sim N(0, \sigma_\varepsilon^2)$ is the random error term. Independence is assumed across all four random components. This equation was estimated using maximum likelihood with

MIXED procedure in SAS 9.4 (SAS Institute 2013). We tested weaning weights for heteroscedasticity with respect to cow age, year, and sex using the Likelihood Ratio test. If heteroscedasticity was present, we report the results for the model that adjusts for the unequal variances.

The calving date that maximizes calf weaning weight (D^*) can be found by taking the first-order conditions of Equation (2) with respect to calving date (*D*) and solved for the D^*, which is expressed as $D_i^* = (-\beta_{1i})/2\beta_{2i}$. Since the cost of production is assumed to not vary by calving season length, the profit-maximizing calving date coincides with the calving date that maximizes weaning weight.

Simulation

Managing a herd for all cows to give birth on the profit-maximizing calving date is not physiologically feasible. In practice, bulls are turned out in the same pasture with the cows and could breed cows any day within the breeding season. Determining the profit-maximizing calving date for each calving season will indicate when producers would prefer to start and end the breeding season so that the producer would have a distribution of calving dates around the profit-maximizing calving date. Because of this uncertainty of calving date, we use Monte Carlo simulation to generate distributions of net returns considering the variability of calving date as well as weaning weights for each calving season.

For each calving herd, we used the profit-maximizing calving date found from Equation (2) to establish starting and ending points of the 30-, 60-, and 90-day calving periods. These calving dates were randomly drawn from a triangle distribution of the 30-, 60-, and 90-day calving period. This distribution was selected to avoid having a calving date outside the calving period and fits the shape of the data (discussed below).

For each calving season length, we assumed different calving and replacement rates. A 75%, 80%, and 85% calving rate was assumed for the 30-, 60-, 90-day calving seasons, respectively. Similarly, a 25%, 20%, and 15% replacement rate was assumed for the 30-, 60-, 90-day calving seasons, respectively. We selected these calving rates based on results from studies that measured calving rate for different breeding seasons (Deutscher, Stotts, and Nielson, 1991; Mousel et al., 2012). We also simulate net returns assuming the producer implements some IRM practice such as ES with TAI in the 30- and 60-day calving periods. In these two scenarios, we assumed this practice increases calving rates for 30- and 60-day calving rates to equal the 90-day calving period (i.e., 85%). We did not associate a higher cost of production with the adoption of the IRM practice since this is specific to labor availability and facilities, nor did we account for the ability to purchase superior genetics through sires when using an IRM practice. Additionally, we did not account for the reduction in sires necessary for natural service breeding when utilizing an IRM practice. However, by taking the difference between the expected net returns for the 30-day with and without the IRM practice, and the difference between the expected net returns for the 60-day with and without the IRM practice, we find the threshold cost of this practice where a producer would return more profit by adopting this practice.

Production risk was also introduced into the model by assuming the weaning weight response function parameters found in Equation (2) were stochastic. The response parameters were drawn from the multivariate normal (MVN) distribution:

$$\begin{bmatrix}\tilde{\beta}_{0i}\\ \vdots \\ \tilde{\beta}_{3i}\end{bmatrix} \sim MVN\left(\begin{bmatrix}\hat{\beta}_{0i}\\ \vdots\\ \hat{\beta}_{3i}\end{bmatrix}, \begin{bmatrix}\hat{\sigma}^2_{\beta_{0i}} & \cdots & \hat{\rho}_{\beta_{0i},\beta_{3i}}\hat{\sigma}_{\beta_{0i}}\hat{\sigma}_{\beta_{3i}}\\ \vdots & \ddots & \vdots\\ \hat{\rho}_{\beta_{3i},\beta_{0i}}\hat{\sigma}_{\beta_{3i}}\hat{\sigma}_{\beta_{0i}} & \cdots & \hat{\sigma}^2_{\beta_{3i}}\end{bmatrix}\right) \tag{3}$$

where the mean of the distribution is the vector of the estimated yield response function coefficients $[\hat{\beta}_{0i}, \ldots, \hat{\beta}_{3i}]$; $\hat{\sigma}^2_{\beta_{0i}}$ are variance estimates of the parameters; and $\hat{\rho}_{ab}\hat{\sigma}_a\hat{\sigma}_b$ are estimated covariances between the parameters. The covariance matrix of parameters is therefore a four-by-four matrix where ρ is the correlation coefficient. The "~" denotes a randomly drawn parameter from the MVN distribution (Cuvaca et al., 2015). Random draws for each parameter are centered on the parameter estimated with the respective variances as dispersion around these means, and covariance with other parameters. This approach has successfully been implemented for crop response functions by Harmon et al. (2017) and Boyer et al. (2018), but this is the first time this approach has been applied to a livestock response function.

Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to conduct the simulations (Richardson et al., 2008). A total of 5,000 net return observations were simulated for all calving seasons and calving season lengths. The expected net returns for each scenario were compared to determine the profit-maximizing calving season and calving season length.

Risk Analysis

For the risk analysis, stochastic dominance was used to compare the cumulative distribution function (CDF) of net returns for all scenarios. For first degree stochastic dominance, the scenario with CDF *F* dominates another scenario with CDF *G* if $F(\pi) \leq G(\pi)\ \forall\ \pi$ (Chavas, 2004). If first degree stochastic dominance does not indicate the dominant calving season and calving season length, second degree stochastic dominance is used to compare these scenarios. Second degree stochastic dominance is defined by the scenario where CDF *F* dominates another scenario with CDF *G* if $\int F(\pi)\, d\pi \leq \int G(\pi)\, d\pi\ \forall\ \pi$ (Chavas, 2004).

If first and second degree stochastic dominance does not find a dominant calving season and calving season length, we used stochastic efficiency with respect to a function (SERF) to rank the calving season and calving season lengths over a range of absolute risk aversion (Hardaker et al., 2004). It requires the specification of a utility function, $U\left(\tilde{\pi}_{ij}, r\right)$, which is a function of the distribution of net returns and absolute risk-preference level r. Specifying a utility function, we can determine the certainty equivalent (CE), which is defined as the guaranteed net return a producer would rather take than taking an uncertain but potentially higher net return. A risk averse producer would be willing to take a lower expected net return with certainty instead of a higher expected net return with uncertainty. A rational, risk averse producer would select the calving season and calving season length with the highest CE at a given risk aversion level.

Taking the difference between CEs of any two calving seasons and calving season lengths gives a utility weighted risk premium. The risk premium is the minimum amount of money a producer would need to receive to switch from the calving season and calving season length with the greatest CE to the alternative calving season and calving season length with the lesser CE.

A negative exponential utility function was used in this analysis, which specifies a constant absolute risk-aversion coefficient (ARAC) to calculate the CE (Pratt, 1964). The ARAC is found by dividing the derivatives of the person's utility function $r_a(r) = -U''(r)/U'(r)$. Following Hardaker et al. (2004), a vector of CEs were derived bounded by a low and high ARAC. The lower bound ARAC was zero, which assumes the producer was risk neutral and a profit-maximizer. The upper bound ARAC was found by dividing four by the average net returns for all the calving seasons and calving season lengths, which indicates extreme aversion to risk. ARAC values in this study ranged from 0.0 for risk neutral to 0.2 for extremely risk averse.

Stochastic dominance and the SERF analysis were also conducted in SIMETAR© (Richardson et al., 2008).

Data

Data originate from spring- and fall-calving herds that are located at the Ames Plantation Research and Education Center, near Grand Junction, Tennessee, spanning from 1990 to 2008. These herds included both commercial and purebred Angus cattle. The commercial cattle were mostly Angus with Hereford and Simmental influence. Bulls and replacement heifers for the purebred Angus herd were developed at Ames Plantation, but bulls were also purchased to maintain the genetic diversity within the herd. Bulls for the commercial cattle were purebred Angus. The spring-calving herd calved from the first of January through mid-April (Figure 1), and the fall-calving herd calved from early-September through mid-November (Figure 2). From the calving distributions, we can determine the breeding season for both herds was approximately 100 days (Figures 1, 2). Cows were not exchanged between the spring- and fall calving herds.

<<< INSERT FIGURE 1 HERE >>>

<<< INSERT FIGURE 2 HERE >>>

Both herds primarily grazed endophyte-infected tall fescue and were supplemented with free choice mineral and corn silage year-round as needed. Cows were culled due to failure to rebreed, poor calf performance (i.e., below average weaning weights), and age. Over the span of these data, the spring herd totaled 478 individual cows with 1,534 individual calves born, and the fall herd totaled 474 individual cows with 1,727 calves born. These cow and calf totals reflect the number of cows and calves that were included in the herd at some point over the 19-year period of the data.

Data consisted of identification number, breed, calving herd, sire, dam, and date of birth. Records were not kept for cows that did not calve; thus, percent calf rate could not be directly calculated. Data for the calves included calf number, date of birth, sex, sire, number of calves the cow has calved, average daily gain, birth weight, and weaning weight. Weaning weights for the spring- and fall-calving herd as a function of calving date are shown in Figure 1 and Figure 2, respectively. Detailed information on the summary statistics for these herds can be found in Campbell et al. (2013) and Henry et al. (2016).

Production costs on a per head basis came from the University of Tennessee Extension Livestock Budgets (University of Tennessee, 2018) and supplemental feed costs for spring- and fall-calving herds were found using Henry et al. (2016). Total variable costs for the spring- and fall-calving herds were $690 and $695 per head, respectively. Monthly Tennessee beef price data for steers, heifers, and culled cows were collected from 2000 to 2017 (USDA Agricultural Marketing Service, 2017). All beef prices were adjusted into 2017 dollar values using the U.S. Bureau of Labor Statistics Consumer Price Index (2017). Calves born in the spring were assumed to be sold at weaning during the months of September, October, and November. The average prices for 500-600 lb steers, 500-600 lb heifers, and culled cows during this timeframe were $1.50, $1.37, and $0.70/lb, respectively. Calves born in the fall were assumed to be sold at weaning during the months of March, April, and May. The average prices for 500-600 lb steers, 500-600 lb heifers, and culled cows during this timeframe were $1.56, $1.43, and $0.73/lb, respectively. Revenue from culled cows was found by multiplied cull cow price by an average cull cow weight of 1,200 pounds.

Results

Weaning Weight Response Function

Table 1 presents the parameter estimates for weaning weight response to calving date for the spring- and fall-calving season. For both calving seasons, the parameter estimate for calving date was positive ($p < 0.001$) and calving date squared was negative ($p < 0.001$). This indicates weaning weights were increasing at a decreasing rate until a specific calving date and then weaning weights began to decrease as calving date increases. The profit and weaning weight maximizing calving date for the spring-calving herd was February 15th, and the profit and weaning weight maximizing calving date for the fall-calving herd was September 11th. Steer calves were found to weigh, on average, 34 lb/head more than heifer calves born in the spring ($p < 0.001$). For fall-born calves, steers were 30 lb/head heavier than heifer calves on average ($p < 0.001$).

<<< INSERT TABLE 1 HERE >>>

Figure 3 shows the estimated response functions for the spring- and fall-calving herds. A spring-born calf would be 16 lb/head lighter at weaning if the calf was born 30 days past the profit-maximizing calving date, and 69 lb/head lighter if the calf was born 60 days past the profit-maximizing calving date. Using the average price for spring-born calves, delaying calving date 30 and 60 days decreased revenue by $21 and $94/head for heifers and $24 and $103/head for steers, respectively. For a fall-born calf, weaning weight was six lb/head lighter if born 30 days after the profit-maximizing calving date, and 54 lb/head lighter if born 60 days after the profit-maximizing calving date. Revenues decreased from delaying calving 30 and 60 days by $10 and $84/head for steers and $9 and $76/head for heifers, respectively. These results show that revenue losses due to delaying calving date were greater for the spring-calving herd than the fall-calving herd.

<<< INSERT FIGURE 3 HERE >>>

Simulation

As mentioned above, the bounds of the 30-, 60-, and 90-day calving periods were determined using the profit-maximizing calving dates. This date was selected to be the mid-point of the 30-day calving period for both calving herds. That is, we subtracted 15 days from the profit-maximizing calving date to set the lower bound and added 15 days to the profit-maximizing calving date to set the upper bound of the calving distribution for the 30-day calving period. The same starting date was used for all calving season lengths in each calving season. This assumes producers target the profit-maximizing calving date for the first estrous cycle for all three calving season lengths. For the spring born calves, the 30-day calving season ran from January 31st to March 1st, the 60-day calving season ran from January 31st to March 31st, and the 90-day calving interval ran from January 31st to April 30th. For the fall born calves, the 30-day calving season ran from August 27th to September 26th, the 60-day calving season ran from August 27th to October 26th, and the 90-day calving interval ran from August 27th to November 25th.

Expected net returns for spring-calving cows were negative for the 30- and 90-day calving season, but were slightly positive for the 60-day calving season (Table 2). The results demonstrate the importance of the tradeoff between increasing calving rate at the expense of selling lighter calves. Expected weaning weights were the heaviest for the 30-day calving season and decreased by five lb/head when going from a 30- to 60-day calving season and 20 lb/head when going from a 30- to 90-day calving season. Going from a 30- to 60-day calving season, a producer would sell more calves that were lighter, but this would be more total beef pounds than the 30-day calving season given the assumption of a 75% calving rate for the 30-day scenario and 80% calving rate for the 60-day scenario. A producer using the 90-day calving season would sell more calves but fewer total pounds of beef because calves were lighter.

<<< INSERT TABLE 2 HERE >>>

Assuming the producer implements some IRM practice to increase calving rate to 85%, the expected net returns increased for both the 30- and 60-day calving season, and expected net returns were the highest with the 30-day calving period. If the cost of implementing this practice was less than $25/head $(21.01-(-4.55))$ in a 30-day calving season length, the producer would maximize expected net returns by adopting this practice. If the cost of the practice for the 60-day calving season was greater than $12/head $(14.29-2.72)$, the producer would be better off not implementing this practice. Producers would be willing to pay more for the IRM practice in the 30-day calving season than 60-day calving season because the marginal benefit received from adopting this practice was less for the 60-day calving season than the 30-day calving season.

For the fall-calving herd, expected net returns were positive for all calving season lengths and highest for the 30-day calving season (Table 2). Expected weaning weights decreased by six lb/head from the 30- to 60-day calving season, and 23 lb/head from the 30- to 90-day calving season, respectively. Despite selling more calves with an extended calving season, the decrease in expected weaning weight resulted in fewer total pounds of beef sold with the longer calving seasons. Adopting an improved reproductive practice to increase calving rate to 85%, increases expected net returns for the 30- and 60-day calving season. A producer would be willing to pay

\$12/head $(68.87 - 56.53)$ to adopt this practice in a 30-day calving season and \$6/head $(61.83 - 56.31)$ to adopt this practice in the 60-day calving interval.

Similar to what Henry et al. (2016) found, the fall-calving season was more profitable than the spring-calving season even though the spring-born calves were heavier on average. Gains from higher cattle prices for fall-born calves were greater than the losses from higher feed expenses and lighter weaning weights. Shortening the calving season length from the 90-day calving period, increased expected net returns more in the fall-calving herd than the spring-calving herd. This indicates that fall-calving producers would gain more from a shorter calving season than spring-calving producers. Overall, fall-calving following a 30-day calving season resulted in the highest expected net returns with and without the use of an IRM practice. However, the variation in the expected net returns was higher in the fall-calving herd, indicating more risk.

Risk Analysis

The distribution of net returns for calving season and calving season length were compared and first- and second-degree stochastic dominance did not exist across the calving seasons and calving season lengths. SERF was used to determine the preferred calving season and calving season length by cow-calf producers across a range of absolute risk aversion levels. Figure 4 shows the utility-weighted risk premiums for each calving season and calving season length. A risk-neutral (ARAC = 0) producer (or profit-maximizer) would prefer the fall-calving herd with the 30-day calving period and IRM practice (Fall 30-day with IRM). An extremely-risk averse producer (AREC = 0.2), however, would prefer a fall-calving herd with the 30-day calving period (Fall 30-day). For spring-calving herds, a risk neutral, profit-maximizer and extremely risk averse producer would prefer the 30-day calving period with the adoption of the IRM practice (Spring-30 day with IRM). If an IRM practice is not adopted, a risk neutral, profit-maximizer would prefer the 60-day calving period (Spring 60-day), but a risk averse producer would prefer the 30-day calving period (Spring 30-day).

<<< INSERT FIGURE 3 HERE >>>

Conclusions

Selecting a calving season and calving season length for cow-calf producers can be a complex decision. Several factors such as nutritional demands for brood cows, calf weaning weight, calving rate, and cattle and feed prices can impact net returns (Bagley et al., 1987; Smith et al., 2012) and risk exposure for producers (Henry et al., 2016). Research has shown that fall-calving herds have higher net returns than spring-calving herds in the Mid-South United States (Bagley et al., 1987; Henry et al., 2016; Smith et al., 2012). However, little knowledge exists on the implication calving season length has on herd profitability for both spring- and fall-calving herds. Thus, this research determined the impacts of calving season length on net returns and variability in net returns for spring- and fall-calving herds in Tennessee.

Data came from a 19-year study in Tennessee of spring- and fall-calving herds. A response function was estimated for calf weaning weight as a function of calving date, and Monte Carlo simulation models were developed that consider production risk for 30, 60, and 90-day calving periods. Two scenarios were developed for 30- and 60-day calving season length that assumed the producer adopted an IRM practice to increase calving rate. These results will be extended to cow-calf producers in the Mid-South to improve profitability through reproductive management.

For both calving seasons, the response function indicated weaning weights were increasing at a decreasing rate until a certain calving date and then weaning weights began to decrease as calving date increased. The profit and weaning weight maximizing calving date for the spring-calving herd was February 15th, and the profit and weaning weight maximizing calving date for the fall-calving herd was September 11th. The results from the simulation demonstrated the importance of the tradeoff between increasing calving rate but having lighter calves. That is, instead of calving rate and weaning weight, a producer might be better off considering the total pounds of beef sold. The fall-calving season was more profitable than the spring-calving season. Shortening the calving season length from the 90-day calving period, increased expected net returns more in the fall-calving herd than the spring-calving herd. This indicates that fall-calving producers could gain more from a shorter calving season than spring-calving producers. We can conclude that a risk-neutral, profit-maximizing producer would select the 30-day fall-calving herd with the use of an IRM practice; however, an extremely-risk averse producer would select a 30-day fall-calving period.

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Table 1. Parameter Estimates for Weaning Weight Response to Calving Date for Spring- and Fall-Calving

Parameter Estimates	Spring- Calving Season	Fall-Calving Season
Intercept (β_0)	464.48**	-786.75
D (β_1)	1.9075***	10.1382***
D^2 (β_2)	-0.0204***	-0.01984***
S (β_3)	34.7643***	29.8307***
Optimal Calving Date (D^*)	February 15th	September 11th

Note: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level. Units are reported in lb/head.

Table 2. Summary Statistics of the Distribution of Net Returns and Weaning Weight by Calving Season and Calving Season Length

		Spring-Calving Season		Fall-Calving Season	
Calving Season Length	Calving Rate	Net Returns ($/head)	Weaning Weight (lb/head)	Net Returns ($/head)	Weaning Weight (lb/head)
30-day[a]	75%	-4.56 (6.445)	525 (6.96)	56.53 (16.07)	522 (16.93)
30-day with Improved Reproductive Management	85%	21.01 (7.953)	525 (6.95)	68.87 (19.63)	522 (16.80)
60-day[b]	80%	2.72 (10.105)	520 (7.21)	56.31 (20.89)	516 (18.23)
60-day with Improved Reproductive Management	85%	14.92 (11.36)	520 (7.19)	61.83 (23.18)	516 (18.32)
90-day[c]	85%	-3.04 (26.002)	504 (10.88)	42.55 (35.41)	499 (21.69)

Standard Deviation in parentheses.

[a] 30-day calving season was January 30th to February 29th for spring born and August 27th to September 26th for fall born calves.

[b] 60-day calving season was January 30th to March 30th for spring born and August 27th to October 26th for fall born calves.

[c] 90-day calving season was January 30th to April 29th for spring born and August 27th to November 26th for fall born calves.

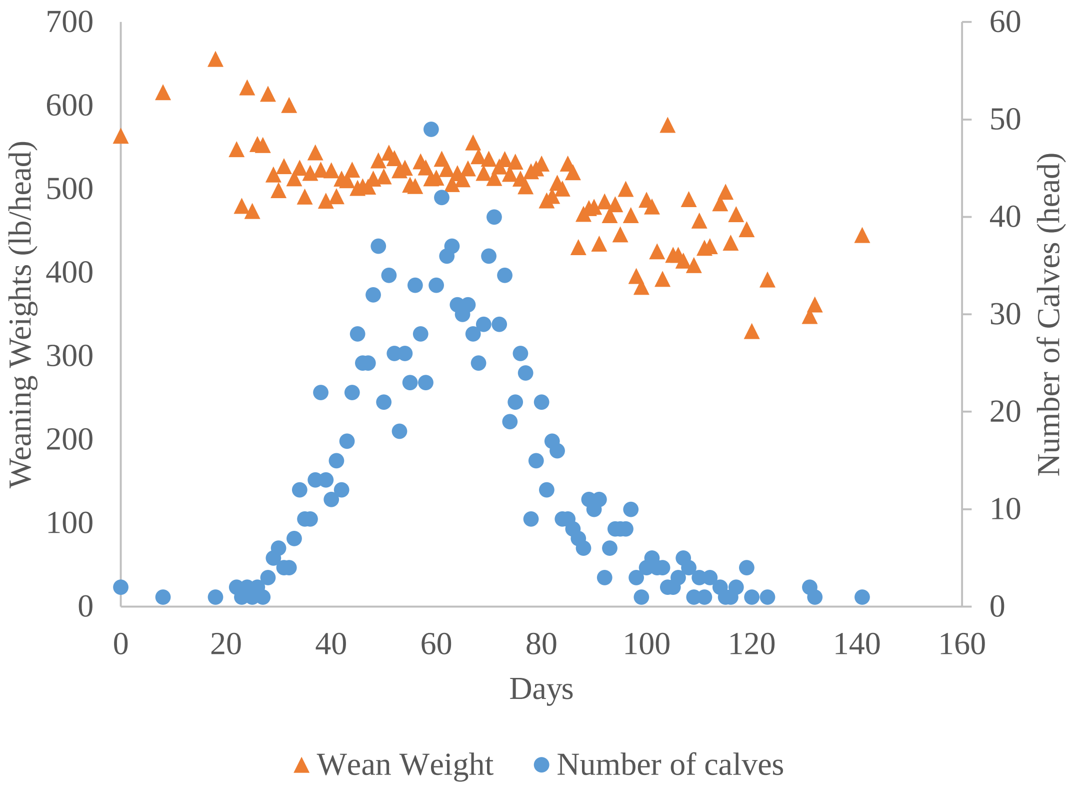

Figure 1. Calving Date and Weaning Weight for Spring born Calves

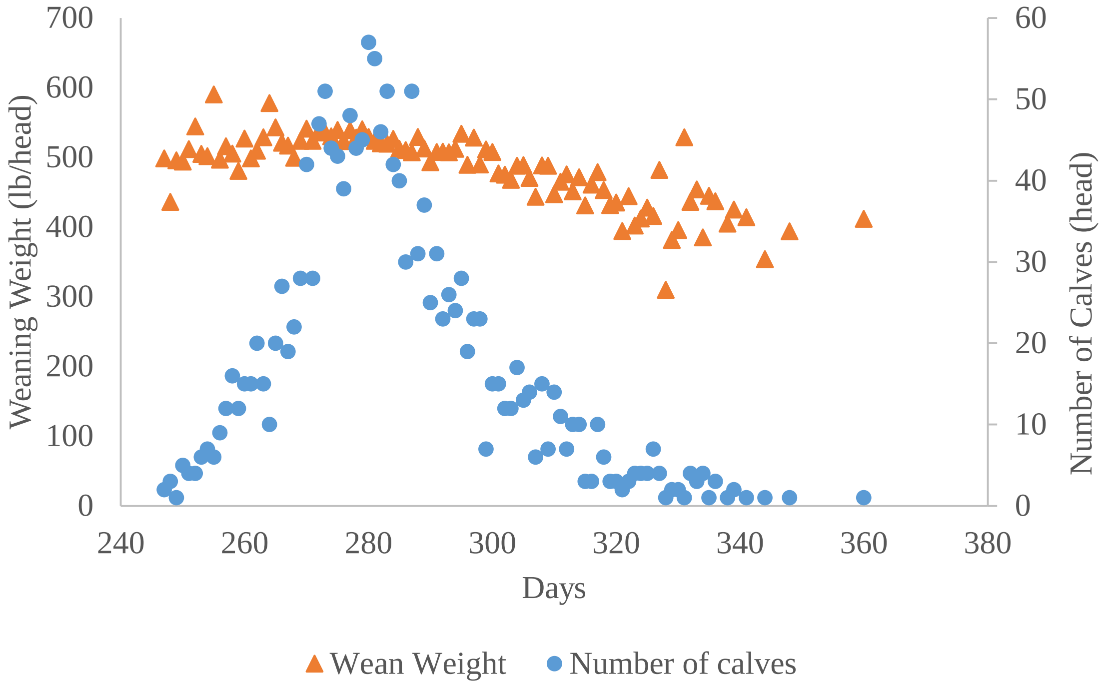

Figure 2. Calving Date and Weaning Weight for Fall born Calves

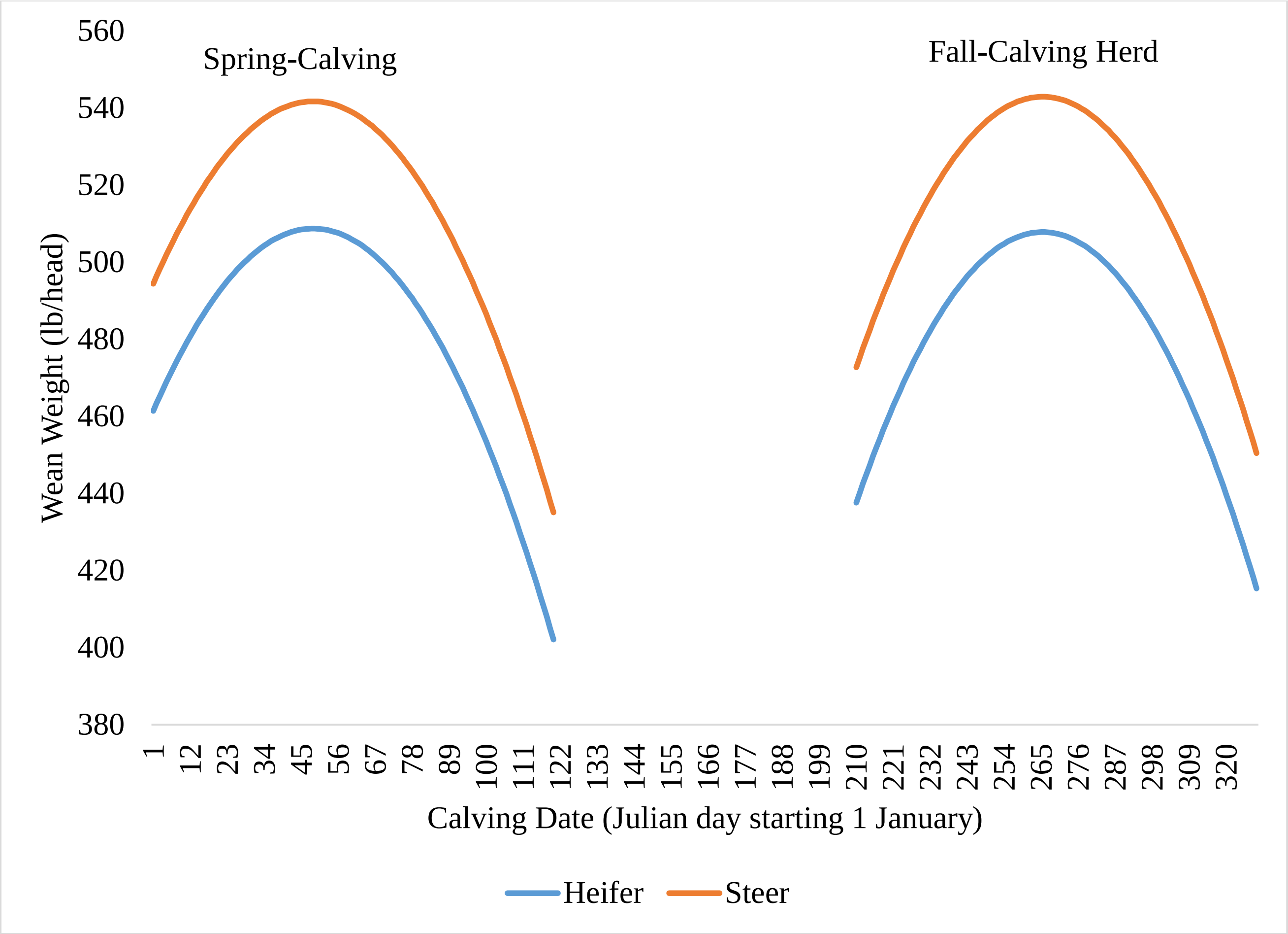

Figure 3. Predicted Weaning Weights for Steer and Heifer Calves using the Parameter Estimates from the Weaning Weight Response Function

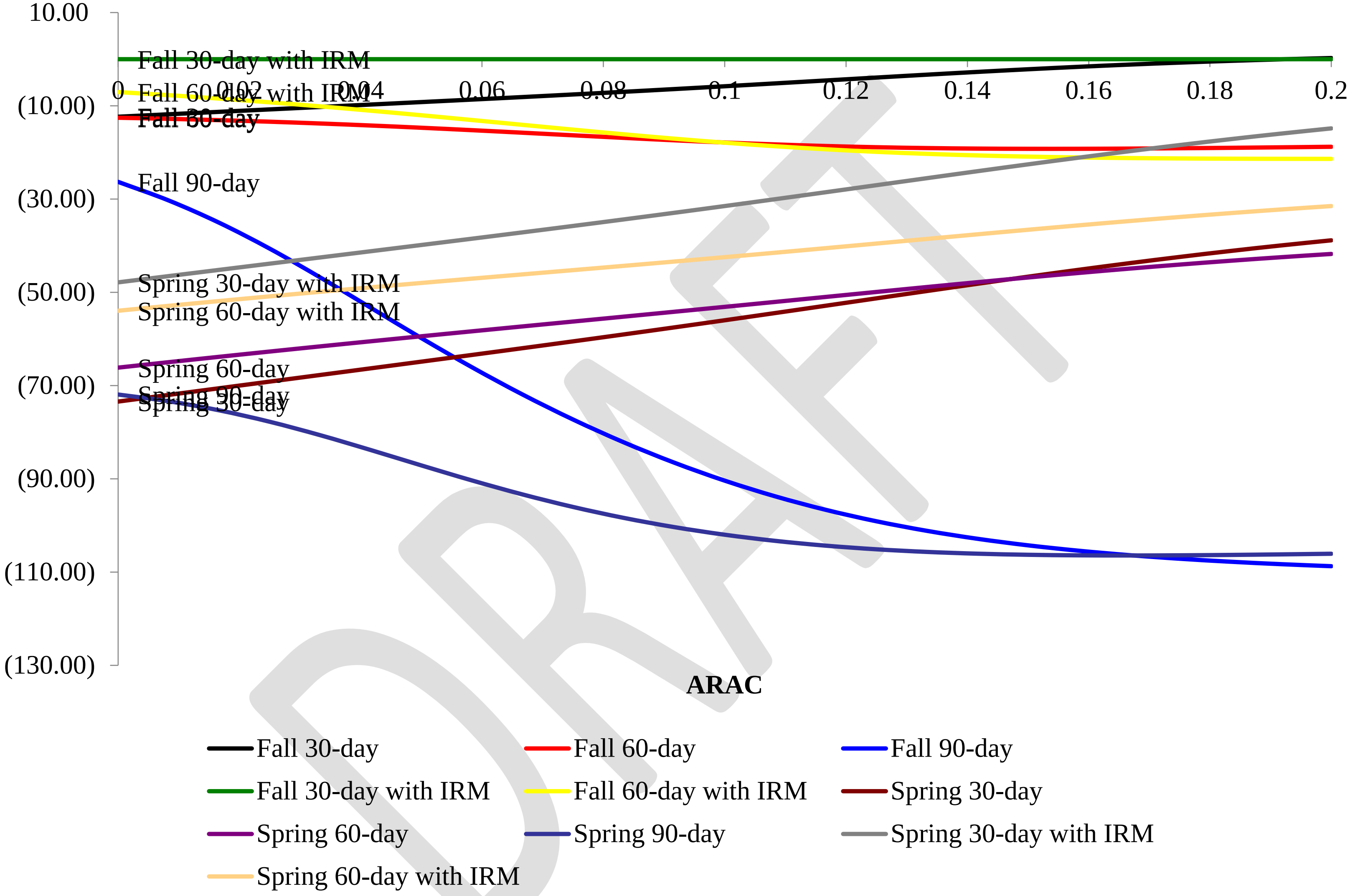

Figure 4. Utility Weighted Risk Premiums for each Calving Season and Calving Season Length