Journal of Applied Farm Economics

Volume 3 | Issue 1 Article 2

2020

Improving Beef Cattle Profitability by Changing Calving Season Length

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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 a 19-year data set and simulation models generated distributions of net returns for 45-, 60-, and 90-day calving periods with and without using hypothetical improved reproductive management (IRM) practices. Shortening the calving period from 90 days increased expected net returns in the spring- and fall-calving herds. The 45-day fall-calving period with IRM maximized profits, but an extremely risk-averse producer would select a 45-day fall-calving period without IRM.

KEYWORDS

beef cattle, profitability, simulation, stochastic dominance

INTRODUCTION

About 33% of all U.S. cow-calf operations have a defined calving season, which is the time of the year when calves are born (U.S. Department of Agriculture, 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, & 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, cattle prices, and feed costs (Bagley et al., 1987; Caldwell et al., 2013; Campbell, Backus, Dixon, Carlisle, & Waller, 2013; Leesburg, Tess, & Griffith, 2007; Smith et al., 2012). Additionally, the calving season has implications on net returns (i.e., profitability) and risk exposure for producers (Henry, Boyer, Griffith, Larson, Smith, & Lewis, 2016). Therefore, a producer has to consider nutritional demands, reproduction, calf performance, and market prices 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 had higher net returns and 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 for spring-born calves, resulting in fall calving being more profitable. Other studies conducted in the U.S. mid-South such as Bagley et al. (1987) and Smith et al. (2012) also found fall calving to be more profitable than spring calving.

Far less knowledge, however, exists on the implication that 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. 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) is 60 days, from mid to late April to mid to late June.

Most cow-calf producers in the United States sell calves at weaning (U.S. Department of Agriculture, 2009). Weaning often occurs when it is convenient for the producer, 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, &

Nielson, 1991; Funston, Musgrove, Meyer, & Langston, 2012; Mousel, Cushman, Perry, & Kill, 2012; Ramsey, Doye, Ward, McGrann, Falconer, & Bevers, 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).

On the other hand, a longer calving season provides more opportunities for cows to breed and wean a calf. For example, if a producer decides to shorten a 60-day breeding season to a 30-day breeding season, cows will most likely have only one estrous cycle (21 days average length) and one opportunity to become pregnant. Cows in a 60-day breeding season would have at least two estrous cycles, increasing the likelihood of pregnancy and weaning a calf (Deutscher et al., 1991; Mousel et al., 2012). Thus, producers could increase weaning weight and calf uniformity by shortening their calving season length but at the risk of decreasing the percentage of cows bred and weaning a calf. This is an important economic tradeoff that producers might need to consider in determining their maximum revenue from the total beef pounds sold from a shorter calving season length.

Reproductive management practices that could be implemented to address these challenges include 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 & Jones, 2008; Lamb & Mercadante, 2016). This practice can shorten the calving season length and produce heavier and more uniform calves while maintaining a pregnancy rate similar to the longer breeding season (Johnson, 2005; Johnson & Jones, 2008; Lamb & Mercadante, 2016). Furthermore, ES with TAI could increase net returns by improving herd genetics relative to natural service breeding (Lamb & 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 & Jones, 2008; Lamb & Mercadante, 2016; Parcell et al., 2011; Rodgers et al., 2012).

These previous studies are insightful, but an analysis is needed to identify a profit-maximizing calving season length for cow-calf producers as well as to determine the calving season length that reduces production risk. These results build on the economic literature of calving season and provide insight into the production 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 impacts the profitability of a herd.

The objective of this research was to determine the effects 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 estimated a response function for calf weaning weight as a function of calving date and determined the profit-maximizing calving date for a spring- and fall-calving herd. Monte Carlo simulation models were used to determine production risk when calving season lengths were 45, 60, and 90 days. We also included two scenarios for 45- and 60-day calving season lengths that assumed that the producer used an IRM practice to increase calving rates. Results will benefit producers by demonstrating the importance of reproductive management on the profitability of the herd.

ECONOMIC MODEL

Net Returns

A risk-neutral, profit-maximizing cow-calf producer would select the ith calving season (i = fall, spring) with calving season length j (j = 45, 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 generated by selling steers, heifers, and culled cows. Revenue also is influenced by cattle price fluctuations through the year and calf weaning age. Production expenses for a cow-calf operation include land, labor, pasture, feed, animal health, trucking costs, 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 due to higher nutritional demand in the winter months (Henry et al., 2016).

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

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

where π_{ij} is the expected annual net returns ($/head) for the *i*th calving season with calving season length *j*, p_i^s is the price of steer calves ($/pound), y_{ij}^s is the weight of the steer calves (pounds/head) and is a function of calving date CD_{ij}, CR_{ij} is the calving rate $0 \le CR_{ij} \le 1$, p_i^b is the price of heifer calves ($/pound), y_{ij}^b is the weight of heifer calves (pounds/head), RR_{it} is the replacement rate of the cow herd $0 \le RR_{ij} \le 1$, p_i^c is the price of culled cows ($per pound), y_i^c is the weight of cull cows (pounds/head), FC_i is the supplemental or harvested feed costs ($/head) for each calving season, and PC includes all other variable production expenses ($/head). Following Henry et al. (2016), we assumed that only the feed costs would vary by calving season and that all other production expenses would 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 smaller and less uniform 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 a 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 $U(\pi_{ij}, r)$ where r is the producer's risk preference level (Hardaker, Richardson, Lien, & Schumann, 2004). 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 risk-averse producer would select the calving season and calving season length with the highest CE at a given risk-aversion level. For our analysis we used a negative exponential utility function, 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 $r_a(r) = -U''(r)/U'(r)$. Hardaker et al. (2004) discusses several advantages to using the negative utility function and recommends that this functional form be used. However, this utility function is not without limitations, as noted by Hardaker, Lien, Anderson, and Huirne (2015).

DATA

Data originated 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 that the breeding season for both herds was about 100 days (see Figures 1 and 2). Cows were not exchanged between the spring and fall calving herds.

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,

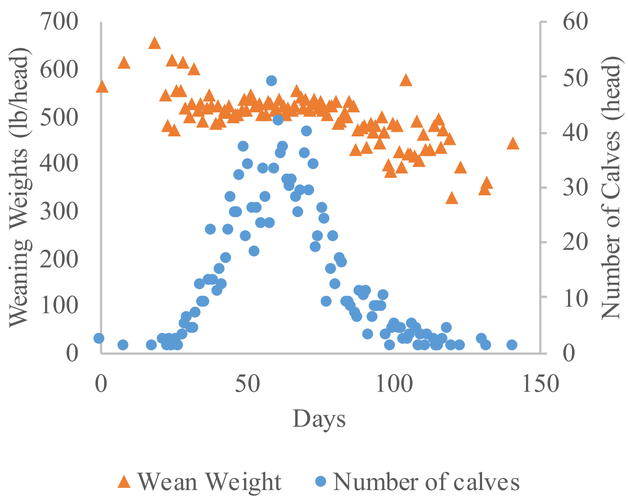

Figure 1. Calving Date and Weaning Weight for Spring-Born Calves

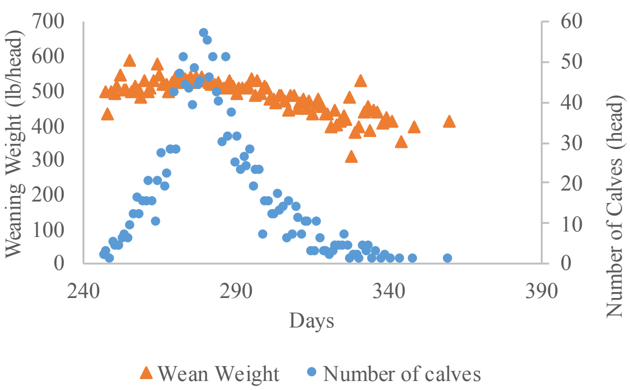

Figure 2. Calving Date and Weaning Weight for Fall-Born Calves

poor calf performance, 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. Therefore, we assumed the calving rates of 75%, 80%, and 85% and replacement rates of 25%, 20%, and 15% for the 45-, 60-, and 90-day calving seasons, respectively (Deutscher et al., 1991; Mousel et al., 2012).

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, 2017). Supplemental feed costs for spring- and fall-calving herds are from 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 (U.S. Department of Agriculture—Agricultural Marketing Service, 2017). All beef prices were adjusted into 2017 dollar values using the U.S. Bureau of Labor Statistics (2017) Consumer Price Index. 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-pound steers, 500–600-pound heifers, and culled cows during this time frame were $1.50, $1.37, and $0.70 per pound, 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-pound steers, 500–600-pound heifers, and culled cows during this time frame were $1.56, $1.43, and $0.73 per pound, respectively. Revenue from culled cows was found by multiplying cull cow price by an average cull cow weight of 1,200 pounds.

METHODS

Statistical Analysis

To implement the economic analysis, we first estimate calf weaning weight as a function of calving day (Julian calendar, starting January 1 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 (see Figures 1 and 2). Earlier-born calves are commonly assumed to have the heaviest weights, but in this data set some of the earliest-born calves had lower weaning weights. Perhaps earlier-born spring calves were negatively impacted by the cold and wet weather. Similarly, the calves born in the early fall calving period may be negatively impacted by extremely hot temperatures and external parasites.

We hypothesize that weaning weights increase to a certain date on the Julian calendar and then begin to decrease given established calving seasons. 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 control for unobserved heterogeneity. The response function was specified as

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

where y_{itkl} is calf weaning weight (pounds/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 the 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. The multiplicative variance equation was specified as cow age as a continuous variable, while year and sex were indicator variables and was defined as

$$E[\varepsilon_i^2] = \sigma_i^2 = \exp\left[\alpha_0 + \alpha_1 A + \alpha_2 S + \sum_{t=1}^{T-1} \alpha_t t\right] \quad (3)$$

where A is cow age. If heteroscedasticity was present, we corrected it using multiplicative heteroscedasticity in the variance equation and report the results for the mean equation parameter estimates adjusted for the unequal variances.

The calving date that maximizes calf weaning weight (CD^*) is found by taking the first-order conditions of Equation (2) with respect to calving date (CD) and solved for the CD^*, which is expressed as $CD_i^* = (-\beta_{1i})/2\beta_{2i}$. 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 as to 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 45-, 60-, and 90-day calving periods. These calving dates were randomly drawn from a triangle distribution of the 45-, 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 45-, 60-, 90-day calving seasons, respectively. Similarly, a 25%, 20%, and 15% replacement rate was assumed for the 45-, 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 et al., 1991; Mousel et al., 2012). We also simulate net returns assuming that the producer implements some IRM practice such as ES with TAI in the 45- and 60-day calving periods. In these two scenarios, we assumed that this practice increases calving rates for 45- 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. These assumptions suggest that the reduction in cost of sires is equal to the cost of TAI. However, by taking the difference between the expected net returns for the 45-day calving season with and without the IRM practice and the difference between the expected net returns for the 60-day calving season 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 that the weaning weight response function parameters found in Equation (2) were stochastic. The response parameters were drawn from the multivariate normal distribution, which is shown in detail in the appendix. This approach has successfully been implemented for crop response functions by Harmon, Boyer, Lambert, and Larson (2017) and Boyer, Lambert, Larson, and Tyler (2018), but this is the first time this approach has been applied to a livestock response function. Prices for culled cows, steers, and heifers were randomly drawn from a multivariate empirical distribution derived using historical Tennessee price data from 2000–2017.

Risk Analysis

Stochastic dominance was used to compare the cumulative distribution function of net returns for all scenarios. If first- and second-degree stochastic dominance does not find a dominant calving season and calving season length, we use 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).

SERF requires the specification of a utility function and can be used to determine the CE. Taking the difference between CEs of any two calving seasons and calving season lengths generates 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. The appendix provides more detail on the first- and second-degree stochastic dominance and SERF.

RESULTS

Weaning Weight Response Function

Table 1 presents the parameter estimates for weaning weight response to calving date for the spring- and fall-calving seasons. Heteroscedasticity was detected in the data; thus, results are estimated using multiplicative heteroscedasticity in the variance equation, correcting for unequal variances. For both calving seasons, the parameter estimate for calving date was positive (p <0.001), and its quadratic term was negative (p <0.001). This indicates that weaning weights were increasing at a decreasing rate until a specific 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 15, and the profit and weaning weight maximizing calving date for the fall-calving herd was September 11. Steer calves were found to weigh on average 35 pounds per head more than heifer calves born in the spring (p < 0.001). For fall-born calves, steers were 30 pounds per head heavier than heifer calves on average (p < 0.001).

A spring-born calf would be 16 pounds per head lighter at weaning if the calf was born 30 days past the profit-maximizing calving date and would be

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
CD (β_1)	1.9075***	10.1382***
CD^2 (β_2)	–0.0204***	–0.01984***
S (β_3)	34.7643***	29.8307***
Optimal Calving Date (CD^*)	February 15	September 11

Note: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% levels, respectively. Units are reported in pounds per head.

69 pounds per 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 per head for heifers and $24 and $103 per head for steers, respectively. For a fall-born calf, weaning weight was 6 pounds per head lighter if born 30 days after the profit-maximizing calving date, and 54 pounds per head lighter if born 60 days after the profit-maximizing calving date. Revenue decreased from delaying the calving 30 and 60 days by $9 and $76 per head for heifers and $10 and $84 per head for steers, respectively. These results suggest that revenue losses due to delaying calving date were greater for the spring-calving herd than the fall-calving herd.

Simulation

The bounds of the 45-, 60-, and 90-day calving periods were determined using the profit-maximizing calving dates. This date was selected to be the midpoint of the 45-day calving period for both calving herds. The same starting date was used for all calving season lengths in each calving season. This assumes that producers target the profit-maximizing calving date for the first estrous cycle for all three calving periods. For the spring-born calves, the 45-day calving season ran from January 31 to March 15, the 60-day calving season ran from January 31 to March 31, and the 90-day calving season ran from January 31 to April 30. For the fall-born calves, the 45-day calving season ran from August 27 to September 26, the 60-day calving season ran from August 27 to October 26, and the 90-day calving season ran from August 27 to November 25.

Expected net returns for spring-calving cows were negative for the 45- and 90-day calving season but were 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 45-day calving season and decreased by 5 pounds per head when going from a 45- to 60-day calving season and 21 pounds per head when extending the calving season from 45 to 90 days. Extending calving from 45 to 60 days, a producer would sell more calves that were lighter, but this would be more total beef pounds than the 45-day calving season, given the assumption of a 75% calving rate for the 45-day scenario and an 80% calving rate for the 60-day scenario. A producer using the 90-day calving season would sell more calves but

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 ($/head)	Weaning Weight (pounds/head)	Net Returns ($/head)	Weaning Weight (pounds/head)
45 days[a]	75%	–5.89 (6.61)	525 (6.96)	56.53 (16.07)	522 (16.93)
45 days with improved reproductive anagement	85%	19.54 (8.30)	525 (6.95)	68.87 (19.63)	522 (16.80)
60 days[b]	80%	2.72 (10.11)	520 (7.21)	56.31 (20.89)	516 (18.23)
60 days with improved reproductive management	85%	14.92 (11.36)	520 (7.19)	61.83 (23.18)	516 (18.32)
90 days[c]	85%	–3.04 (26.00)	504 (10.88)	42.55 (35.41)	499 (21.69)

Standard deviation in parentheses.

[a] 30-day calving season was January 30 to March 15 for spring-born calves and August 27 to October 11 for fall-born calves.

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

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

fewer total pounds of beef because calves would be lighter. One limitation of this study is the lack of consideration of the price slide due to different weaning weights. For example, lighter calves will likely bring a higher price. Since weaning weights only varied by calving date, we assumed that the price slide was insignificant.

Assuming that the producer implements some IRM practice to increase calving rate to 85%, the expected net returns increased for both the 45- and 60-day calving seasons, and expected net returns were the highest with the 45-day calving period. If the cost of implementing this practice was less than \$25 per head (19.54 – (–5.89)) in a 45-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 per head (14.92 – 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 45-day calving season than the 60-day calving season because the marginal benefit received from adopting this practice was less for the 60-day calving season than the 45-day calving season.

For the fall-calving herd, expected net returns were positive for all calving season lengths and highest for the 45-day calving season (see Table 2). Expected weaning weights decreased by 6 pounds per head from the 45- to 60-day calving season and 23 pounds per head from the 45- to 90-day calving season, respectively. Despite more calves being sold 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 45- and 60-day calving seasons. A producer would be willing to pay \$12 per head (to adopt this practice in a 45-day calving season and \$6 per head (in the 60-day calving season.

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 45-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 than the spring-calving herd for all calving season lengths.

Risk Analysis

First- and second-degree stochastic dominance was not evident across the calving seasons and calving season lengths. The SERF analysis was used to determine the preferred calving season and calving season length by cow-calf producers across a range of absolute risk-aversion levels. Figures in the appendix show 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 45-day calving period and IRM practice (Fall 45-day with IRM). An extremely risk-averse producer (AREC = 0.2), however, would prefer a fall-calving herd with the 45-day calving period (Fall 45-day). For spring-calving herds, a risk-neutral profit-maximizing and extremely risk-averse producer would prefer the 45-day calving period with the adoption of the IRM practice (Spring 45-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 45-day calving period (Spring 45-day).

CONCLUSION

Selecting a calving season and calving-season length for cow-calf producers is a complex decision, and little knowledge exists on the implications that calving season length have on herd profitability for both spring- and fall-calving herds. 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 45-, 60-, and 90-day calving periods. Two scenarios were developed for 45- and 60-day calving season lengths 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 that 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 15, and the profit and weaning weight maximizing calving date for the fall-calving herd was September 11.

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 conclude that a risk-neutral profit-maximizing producer would select the 45-day fall-calving herd with the use of an IRM practice. However, an extremely risk-averse producer would select a 45-day fall-calving period. The results demonstrate the importance of the tradeoff between increasing calving rate but having lighter calves.

While a 45-day calving period was found to be economically optimal for spring- and fall-calving herds, a more general conclusion is that producers would be better off with a shorter calving period. This does not mean that producers should try to have an exact 45-day calving period. Shortening the calving period would likely require producers to adopt more intensive reproductive management practices and rigid culling criteria to replace open- and later-calving cows. These are additional costs that producers should consider before shortening their calving period. It might be optimal for some producers to target a 50- or 55-day calving period than a 45-day period.

One limitation of this study is the lack of consideration of the price slide due to different weaning weights. Future research could extend this work by incorporating a price slide as well as premiums for cattle uniformity. Also, exploring impacts of different distributions of calving date and weaning weight function forms could be extensions of this work. Finally, the use of other utility functions from the negative exponential utility function could help improve the results from this study.

ACKNOWLEDGMENTS

We thank the leadership and staff at Ames Plantation in Grand Junction, Tennessee, for field research support. Financial support came from the University of Tennessee AgResearch and USDA National Institute of Food and Agriculture Hatch project TEN00248.

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APPENDIX

Simultion

The response parameters were drawn from the multivariate normal (MVN) distribution

$$(4)\quad \begin{bmatrix} \tilde{\beta}_{0i} \\ \vdots \\ \tilde{\beta}_{3i} \end{bmatrix} \sim MVN\left(\begin{bmatrix} \hat{\beta}_{0i} \\ \vdots \\ \hat{\beta}_{3i} \end{bmatrix}, \begin{bmatrix} \hat{\sigma}^2_{\beta_{0i}} & \cdots & \hat{\rho}_{\beta_{0i},\beta_{3i}}\hat{\sigma}_{\beta_{0i}}\hat{\sigma}_{\beta_{3i}} \\ \vdots & \ddots & \vdots \\ \hat{\rho}_{\beta_{3i},\beta_{0i}}\hat{\sigma}_{\beta_{3i}}\hat{\sigma}_{\beta_{0i}} & \cdots & \hat{\sigma}^2_{\beta_{3i}} \end{bmatrix}\right)$$

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, Lambert, Walker, Marake, & Eash, 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.

Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to conduct the simulations (Richardson, Schumann, & Feldman, 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 first-degree stochastic dominance, the scenario with cumulative distribution function (CDF) F dominates another scenario with CDF G if $F(\pi) \le G(\pi)\, \forall \pi$ (Chavas, 2004). First-degree stochastic dominance assumes that individuals would prefer more wealth to less and have absolute risk aversion. 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 $\int F(\pi)d\pi \le \int G(\pi)d\pi\, \forall \pi$ (Chavas, 2004). Second-degree stochastic dominance assumes that the individuals are not risk preferring.

If first- and second-degree stochastic dominance does not find a dominant calving season and calving season length, we used SERF to rank the calving season and calving season lengths over a range of absolute risk aversion (Hardaker et al., 2004). The SERF analysis requires the specification of a utility function, $U(\tilde{\pi}_{ij}, r)$, which is a function of the distribution of net returns and absolute risk-preference level r. 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). Following Hardaker et al. (2004), a vector of CEs was derived bounded by a low and high ARAC. The lower-bound ARAC was zero, which assumes that 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).

Figures 3 and 4 show the utility-weighted risk premiums for each calving season and calving season length.

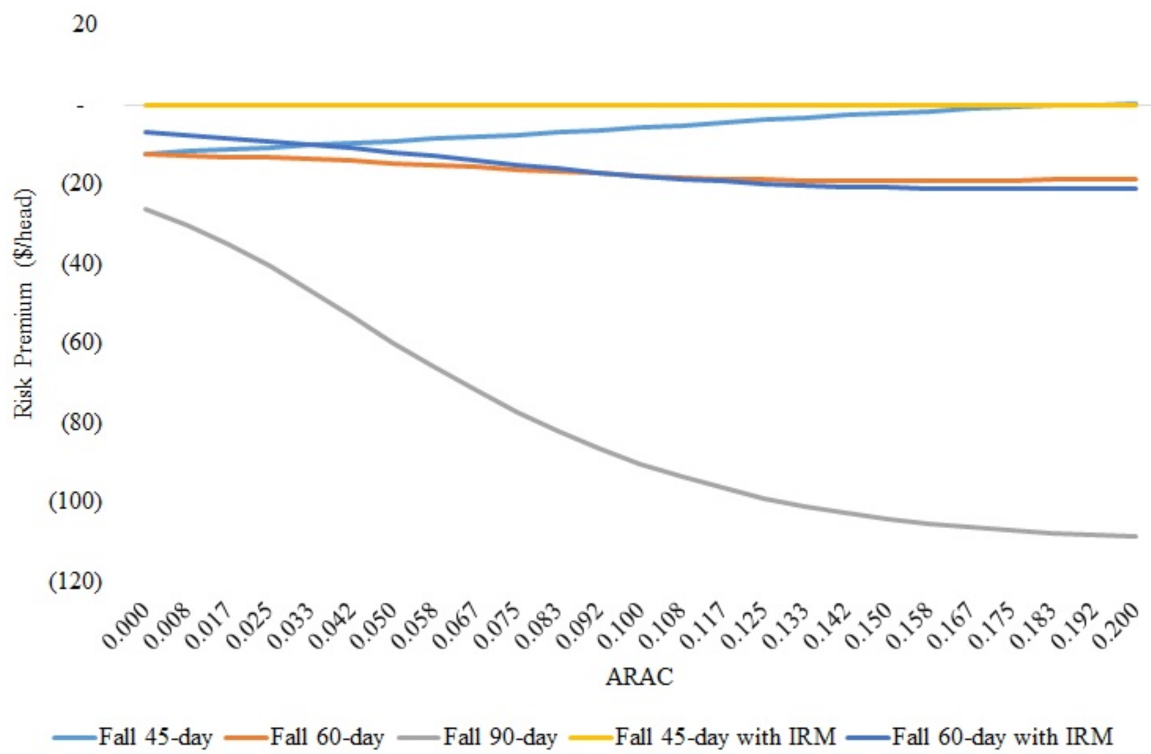

Figure 3. Utility Weighted Risk Premiums for Spring Calving by Calving Season Length

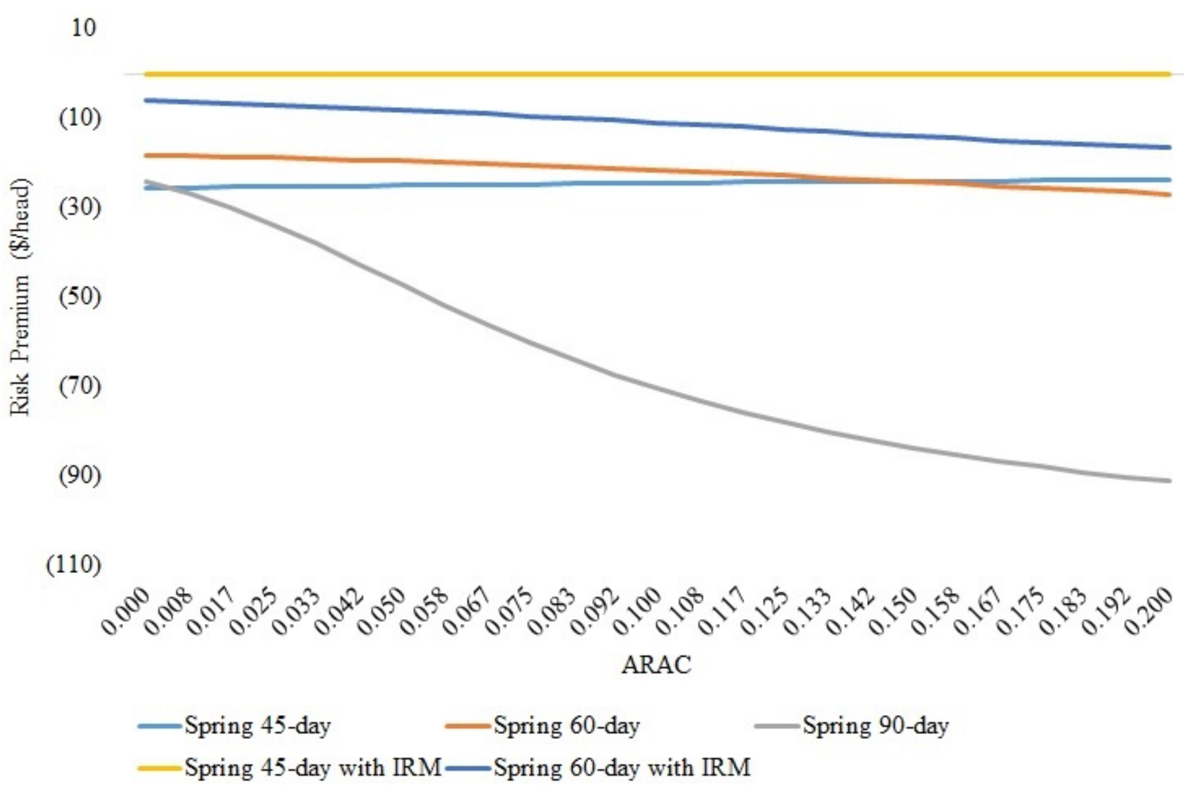

Figure 4. Utility Weighted Risk Premiums for Fall Calving by Calving Season Length