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Replacing Late-Calving Beef Cows to Shorten Calving Season

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We simulated beef cattle producers' returns to shortening a 120-day calving season to 45 and 60 days by replacing late-calving cows for two herd sizes. We developed dynamic simulation models to consider production and price risk. We explored outcomes from annually replacing 10% or 20% of the late-calving cows to reach the desired calving-season length. The optimal scenario depends on herd size and whether the producer wants to maximize profits or certainty equivalent. The smaller herd benefited more from shortening calving season relative to the large herd.

Key words: beef cattle, profitability, simulation, reproduction

Introduction

Failed pregnancy decreases the likelihood of a beef cow or heifer being profitable over her life (Mathews and Short, 2001; Ibendahl, Anderson, and Anderson, 2004; Mackay et al., 2004; Boyer, Griffith, and DeLong, 2020). Many factors can cause failed pregnancy, but retaining females that birth calves late within a defined calving season (days between birth of the first and last calf of an individual herd and/or multiple herds) can increase the likelihood of future failed pregnancy (Johnson, 2005; U.S. Department of Agriculture, 2009; Mousel et al., 2012). Late-calving females have a shorter time period for uterine repair (involution) and overcoming postpartum anestrous before the next breeding season (postpartum interval), reducing the likelihood of the female becoming pregnant during the next breeding season (Johnson, 2005; Mousel et al., 2012). Mousel et al. (2012) used U.S. Department of Agriculture (2009) data to show that heifers that calve within the first 22 days of the defined calving season were more likely to remain in the herd longer (or have increased longevity) than heifers that calved on or after day 23.

Most cow–calf producers in the United States sell calves at weaning (U.S. Department of Agriculture, 2009), and weaning typically happens when time allows, regardless of calf age or weight. Calves born late in the calving season will be younger and weaned at a lighter weight than early-born calves (Deutscher, Stotts, and Nielsen, 1991; Funston et al., 2012; Mousel et al., 2012; Ramsey et al., 2005). Therefore, a longer calving season will result in lighter average weaning weights with more variability. Calves are typically sold in lots grouped on weight ranges and buyers commonly pay higher prices for cattle sold in larger lots (i.e., more uniform) to fill and ship truckloads more efficiency (Dhuyvetter and Schroeder, 2000; Bulut and Lawrence, 2007; Zimmerman et al., 2012; Burdine et al., 2014). Shortening calving season provides an opportunity to capture price premiums from weaning weight uniformity when marketing calves.

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Conversely, a longer calving season provides more opportunities for cows to become pregnant and wean a calf. For example, cows in herds with a 60-day breeding season will have at most three estrous cycle to become pregnant (assuming a 21-day average length and the postpartum resumption of normal estrous cycles at or before the beginning of the breeding season); while cows in herd with a 90-day breeding season will have at least four opportunities to become pregnant (Deutscher, Stotts, and Nielsen, 1991; Mousel et al., 2012). However, providing cows more opportunities for becoming pregnant may not increase the likelihood of producing a calf. A longer breeding season may encourage retention of cows that calve later, which will likely increase the likelihood of reproductive failure in the future as average days postpartum at the beginning of subsequent breeding seasons decreases (Mousel et al., 2012).

Trade-offs exist between shortening the calving-season length to increase weaning weight, calf uniformity, and a longer postpartum interval at the potential risk of decreasing the opportunities for a cow or heifer to become pregnant and wean a calf. Ramsey et al. (2005) reported that a shorter calving season reduced the cost of production for beef cattle operation. Boyer, Griffith, and DeLong (2020) compared the profitability of cow–calf operations with 45-, 60-, and 90-day calving seasons. They found that shortening the calving period from 90 days to either 45 or 60 days increased expected net returns in both spring- and fall-calving herds.

While these studies showed economic benefits from shorting calving season, other important questions remain. As noted, it is difficult to change late-calving cows into early-calving cows given the shortened postpartum interval (Johnson, 2005; Mousel et al., 2012). The most common recommended practice for producers to shorten calving season is to follow a rigid culling program that replaces open and later-calving cows with pregnant heifers that are expected to calve early in the designated season (Johnson, 2005; Johnson and Jones, 2008). Research is needed to explore the short- and long-term impact on a producer's returns and risk for these more aggressive culling programs to shorten calving season. A dynamic model incorporating breeding date and corresponding calving date is needed to evaluate different culling programs to shorten calving season until the desired calving-season length is reached. Moreover, previous studies did not consider variation in prices for calves at various weights (i.e., price slide) and price premiums for larger, more uniform lots.

This study estimates how shortening a 120-day calving season to 45 or 60 days by replacing late-calving cows impacts Southeastern U.S. beef cattle producers' returns and risk. Specifically, we build dynamic simulation models to analyze annually replacing 10% and 20% of the latest calving and nonpregnant (open) cows with heifers that become pregnant in the first 21 days (i.e., first estrous cycle) of the breeding season, until the 120-day calving season has shifted to 45 and 60 days. The annual 10% and 20% replacement rates are in addition to replacement of open cows. These scenarios were simulated for a small herd of 25 head and large herd of 250 head. Revenue was estimated to consider price slide and premiums from selling larger lots of uniform calves. Results will benefit both small and larger cow-calf producers by demonstrating how enhanced reproductive management can potentially improve beef herd profitability and analyzing the optimal replacement rate per year for shortening calving season.

Economic Framework

Revenue

Most cow–calf producers (83%) replace cows with retained heifers from their herd (U.S. Department of Agriculture, 2009). Raising replacement heifers can reduce disease exposure and health risks, make use of genetics that are better acclimated to the environment of the operation, and cost less than purchasing heifers (Schulz and Gunn, 2014). Following these common producer practices, we assume in our model that calving season will be shortened by replacing late-calving cows with early-calving, home-raised heifers. Increasing the replacement rate by selling late-calving cows along with

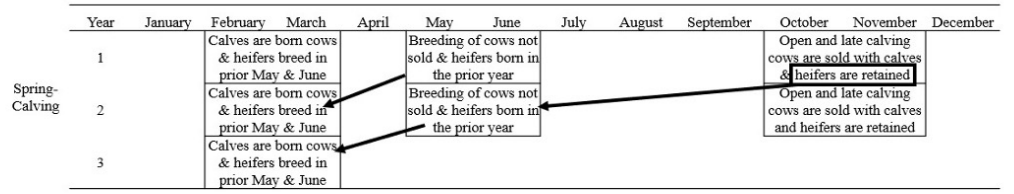

Figure 1. Timeline for Calving, Breeding, and Retaining Heifers for a Spring-Calving Herd

open cows will decrease the number of breeding cattle in the next calving season, and a retained replacement heifer will not produce a calf for two calving seasons post-birth. Figure 1 shows an example for a spring-calving herd. Cows could be bred in May or June and calve in February or March of the next year. These calves will be weaned in October or November. The retained heifers will be bred in the following May or June (year 2) and calve in February or March the year after that (year 3). The lag in replacement heifers calving will result in fewer bred animals and fewer marketed calves the year after late-calving cows are replaced. Considering the dynamic change to the number of head, it would be appropriate to measure profitability of implementing a culling program of late-calving cows over time using net present value (NPV), which is the sum of the discount value of future returns.

Finding the NPV starts with calculating annual net returns. Net returns for a cow–calf producer are found by subtracting expenses from revenue. Revenue is received from selling steers, heifers, and cull cows and depends on cattle price, the percentage of cows that wean a calf (calving rate), the number of cows that will be replaced (replacement rates), and weaning weights of calves and cull cow weight. Production expenses include land, labor, pasture, feed, animal health, trucking, and marketing fees. As noted, average calving date will impact weaning weight and a longer calving season means less weight uniformity (assuming a single weaning date for all calves). Cattle prices vary across weights, with prices for heavier cattle normally being lower per pound than prices for lighter cattle. Price per pound also varies based on the lot size of uniform cattle sold, where the price increases as the number of similar weight cattle per lot increases up to 50,000 total pounds (the regulated weight limit for single truck transportation). Therefore, the producer's annual net returns per lot could be generally defined as

$$(1)\qquad \mathrm{E}\left[\pi_t\right] = \sum_{l=1}^{3} \frac{p^s_{tl}\left(y^s_{tl}\right) y^s_{tl}\left(CD_t\right)\left(\frac{CR}{2}\right) + p^h_{tl}\left(y^h_{tl}\right) y^h_{tl}\left(CD_t\right)\left(\frac{CR}{2}\left(1 - RR_t\right)\right)}{LS_l} + p^c_t y^c_t \left(RR_t\right) - PC,$$

where π_t is the expected annual net returns (\$/head) in period t $(= 1,\ldots,T)$; y^s_{tl} and y^h_{tl} are the average weights of the steer calves and heifer calves, respectively, in lot l (1 = 300–400 lb/head, 2 = 400–500 lb/head, 3 = 500–600 lb/head) and are a function of calving date CD_t; $p^s_{tl}$is the price of steer calves and p^h_{tl} is the price of heifer calves, which are a function of weaning weights of the lot; CR is the calving rate $0 \leq CR \leq 1$, RR_t is the replacement rate of cows, $0 \leq RR_t \leq 1$, LS_l is the number of head in each lot; y^c_t are average weights of cull cows; p^c_{tl} is the price of cull cows; and PC includes all production expenses (\$/head).

The price slide adjustments were made from the base price of 500–600-lb steers and heifers and lot adjustments were added. Therefore, all weaned calves in the lot were sold at the same price. For example, the weight-adjusted steer prices were calculated as

$$(2)\qquad p^s_{tl} = sp^{500-600}_t + \left(\frac{550 - LW_t}{100}\right)\left(sp^{500-600}_t - sp^{400-500}_t\right) + LP_l\left(LS_l\right),$$

where $sp^{500-600}_t$ is the 500–600-lb steer price (\$/lb) at the time of the sale; LW_t is the average calf weight in each lot; $sp^{400-500}_t$ is the 400–500-lb steer price (\$/lb) at the time of the sale; and LP_l is the premium paid based on lot size (\$/lb). Finding the weight-adjusted price for calves in the 300–400-lb lot was found by replacing the 400–500-lb steer price (\$/lb) at the time of the sale ($sp_t^{400-500}$) with the 300–400-lb steer price (\$/lb) at the time of the sale ($sp_t^{300-400}$). This same method was applied to find weight-adjusted heifer prices.

A longer calving season could increase labor expenses, but incorporating these changes would be difficult since labor constraints vary across operations. The revenue generated from heifer sales considers the replacement rate and reduces revenue from heifers retained for development. This would consider the opportunity cost of selling the heifer at weaning (i.e., the cost of forgoing revenue from a heifer to retain her for breeding). When replacement rates increase, the cost of feed needed to develop the heifer to become pregnant will also increase. Cost of production needs to be adjusted to consider additional feed costs with a higher replacement rate. However, all other production expenses were assumed to be constant across calving length. These assumptions can simplify the net returns to a partial budgeting analysis to measure impacts of earlier and shorter calving seasons on producers' net returns above development costs.

Since the herd size changes based on increased replacement rates, we calculated partial returns on the basis of exposed females, defined as the number of cows and heifers exposed to a bull. This would consider the annual change in the number of females available for breeding and would allow for a consistent comparison across the changes in the herd size over time:

$$\text{(3)} \qquad \mathrm{E}[R_t] = \frac{\sum_{l=1}^{3} \frac{p_{tl}^{s}\left(y_{tl}^{s}\right) y_{tl}^{s}(CD_t)\left(\frac{CR}{2}\right) + p_{tl}^{h}\left(y_{tl}^{h}\right) y_{tl}^{h}(CD_t)\left(\frac{CR}{2}(1-RR_t)\right)}{LS_l} + p_t^c y_t^c\,(RR_t) - DC(N_t RR_t)}{N_t},$$

where R_t is the revenue per exposed female; DC is the expected cost of feed to develop the heifer; and N_t is the number of exposed females (head), which includes the exposed females in the previous calving season (N_{t-1}), the number of exposed females sold last year due to being open or late calving ($N_{t-1}RR_{t-1}$), and the number of heifers retained and developed from 2 years ago ($N_{t-2}RR_{t-2}$):

$$\text{(4)} \qquad N_t = N_{t-1}\left(1 - RR_{t-1}\right) + N_{t-2}RR_{t-2}.$$

The risk-neutral profit maximizer's objective function to select the replacement rate that shifts calving distribution to achieve the calving length that maximizes NPV, which is generally expressed as

$$\text{(5)} \qquad \max_{RR}\ E\left[NPV_{RR}\right] = \sum_{t=1}^{T} R_t/(1+\gamma)^t,$$

where NPV_{RR} is the sum of the discounted annual partial net returns per exposed female; γ is the risk-adjusted discount rate; and $T = 30$ demonstrates the long-term value added to the herd from making this shift. By selecting a 30-year time frame, we are estimating the present value of future partial returns on a per cow basis if the producer chooses to start replacing late-calving females today and replaces them over the 30-year time frame with females that become pregnant and calve early in the season.

Risk

Production and price risk are almost always important factors to consider when evaluating changes to farm management practices. Variability in weaning weights due to longer calving seasons could add production risk (Funston et al., 2012; Mousel et al., 2012). Annual price variability or price risk for heifer, steers, and cull cows could impact the risk of making changes to the calving distribution.

If the producer considers these risks, the decision-making framework to select the optimal replacement rate to achieve the optimal calving season changes from profit maximization to utility maximization, defined as $U(NPV_{RR}, r)$, where r is the producer's risk preference level (Hardaker et al., 2004). Specifying a utility function, we can determine the certainty equivalent (CE), which is defined as the guaranteed returns a producer would rather take than taking an uncertain but potentially higher return. A risk-averse producer would be willing to take a lower expected return with certainty instead of a higher expected return with uncertainty. This means a risk-averse producer would select the replacement rate to achieve a calving-season length with the highest CE at a given risk-aversion level.

Methods

First, we developed dynamic stochastic programming models to account for changes in herd size, heifers retained, and females sold. These values vary based on herd size (25 or 250), replacement rate (10% or 20%), and calving-season length (45 or 60 days). Next, we developed simulation models considering production and price risk for the scenarios. These models generate distributions of NPV for each scenario, which are analyzed to determine the optimal scenario for the profit-maximizing producer and the risk-averse producer.

Dynamic Herd Model

We analyzed five combinations of replacement rates and calving-season lengths for each herd size: (i) baseline or no change to 120-day calving, (ii) annual replacement of 10% of late-calving females to reach a 60-day calving season, (iii) annual replacement of 20% of late-calving females to reach a 60-day calving season, (iv) annual replacement of 10% of late-calving females to reach a 45-day calving season, and (v) annual replacement of 20% of late-calving females to reach a 45-day calving season. Late-calving females were identified by the timing they became pregnant during the breeding season. Table 1 shows the percentage of females that became pregnant across possible 21-day estrous cycles and the timeline necessary to achieve the desired calving-season length for each replacement rate. Considering the timing of when female cattle become pregnant is an extension of previous research (Boyer, Griffith, and DeLong, 2020).

The assumed breeding season starts April 25, which starts calving season in mid-February. The 120-day calving season would extend through mid-May which, assuming all cows have overcome postpartum anestrous, results in a maximum of five 21-day estrous cycles during the breeding season. The 60-day calving season would mean calving is finished by the end of March and breeding cattle would have up to three estrous cycles to become pregnant. Finally, the 45-day calving season would move the end of calving to around early March and breeding cattle would have no more than two estrous cycles to become pregnant. For all calving-season lengths, we assumed a base calving rate across all scenarios of 90% calving. While a long breeding season (i.e., longer calving season) provides more opportunities for cows to become pregnant, the literature does not clearly show changes in calving rates based on calving-season length; therefore, we hold calving rate constant. We also assumed a 205-day weaning date that occurs in mid-October.

A 60-day calving season was achieved when 60% of females became pregnant in the first estrous cycle, 20% became pregnant in the second estrous cycle, and 10% became pregnant in the third estrous cycle. All estrous cycles were assumed to be 21 days. A 45-day calving season was achieved with 70% of females becoming pregnant in the first estrous cycle and 20% become pregnant in the second estrous cycle. Table 1 shows the annual replacement rate required to achieve the target calving-season length. By increasing replacement beyond the baseline rate of 10%, which is shown in the baseline scenario, it would take 4 years to reach a 60-day calving and additional fifth year to grow the number of females to the original herd size. The additional year would be the year in which heifers retained from year 4 would calve. With an additional replacement rate of 20% to achieve a 60-day calving season, the first year the replacement rate for late-calving cows was increased 20% but was increased only 10% in year 2. The desired calving distribution is achieved and herd size restored a year sooner than if replacement were increased 10%.

Table 1. Percentage of Pregnant Females by Estrous Cycle and Annual Replacement Rate of Late-Calving and Open Females to Reach 45- and 60-Day Calving Seasons for Each Scenario

	21-Day Estrous Cycle					Replacement
Time	**1st**	**2nd**	**3rd**	**4th**	**5th**	**Rate**
Baseline						
Year 1	30%	20%	20%	10%	10%	10%
10% to 45-day						
Year 1	30%	20%	20%	10%	10%	20%
Year 2	40%	20%	20%	10%	–	20%
Year 3	50%	20%	20%	–	–	20%
Year 4	60%	20%	10%	–	–	20%
Year 5	70%	20%	–	–	–	10%
Year 6	70%	20%	–	–	–	10%
20% to 45-day						
Year 1	30%	20%	20%	10%	10%	30%
Year 2	50%	20%	20%	–	–	30%
Year 3	70%	20%	–	–	–	10%
Year 4	70%	20%	–	–	–	10%
10% to 60-day						
Year 1	30%	20%	20%	10%	10%	20%
Year 2	40%	20%	20%	10%	–	20%
Year 3	50%	20%	20%	–	–	20%
Year 4	60%	20%	10%	–	–	10%
Year 5	60%	20%	10%	–	–	10%
20% to 60-day						
Year 1	30%	20%	20%	10%	10%	30%
Year 2	50%	20%	20%	–	–	20%
Year 3	60%	20%	10%	–	–	10%
Year 4	60%	20%	10%	–	–	10%

Simulation

We developed a simulation model that incorporates production and price variability and generates distributed NPV values for each scenario. Production risk was introduced into the model in two ways. First, we used parameters for a weaning weight response function to calving date for spring-calving cows found in Boyer, Griffith, and DeLong (2020). They used a quadratic functional form for calving date and included random effects that control for unobserved heterogeneity for year and sire. The response parameters in Boyer, Griffith, and Pohler were drawn from the multivariate normal distribution and was incorporated production risk as a function of calving date. These were incorporated in equation (1). 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 type of function has been used in other livestock production functions (Boyer, Griffith, and DeLong, 2020).

Second, calving dates were randomly drawn from a PERT distribution for each 21-day estrous cycle. Within each estrous cycle data, the PERT distribution randomly draws a calving date that is bound between day 1 and day 21, with a central value at day 16 of each estrous cycle. Table 2 shows the dates assumed by estrous cycle to generate a random calving date.

Table 2. Dates for Each 21-day Estrous Cycle Used in the PERT Distribution to Generate Random Calving Date

Estrous Cycle	Day 1	Day 16	Day 21
1	April 25	May 11	May 16
2	May 17	June 1	June 7
3	June 8	June 23	June 29
4	June 30	July 15	July 21
5	July 22	August 8	August 12

These randomly generated weaning weights were sorted into three lots based on weight: 300–400, 400–500, and 500–600 pounds per head. Several studies have estimated price premiums from lot sizes (Dhuyvetter and Schroeder, 2000; Bulut and Lawrence, 2007; Zimmerman et al., 2012; Burdine et al., 2014). We value calf uniformity or lot size by following results from Burdine et al. (2014), who estimated the impact of lot size on cattle prices while controlling for other factors such as cattle breed, sex, corn prices, weight, and futures prices. They followed the approach in Zimmerman et al. (2012) of taking the natural log of the lot size and lot size squared and found increasing lot size resulted in higher price, but at a decreasing rate and with a terminal point of diminishing returns. We selected parameters from Burdine et al. (2014) because these data were from a southeastern market and the recent time frame of the study. Price premiums based on lot size were defined as

$$(6) \qquad \widetilde{LP_l} = 8.27 \ln\left(\widetilde{LS_l}\right) - 0.791 \ln\left(\widetilde{LS_l^2}\right).$$

Price variability was considered in the model by randomly drawing steer and heifer prices for each weight class as well as for cull cow prices from a multivariate empirical distribution. Equation (2) can be rewritten as

$$(7) \qquad \widetilde{p_{tl}^{s}} = \widetilde{sp}_t^{500-600} + \left(\frac{550 - LW_t}{100}\right)\left(\widetilde{sp}_t^{500-600} - \widetilde{sp}_t^{400-500}\right) + \widetilde{LP_l}.$$

The data section discusses the range and summary statistics of the price data used.

These equations were used to simulate the expected NPV over a 30-year period. Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to conduct the simulations (Richardson, Schumann, and Feldman, 2008). A total of 1,000 annual revenue observations were simulated for all scenarios.

Economic and Risk Analysis

The expected returns for each scenario were compared to determine the replacement rate that achieved the profit-maximizing calving-season length. A risk-neutral profit maximizer would select the scenario with the highest NPV. When risk is considered, 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 $F(NPV) \leq G(NPV)\ \forall\ NPV$ (Chavas, 2004). If first-degree stochastic dominance does not indicate the dominant scenario, second-degree stochastic dominance is used. Second-degree stochastic dominance is defined by the scenario in which CDF F dominates another scenario with CDF G if $\int F(NPV)\,dNPV \leq \int G(NPV)\,dNPV\ \forall\ NPV$ (Chavas, 2004).

If first- and second-degree stochastic dominance did not identify a dominant scenario, we used stochastic efficiency with respect to a function (SERF) to rank the scenarios over a range of absolute risk aversion (Hardaker et al., 2004), which requires the specification of a utility function, $U(NPV_{RR}, r)$. 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

Table 3. Summary Statistics of September, October, and November Steer, Heifer, and Cull Cow Prices for Tennessee, 2000–2018

Variable	Average	Standard Deviation	Minimum	Maximum
300–400 steer price	1.7	0.46	1.25	3.21
400–500 steer price	1.55	0.41	1.15	2.86
500–600 steer price	1.43	0.36	1.05	2.56
300–400 heifer price	1.46	0.40	1.05	2.74
400–500 heifer price	1.36	0.37	0.97	2.53
500–600 heifer price	1.28	0.34	0.93	2.34
Cull cow price	0.62	0.17	0.44	1.12

ARAC is defined as, $r_a(r) = -U''(r)/U'(r)$. Following Hardaker et al. (2004), a vector of CEs was derived, bounded by a low and a high ARAC. The lower-bound ARAC was 0, which assumes the producer was risk neutral and a profit maximizer. The upper-bound ARAC was found by dividing 4 by the expected NPV for all scenario, which indicates extreme aversion to risk. ARAC values in this study ranged from 0.0 for risk neutral to 0.0003 for extremely risk averse. Stochastic dominance and the SERF analysis were also conducted in SIMETAR© (Richardson, Schumann, and Feldman, 2008).

Taking the difference between the CEs of any two scenarios 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 scenario with the greatest CE to the alternative scenario with the lesser CE. Risk analysis results are discussed in terms of risk premiums.

Data

Boyer, Griffith, and DeLong (2020) used data spanning from 1990 to 2008 from a spring-calving herd located at the Ames Plantation Research and Education Center near Grand Junction, Tennessee, to estimate calf-weaning weight as a function of calving date and calf sex. These data have also been used by Henry et al. (2016) to compare spring- and fall-calving herds. More information about the management of these herds can be found in those papers.

For the NPV simulation model, monthly Tennessee beef price data for steers, heifers, and cull cows were collected from 2000 to 2018 for the simulation (U.S. Department of Agriculture, 2017). All beef prices were adjusted into 2018 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 400–500-lb and 500–600-lb steers and heifers were collected along with cull cow prices. Table 3 reports the average of these prices over this period. Cull cow revenue was found by multiplying cull cow price by an average cull cow weight of 1,400 lb. The discount rate (γ) was assumed to be 5.5%.

Results

Simulation

Table 4 shows the expected annual partial returns per exposed female for all scenarios. These results demonstrate how a producer's expected short-term partial returns change as late-calving cows are replaced with early-calving heifers. For the 25-head herd, the annual partial returns for the baseline scenario of 120-day calving season was $622 per exposed female. When the producer chose to annually replace 10% of the late-calving females to achieve a 60-day calving season, expected partial returns decreased in the first 2 years due to selling more breeding cattle and selling fewer heifer calves, but by year 3, the calving distribution had shifted to produce more earlier born, heavier calves, resulting in a higher partial return per exposed female. By year 5, the expected partial return

Table 4. Summary Statistics of Expected Annual Partial Returns ($/exposed female) for Each Scenario

Year	Baseline	10% to 45-day[a]	20% to 45-day[a]	10% to 60-day[a]	20% to 60-day[a]
25-head herd					
Year 1	622.57	592.66	521.39	589.88	570.38
Year 2	–	575.55	637.00	580.51	640.81
Year 3	–	586.13	648.28	642.17	645.89
Year 4	–	641.15	648.28	647.26	645.89
Year 5	–	646.36	–	647.26	–
Year 6	–	646.36	–	–	–
250-head herd					
Year 1	650.95	620.76	542.36	617.92	595.75
Year 2	–	593.61	662.18	599.13	663.06
Year 3	–	602.91	662.45	663.21	662.68
Year 4	–	658.80	661.47	664.39	662.20
Year 5	–	659.90	–	663.91	–
Year 6	–	659.90	–	–	–

Notes: [a] Indicates replacing 10% of late-calving females to a 45-day calving season.
[b] Indicates replacing 20% of late-calving females to a 45-day calving season.
[c] Indicates replacing 10% of late-calving females to a 60-day calving season.
[d] Indicates replacing 20% of late-calving females to a 60-day calving season.

Table 5. Summary Statistics of the Distribution of Expected Net Present Value for Each Scenario

	Expected Net Present Value ($/exposed female)		Expected Weaning
Scenario	25-Head Herd	250-Head Herd	Weight (lb/Head)
Baseline	12,202	12,759	492
	(2,713)	(2,720)	(7.49)
10% to 45-day[a]	12,438	12,739	523
	(3,186)	(3,207)	(6.29)
20% to 45-day[b]	12,479	12,765	524
	(3,129)	(3,149)	(6.74)
10% to 60-day[c]	12,505	12,856	519
	(2,939)	(2,945)	(6.46)
20% to 60-day[d]	12,491	12,831	520
	(2,914)	(2,919)	(6.64)

Notes: Numbers in parentheses are standard deviations.
[a] Indicates replacing 10% of late-calving females to a 45-day calving season.
[b] Indicates replacing 20% of late-calving females to a 45-day calving season.
[c] Indicates replacing 10% of late-calving females to a 60-day calving season.
[d] Indicates replacing 20% of late-calving females to a 60-day calving season.

was $24 per exposed female higher than the baseline scenario. The same pattern of results was found for the other scenarios in which late-calving females were replaced. When the 20% annual replacement rate was used, expected partial returns decreased more in the first year but increased at a faster rate. Replacing 20% of the late-calving females to achieve a 45-day calving season produced the highest expected annual return per exposed female for the 25-head herd.

The larger herd size (250 head) had a similar pattern of results. The larger herd had a higher expected partial return per exposed cow than the smaller herd. This is due to the larger herd receiving higher prices due to selling larger lot sizes. The scenario of annually replacing 10% of the late-calving females to reach a 60-day calving season had the highest partial returns per exposed female. However, the returns increased by $13 per exposed female, to $664 from the baseline scenario. This gain in returns was not as much as the small herd, showing that the small beef cattle operation in this study had more to gain from shortening calving-season length than the larger beef cattle operation.

Table 5 reports summary statistics of generated NPV of partial returns for each scenario, which is the present value of future returns per exposed female over the next 30 years. That is, if a producer starts shifting their calving season today following the scenarios in this study, these results show how much more partial returns per exposed cow will be generated over the next 30 years. These results show that producers would increase average weaning weights and returns by shortening their calving-season length, which is similar to the findings of previous studies (Ramsey et al., 2005; Boyer, Griffith, and DeLong, 2020).

For both herd sizes, the highest expected NPV was found when 10% of the late-calving females were replaced to reach a 60-day calving season. This scenario earned an average of $303 per exposed female for the small herd and $97 per exposed female for the large herd over a 30-year life relative to the baseline scenario. Similar to the annual partial returns results, the small herd size saw a larger increase in NPV than the 250-head herd.

We took the difference in the NPV for each scenario in which late-calving females were replaced and the baseline scenario to simulate the probability of NPV from shorter calving season being greater than the baseline scenario. Figures 2 and 3 show the stoplight graph of the probability of NPV from shorter calving season being greater than the baseline scenario for the small herd and the large herd, respectively. We report an 83% and 84% chance of NPV being greater than baseline when 10% and 20% of late-calving females were replaced to reach a 45-calving season, respectively. The NPV was 73% and 65% more likely to be higher than the baseline for a 60-day calving season when 10% and 20% of late-calving cows were replaced, respectively. Conversely, for the large herd, a 45-day calving season was less likely than the 60-day calving season to result in higher NPV relative to the baseline. NPV was 57% and 58% more likely to be higher than the baseline for a 60-day calving season when 10% and 20% of late-calving females were replaced, respectively. For the 45-day calving season, we found a 70% and 61% chance of NPV being greater than baseline when 10% and 20% of late-calving females were replaced, respectively. Overall, the probability of NPV being greater for the shorter calving season was lower for the large herd than the small herd. This further demonstrates that small beef cattle producers would receive greater benefits than larger producers from shortening calving season.

Economic and Risk Analysis

First- and second-degree stochastic dominance showed no dominant scenario. SERF was used to determine the preferred scenario across risk aversion levels. Figures 4 and 5 show the utility-weighted risk premiums for each scenario for the small herd and the large herd, respectively. A risk-neutral (ARAC = 0) producer (or profit maximizer) would prefer to replace 10% of late-calving females annually to reach a 60-day calving season for both herd sizes. An extremely risk-averse producer (ARAC = 0.0003), however, would prefer to replace 20% of late-calving females annually to reach a 60-day calving season for the small herd, and an extremely risk-averse producer of the large herd would prefer the baseline scenario of a 120-day calving season. The large-herd producer would shift preferences to the baseline scenario of 120-days (ARAC = 0.000138) before the small herd producer would shift to the replacing 20% of late-calving females (ARAC = 0.00019). This means the large-herd producer would not have to be as risk averse as the small-herd producer before switching their preferred scenarios. Also, the risk premium for the small herd to switch is much less ($8.26 per exposed female when ARAC = 0.0003) than the risk premium for the large herd to switch ($206 per exposed female when ARAC = 0.0003). A possible explanation is that larger producers introduce more variability in their operation making these changes, which a risk-averse producer would like to avoid.

The risk analysis indicates that large herd producers in this paper would prefer the longer calving season. This could explain why some producers are reluctant to shorten their calving season. This

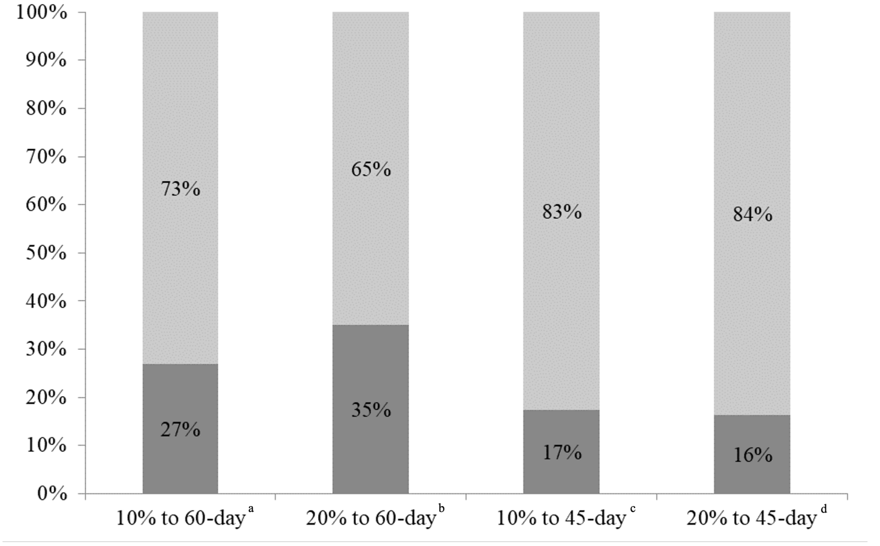

Figure 2. Probability of Net Present Values from Calving Season Scenarios

Notes: Probability of net present value from a shorter calving season is greater than NPV of the baseline scenario (shown in lightest gray) and less than the NPV of the baseline scenario (shown in darkest gray) for the 25-head herd.
[a] 10% to 45-day = replace 10% of late-calving females to a 45-day calving season.
[b] 20% to 45-day = replace 20% of late-calving females to a 45-day calving season.
[c] 10% to 60-day = replace 10% of late-calving females to a 60-day calving season.
[d] 20% to 60-day = replace 20% of late-calving females to a 60-day calving season.

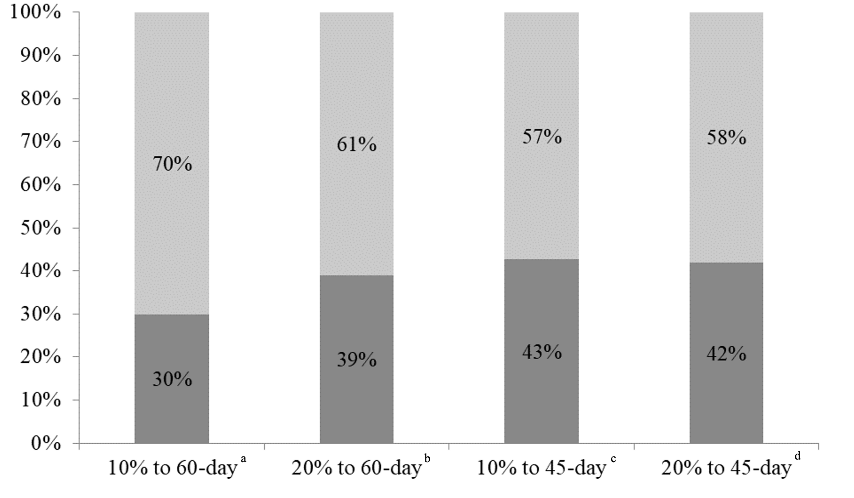

Figure 3. Probability of Net Present Value from a Shorter Calving Season

Notes: Probability of net present value from a shorter calving season is greater than NPV of the baseline scenario (shown in lightest gray) and less than the NPV of the baseline scenario (shown in darkest gray) for the 250-head herd.
[a] 10% to 45-day = replace 10% of late-calving females to a 45-day calving season.
[b] 20% to 45-day = replace 20% of late-calving females to a 45-day calving season.
[c] 10% to 60-day = replace 10% of late-calving females to a 60-day calving season.
[d] 20% to 60-day = replace 20% of late-calving females to a 60-day calving season.

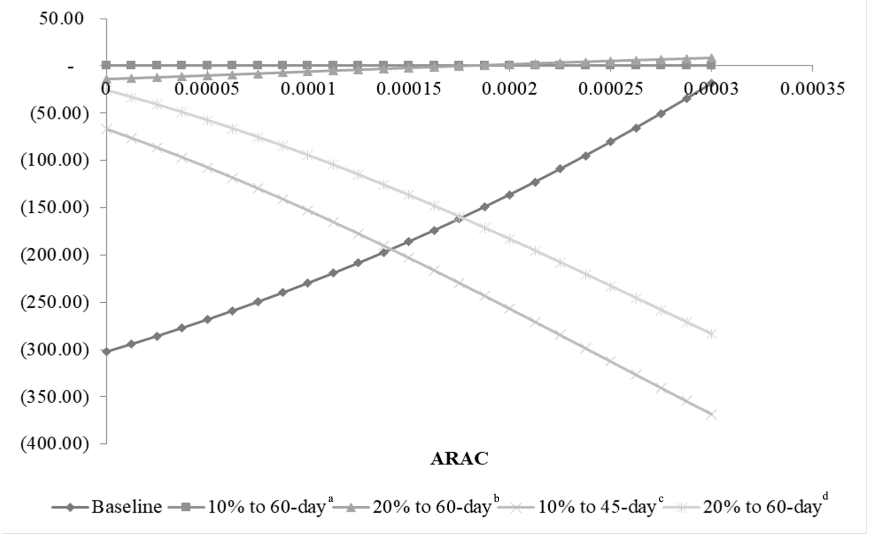

Figure 4. Utility-Weighted Risk Premiums for the 25-Head Herd by Scenario

Notes: [a] 10% to 45-day = replace 10% of late-calving females to a 45-day calving season.
[b] 20% to 45-day = replace 20% of late-calving females to a 45-day calving season.
[c] 10% to 60-day = replace 10% of late-calving females to a 60-day calving season.
[d] 20% to 60-day = replace 20% of late-calving females to a 60-day calving season.

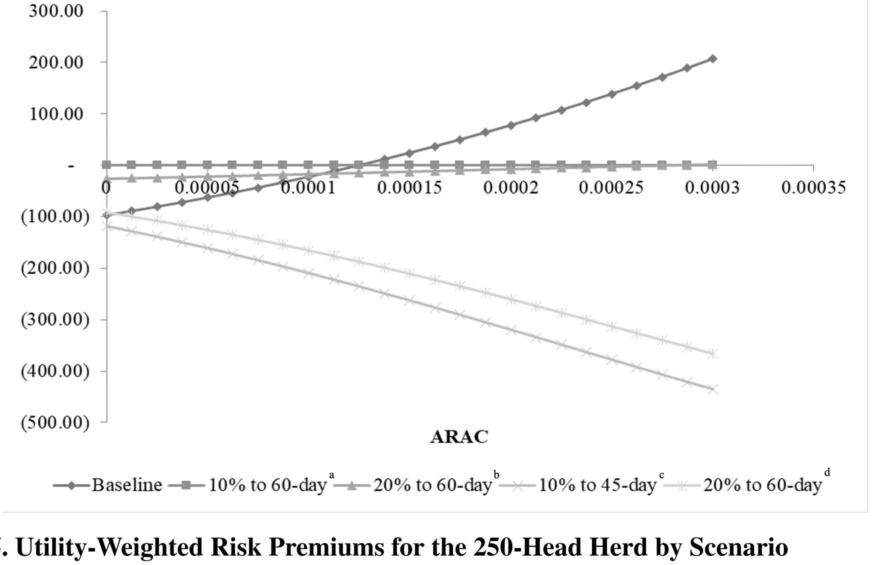

Figure 5. Utility-Weighted Risk Premiums for the 250-Head Herd by Scenario

Notes: [a] 10% to 45-day = replace 10% of late-calving females to a 45-day calving season.
[b] 20% to 45-day = replace 20% of late-calving females to a 45-day calving season.
[c] 10% to 60-day = replace 10% of late-calving females to a 60-day calving season.
[d] 20% to 60-day = replace 20% of late-calving females to a 60-day calving season.

type of finding is helpful in developing impactful Extension education programs. While shorter calving season are shown to have many benefits (Ramsey et al., 2005; Boyer, Griffith, and DeLong, 2020), these benefits might not apply to all types of producers, which is helpful to remember when making recommendations.

Conclusions

This study estimated how shortening a 120-day calving season to 45 or 60 days by replacing late-calving cows impacts Southeastern U.S. beef cattle producers' returns and risk. We construct dynamic simulation models to analyze replacing 10% and 20% of the latest calving cows with heifers that become pregnant in the first 21 days (i.e., the first estrous cycle) of the breeding season until the 120-day calving season has shifted to 45 or 60 days. These scenarios were simulated for a small herd of 25 head and large herd of 250 head. We extend previous work by considering the timing of when brood cattle become pregnant and subsequently calve, and we consider price variation based on weights (i.e., price slide) and price premiums for cattle uniformity. Results will benefit both small and larger cattle producers by demonstrating the importance of reproductive management and provide insight on the optimal replacement rate for shortening calving season.

Profit-maximizing producers of both small and large herds would choose to replace 10% of their late-calving cows to move from a 120- to a 60-day calving season. However, the small producer would receive a larger return than the large producer from shifting the calving season. This is likely because smaller producers see a larger price increase from premiums paid for larger lots of cattle. An extremely risk-averse producer with a 25-head herd would prefer a 60-day calving season but would choose to annually replace 20% of their late-calving cows to reach this calving date. The larger producer who is extremely risk averse was found to prefer the baseline scenario of 120-day calving season. An interesting conclusion is that shorter calving seasons are shown to be more profitable, but the large-herd producer would prefer the baseline scenario of 120-days when considering risk. This is a key finding for understanding why many producers may not want to shorten their calving season. These results are useful for Extension educators to demonstrate how calving-season length impacts profitability and risk to beef cattle producers.

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