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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 a 45- and 60-day calving season by replacing late calving cows for two herd sizes. Dynamic simulation models were developed 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 to shifting calving season length depends on herd size and whether the producer wants to maximize profits or certainty equivalent. The smaller herd benefited more from shortening calving season as compared 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 the U.S. Department of Agriculture (2009) data to show heifers that calve within the first 22 days of the defined calving season were more likely to remain in the herd longer (or increased longevity) than heifers that calved on day 23 or later.

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 Nielson, 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 length provides more opportunities for cows to become pregnant and wean a calf. For example, cows in 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 a 90-day breeding season would have at least four opportunities to become pregnant (Deutscher, Stotts, and Nielson, 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).

Tradeoffs 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 a shorter calving season reduced the cost of production for beef cattle operation. Boyer, Griffith, and Pohler (2020) compared the profitability of cow-calf operations with a 45, 60, and 90-day calving season length. They found shortening the calving period from 90 days to either a 45 or 60-day calving season increased expected net returns in the spring- and fall-calving herds.

While these studies show 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 types of 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.

The objective of this study is to estimate how shortening a 120-day calving season to a 45- and 60-day calving season by replacing late calving cows impacts Southeastern United States beef cattle producers' returns and risk. Specifically, we build dynamic simulation models to analyze annually replacing 10% and 20% of the latest calving and non-pregnant (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 a 45- and 60-day calving season. 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 provide analysis on 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 be lower cost compared to purchasing heifers for some operations (Schulz and Gunn, 2014). Following these as 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 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 and 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 culled cows and depends on cattle price, percentage of cows that wean a calf (calving rate), 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 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 (limit weight regulation for single truck transportation). Therefore, the producer's annual net returns per lot could be generally defined as

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

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

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

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

where $sp^{500-600}_t$ is the 500-600 pound 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 pound 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 pound lot was found by replacing the 400-500 pound steer price (\$/lb) at the time of the sale ($sp^{400-500}_t$) with the 300-400 pound steer price (\$/lb) at the time of the sale ($sp^{300-400}_t$). This same method was applied to find weight adjusted heifer prices.

A longer calving season could increase labor expense but incorporating these changes in labor expense 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 be consider the opportunity cost of selling the heifer at weaning. That is, the cost of forgoing revenue from a heifer to retain her for breeding. When replacement rates increase, 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, partial returns were calculated on a per exposed female basis, which is defined as the number of cows and heifers exposed to a bull. This would consider the annual change in the number available females for breeding and would allow for a consistent comparison across the changes in the herd size over time, and is defined as

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

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). The number of exposed females 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 ($N_{t-1} \times RR_{t-1}$), and the number of heifers retained and developed from two years ago ($N_{t-2} \times RR_{t-2}$) and is defined as

(4) $$N_t = N_{t-1}(1 - RR_{t-1}) + N_{t-2} \times RR_{t-2}\ .$$

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

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

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 to demonstrate 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 her over the 30-year time frame with a female that becomes pregnant and calves early in the seasons.

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 be adding production risk (Funston et al., 2012; Mousel et al., 2012). Annual price variability or price risk for heifer, steers, and cull cows could impact risk of making changes to the distribution of calving.

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, dynamic stochastic programming models were developed to account for changes in herd size, heifers retained, and females sold. These values will vary based on herd size (25 or 250), replacement rate (10% or 20%), and calving season length (45- or 60-day). 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

For each herd size, five combinations of different replacement rates and calving season lengths were analyzed. These scenarios were: 1) baseline or no change to 120-day calving, 2) annually replace 10% of the late calving females to reach 60-day calving, 3) annually replace 20% of the late calving females to reach 60-day calving, 4) annually replace 10% of the late calving females to reach 45-day calving, and 5) annually replace 20% of the late calving females to reach 45-day calving. Late calving females were identified by the timing they became pregnant during the breeding season. Table 1 shows the percentage of females that become pregnant across possible 21-day estrous cycles and the timeline 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.

The assumed breeding season starts April 25th, 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 get bred. Finally, the 45-day calving season would shorten calving to the end 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) provide more opportunities for cows to be 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 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 four years to reach a 60-day calving and additional fifth year to grow the number of females to the original herd size. The additional fifth year would be the year in which heifers retained from year four would calve. Something to point out, 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 two. The desired calving distribution achieved and herd size restored a year sooner than if replacement was increased 10%.

Simulation

Simulation model was developed to incorporate production and price variability into the model and generate distributed NPV values for each scenario. Production risk was introduced into the model two ways. First, we used parameters for a weaning weight response function to calving date for spring-calving cows found in Boyer, Griffith, and Pohler (2020). They used a quadratic functional form for calving date and included random effects that control for unobserved heterogeneity were included for year and sire. The response parameters in Boyer, Griffith, and Pohler (2020) 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 and 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 one 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 random calving date.

These randomly generated weaning weights were sorted into three lots based on weight. Three lots were 300-400, 400-500, and 500-600 pounds per head. Price premiums from lot sizes have been estimated in several studies (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 Halich and Burdine (2015). They 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 Zimmerman et al.'s (2012) approach of taking the natural log of the lot size and lot size squared and found increasing lot size resulted in higher price, but did so at a decreasing rate and with a terminal point of diminishing returns. We selected these parameters due to it being a southeastern market and the recent time frame of the study. Price premiums based on lot size were defined as

$$\widetilde{LP}_l = 8.27 \times \ln\left(\widetilde{LS}_l\right) - 0.791 \times \ln\left(\widetilde{LS}_l^2\right) . \tag{6}$$

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

$$\widetilde{p^s_{tl}} = \widetilde{sp}_t^{500-600} + \left(\frac{550-LW_t}{100}\right) \times \left(\widetilde{sp}_t^{500-600} - \widetilde{sp}_t^{400-500}\right) + \widetilde{LP}_l \tag{7}$$

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 et al., 2008). A total of 1,000 annual revenue observations were simulated for all scenario.

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 where 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 does not find 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). It 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 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 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 et al., 2008).

Taking the difference between 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 Pohler (2020) used data were from a spring-calving herd located at the Ames Plantation Research and Education Center, near Grand Junction, Tennessee, spanning from 1990 to 2008 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 these herds management can be found in those papers.

For the NPV simulation model, Monthly Tennessee beef price data for steers, heifers, and culled cows were collected from 2000 to 2018 for the simulation (U.S. Department of Agriculture Agricultural Marketing Service, 2018). All beef prices were adjusted into 2018 dollar values using the U.S. Bureau of Labor Statistics Consumer Price Index (2018). 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 and 500-600 lb steers and heifers were collected along with cull cow prices. The average of these prices over this time period are shown in Table 3. Cull cow revenue was found by multiplying cull cow price by an average cull cow weight of 1,400 pounds. 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 producers' 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 chooses to annually replace 10% of the late calving females to achieve a 60-day calving season, expected partial returns decrease in the first two years due to selling more breeding cattle and selling fewer heifer calves, but by year three, the calving distribution has shifted to produce more earlier born, heavier calves, resulting in a higher partial return per exposed female. By year five, expected partial return was \$24 per exposed female higher than the baseline scenario. The same pattern of results were found for the other scenarios where late calving females were replaced. When the 20% annual replacement rate was used, expected partial returns decreased more in the first year but increase 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 as the small herd size. 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 increase by $13 per exposed female to $664 from the baseline scenario. This gain in returns was not as much as the small herd, showing the small beef cattle operation in this study had more the gain from shortening calving season length than the larger beef cattle operation.

Table 5 shows the 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 starting shifting 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 producers would increase average weaning weights and returns by shortening their calving season length, which is similar to previous studies findings (Ramsey et al., 2005; Boyer, Griffith, and Pohler, 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 where 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. Figure 2 shows the stoplight graph of the probability of NPV from shorter calving season being greater than the baseline scenario for the small herd and figure 3 shows the same thing for the large herd. 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 60-day calving season when 10% and 20% of late calving cows are replaced, respectively. Conversely for the large herd, the 45-day calving seasons were less likely to result in a higher NPV relative to the baseline than the 60-day calving season. The NPV was 57% and 58% more likely to higher than the baseline for 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 from shortening calving season than larger producers.

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. The utility-weighted risk premiums for each scenario are shown in figure 4 for the small herd and figure 5 shows the same results for the large herd. A risk-neutral (ARAC = 0) producer (or profit-maximizer) would prefer replacing 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 replacing 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 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 less 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 larger producers introduce more variability in their operation making these changes, which a risk-averse producer would like to avoid.

The risk analysis relieves an interesting finding 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 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 Pohler, 2020), these benefits might not apply to all types producers, which is helpful to remember when making recommendations.

Conclusions

The goal of this study is to estimate how shortening a 120-day calving season to a 45- and 60-day calving season by replacing late calving cows impacts Southeastern United States 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., first estrous cycle) of breeding season until the 120-day calving season has shifted to a 45- and 60-day calving season. 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 have their calves, 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 to shortening calving season.

A profit-maximizing producer for a small and large herd would choose to replace 10% of their late calving cows to move from a 120- to 60-day calving season. However, the small producer would receive a larger return to shift the calving season than the large producers. This is likely due to 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 the 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 shorter calving season are shown to be more profit, but when considering risk, the large herd producer would prefer the baseline scenario of 120-days. This is a key finding for understanding way 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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References

Boyer, C.N., A.P. Griffith, and K.L. DeLong. 2020. "Reproductive Failure and Long-Term Profitability of Spring and Fall Calving Beef Cows." *Journal of Agricultural and Resource Economics* 45:78-91. DOI:10.22004/ag.econ.298435

Boyer, C.N., A.P. Griffith, and K.G. Polher. 2020. "Improving Beef Cattle Profitability by Changing Calving Season Length" *Journal of Applied Farm Economics* Vol 3: Iss. 1, Article 2.

Bulut, H. and J.D. Lawrence. 2007. "The Value of Third-Party Certification of Preconditioning Claims at Iowa Feeder Cattle Auctions." *Journal of Agricultural Applied Economics* 39(3):622-640. DOI: https://doi.org/10.1017/S1074070800023312

Burdine, K.H., L.J. Maynard, G.Halich, and J.W. Lehmkuhler. 2014. "Changing Market Dynamics and Value-Added Premiums in Southeastern Feeder Cattle Markets." *The Professional Animal Scientist* 30(3):354-361. https://doi.org/10.15232/S1080-7446(15)30127-3

Chavas, J. P. *Risk Analysis in Theory and Practice the Professional.* San Diego, CA: Elsevier Academic Press, 2004.

Deutscher, G.H., J.A. Stotts, and M.K. Nielson. 1991. "Effects of Breeding Season Length and Calving Season on Range Beef Cows Productivity." *Journal of Animal Science* 69:3453-3460.

Dhuyvetter, K.C. and T.C. Schoeder. 2000. "Price-weight Relationships for Feeder Cattle." *Canadian Journal of Agricultural Economics* 28:299-310. DOI: 10.1111/j.1744-7976.2000.tb00281.x

Funston, R.N., J.A. Musgrave, T.L. Meyer, and D.M. Larson. 2013. "Effects of Calving Distribution on Beef Cattle Progeny Performance." *Journal of Animal Science* 90:5118-5121. doi: 10.2527/jas.2012-5263

Hardaker, B.H, J.W. Richardson, G. Lien., and K.D. Schumann. 2004. "Stochastic Efficiency Analysis with Risk Aversion Bounds: A Simplified Approach." *The Australian Journal of Agricultural and Resource Economics* 48:253-270. https://doi.org/10.1111/j.1467-8489.2004.00239.x

Halich, G., and K.H. Burdine. 2015. "Feedlot vs. Pasture Impacts on Feeder Cattle Prices." Southern Agricultural Economics Association Annual Meeting Atlanta Georgia, January 31 – February 3, 2015.

Henry, G. W., C. N. Boyer, A. P. Griffith, J. A. Larson, S. A. Smith, and K. E.
Lewis. 2016. "Risk and returns of spring and fall calving beef cattle in Tennessee." *Journal of Agricultural and Applied Economics* 48:257-278. DOI: https://doi.org/10.1017/aae.2016.11

Ibendahl, G.A., J. D. Anderson, and L. H. Anderson. 2004. "Deciding When to Replace an Open Beef Cow." *Agricultural Finance Review* 64:61-74. https://doi.org/10.1108/00214660480001154

Johnson, S.K. 2005. "Possibilities with Today's Reproductive Technologies." *Theriogenology* 64:639-656. DOI: 10.1016/j.theriogenology.2005.05.033

Johnson, S.K. and R.D. Jones. 2008. "A Stochastic Model to Compare Breeding System Costs for Synchronization of Estrus and Artificial Insemination to Natural Service." *The Professional Animal Scientist* 24:588-595. https://doi.org/10.15232/S1080-7446(15)30909-8

Mackay, W.S., J.C. Whittier, T.G. Fields, W.J. Umberger, R.B. Teichert, and D.M. Feuz. 2004. "To Replace or Not Replace: Determining Optimal Replacement Rates in Beef Cattle Operations." *The Professional Animal Scientist* 20:87-93.

Mathews, K. H., Jr., and S. D. Short. 2001. "The Beef Cow Replacement Decision." *Journal of Agribusiness* 19:191–211. https://doi.org/10.15232/S1080-7446(15)31277-8

Mousel, E.M., R.A. Cushman, G.A. Perry, and L.K. Kill. "Effects of heifer calving date on longevity and lifetime production." *Proceedings applied reproductive strategies in beef cattle*, Sioux Falls, SD, 2012.

Pratt, J.W. 1964. "Risk Aversion in the Small and in the Large." *Econometrica* 32:122–36.

Ramsey, R., D. Doye, C. Ward, J. McGrann, L. Falconer, and S. Bevers. 2005. "Factors Affecting Beef Cow-Herd Costs, Production, and Profits." *Journal of Agricultural and Applied Economics* 37:91-99. DOI: https://doi.org/10.1017/S1074070800007124

Richardson, J.W., K.D. Schumann, and P. A. Feldman. 2008. "*SIMETAR Simulation for Excel to Analyze Risk*." Agricultural and Food Policy Center, Department of Agricultural Economics, Texas A&M University.

Schulz, L., and P. Gunn. 2014. "Raising Versus Buying Heifers for Beef Cow Replacement." Iowa State Extension, File B1-73. Available at: https://www.extension.iastate.edu/agdm/livestock/pdf/b1-73.pdf

U.S. Department of Agriculture, Agricultural Marketing Services. 2017. *Livestock and Grain Market News*. Available at: http://marketnews.usda.gov/portal/lg.

U.S. Department of Labor, Bureau of Labor Statistics. 2017. *Consumer Price Index*. Available at: http://www.bls.gov/cpi/.

United States Department of Agriculture. 2009. *Beef 2007-2008, Part II: Reference of Beef Cow-Calf Management Practices in the United States, 2007-08*. Fort Collins, CO: U.S. Department of Agriculture, Animal and Plant Health Inspection Service, National Health Monitoring System.

Zimmerman, L.C., T.C. Schroeder, K.C. Dhuyvetter, K.C. Olson, G.L. Stokka, J.T. Seeger, and D.M. Grotelueschen. 2012. "The Effect of Value-Added Management on Calf Prices at Superior Livestock Auction Video Markets." *Journal of Agricultural and Resource Economics* 37:128-143. DOI 10.22004/ag.econ.122317.

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					
Time	**1st**	**2nd**	**3rd**	**4th**	**5th**	**Replacement Rate**
Baseline						
Year 1	30%	20%	20%	10%	10%	10%
10% to 45-day [a]						
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 [a]						
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 [a]						
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 [a]						
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%

[a] 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving

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
1st	April 25th	May 11th	May 16th
2nd	May 17th	June 1st	June 7th
3rd	June 8th	June 23rd	June 29th
4th	June 30th	July 15th	July 21st
5th	July 22nd	August 8th	August 12th

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

Variable	Average	Standard Deviation	Minimum	Maximum
300-400 Steer Price	1.70	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

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	-[b]	575.55	637.00	580.51	640.81
Year 3	-[b]	586.13	648.28	642.17	645.89
Year 4	-[b]	641.15	648.28	647.26	645.89
Year 5	-[b]	646.36	-[b]	647.26	-[b]
Year 6	-[b]	646.36	-[b]	-[b]	-[b]
250 Head Herd					
Year 1	650.95	620.76	542.36	617.92	595.75
Year 2	-[b]	593.61	662.18	599.13	663.06
Year 3	-[b]	602.91	662.45	663.21	662.68
Year 4	-[b]	658.80	661.47	664.39	662.20
Year 5	-[b]	659.90	-[b]	663.91	-[b]
Year 6	-[b]	659.90	-[b]	-[b]	-[b]

[a] 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving

[b] Indicates revenues did not change from previous year since desired calving season length was achieved and herd numbers returned to the original number of brood animals.

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

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

[a] 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving

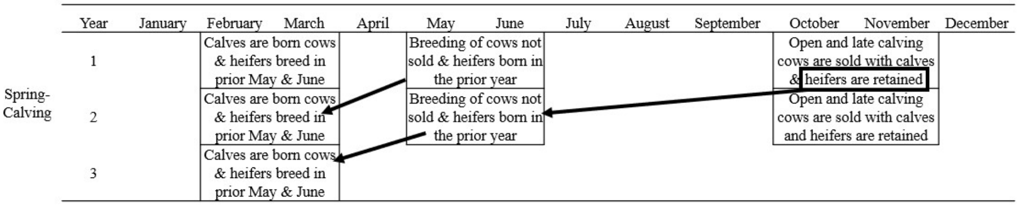

Figure 1. Timeline for Calving, Breeding, and Retaining Heifers for a Spring Calving Herd

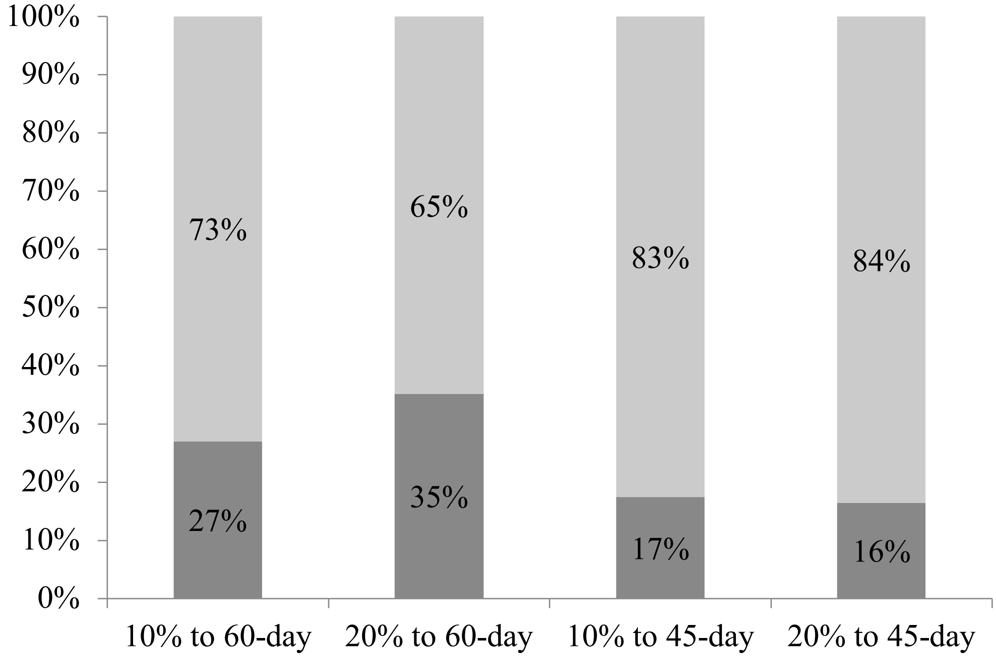

Figure 2. Probability of Net Present Value from a Shorter Calving Season is Greater than NPV of the Baseline Scenario (shown in lightest gray) and Less than the NPV of the Baseline Scenario (shown in darkest gray) for the 25 head herd

Note: 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving

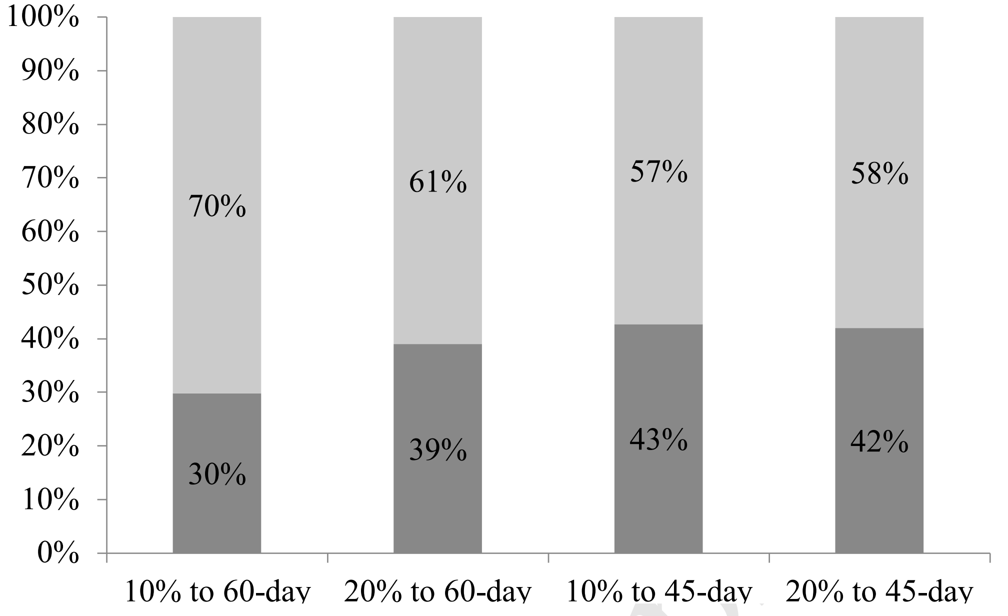

Figure 3. Probability of Net Present Value from a Shorter Calving Season is Greater than NPV of the Baseline Scenario (shown in lightest gray) and Less than the NPV of the Baseline Scenario (shown in darkest gray) for the 250 head herd

Note: 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving

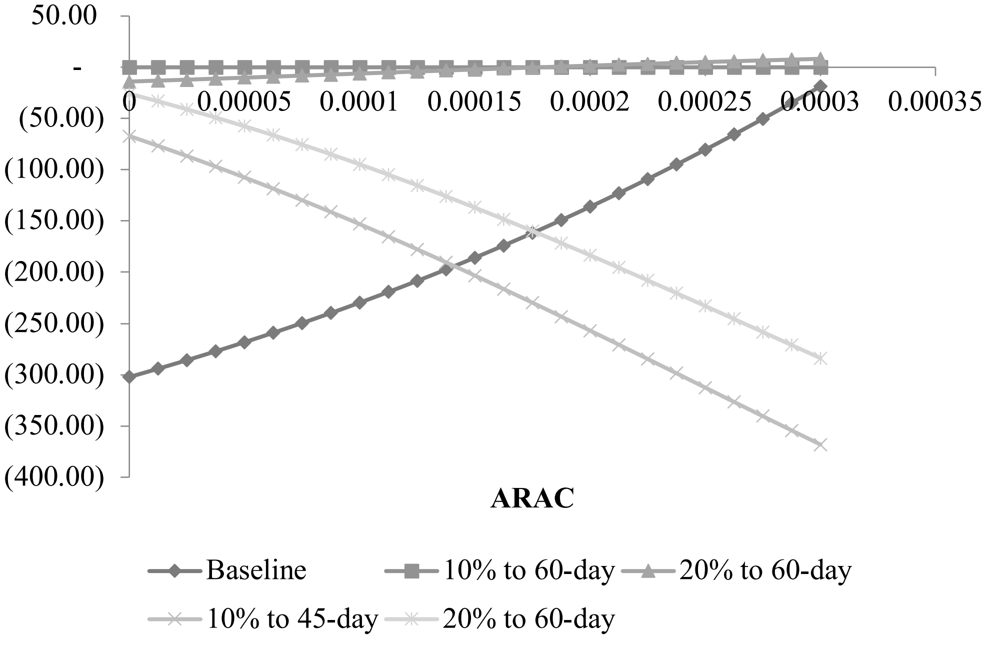

Figure 4. Utility Weighted Risk Premiums for the 25 head herd by Scenario
Note: 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving

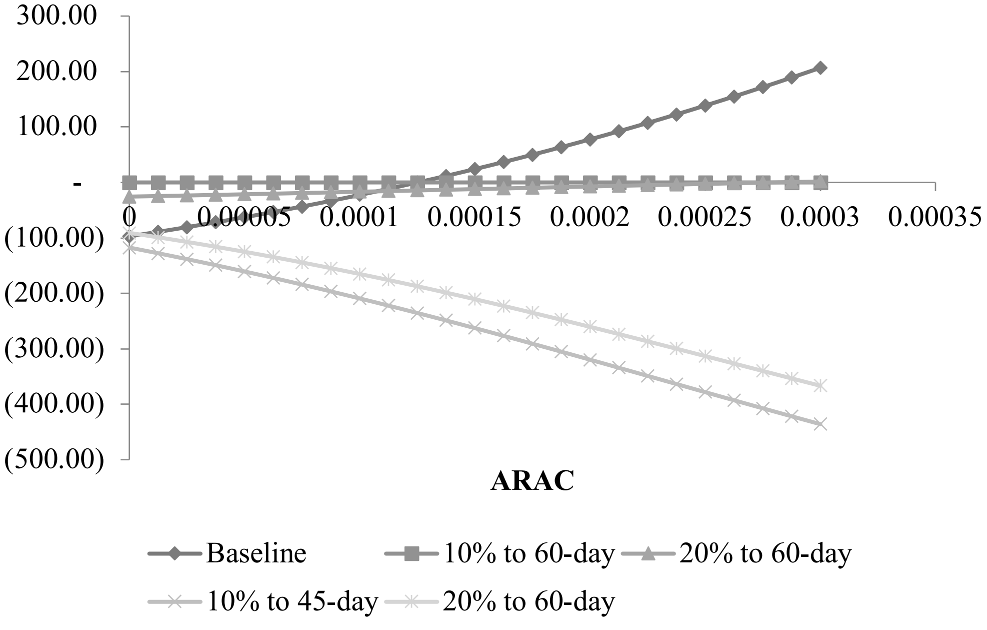

Figure 5. Utility Weighted Risk Premiums for the 250 head herd by Scenario
Note: 10% to 45-day = Replace 10% of Late Calving Females to 45-day Calving; 20% to 45-day = Replace 20% of Late Calving Females to 45-day Calving; 10% to 60-day = Replace 10% of Late Calving Females to 60-day Calving; and 20% to 60-day = Replace 20% of Late Calving Females to 60-day Calving