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Reproductive Failure and Long-Term Profitability of Spring- and Fall-Calving Beef Cows

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We determined how reproductive failure impacts the long-term profitability of beef cows in spring- and fall-calving herds. Simulation models were established to generate distributions of net present value, payback periods, and breakeven prices of calves when a dam fails to wean zero, one, or two calves over her life. Results indicate that giving a dam another calving opportunity after failing to wean a calf would likely result in her being unprofitable. A producer would be better off selling the open dam than giving her another chance to breed. This illustrates the value in selecting replacement heifers based on fertility.

Key words: beef cattle, net present value, reproduction, simulation

Introduction

Cow–calf producers annually identify cows to cull based on age or reproductive failure and select heifers to retain or purchase to replace these culled cows. Whether a producer purchases bred heifers or retains and develops heifers from their farm to replace these culled cows, this can be a substantial investment that will impact the long-term profitability of the operation (Mathews and Short, 2001). Further, future revenue streams from this investment are uncertain and depend on cattle prices, cow reproduction efficiency, and calf performance. Because of the cost and the uncertainty of this investment, many have considered this decision one of the most complicated a cow–calf producer confronts (Melton, 1980), which has spurred substantial research on the economics of this common and important decision over the last several decades (Burt, 1965; Bentley, Waters, and Shumway, 1976; Melton, 1980; Trapp, 1986; Frasier and Pfeiffer, 1994; Mathews and Short, 2001; Ibendahl, Anderson, and Anderson, 2004; Mackay et al., 2004).

A producer's decision to purchase replacement heifers or mature cows versus raising their own replacement heifers can depend on cattle prices, production costs, and tax implications (Clark et al., 2005). There are, however, many advantages to raising replacement heifers, such as increased control of genetic potential, reduced disease exposure and health risks, and better acclimated to the environment of the operation (Schulz and Gunn, 2014). This explains why 83% of all cow–calf operations in the United States reported in 2007–2008 that they raised their own replacement heifers (U.S. Department of Agriculture, 2009). Since this is the common practice among cow–calf producers, research has primarily focused on the economics of raising replacement heifers versus purchasing replacement heifers from another farm.

The common approach to analyzing the economics of raising replacement heifers has followed capital asset replacement models and the estimation of net present value (NPV) for the investment

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(Burt, 1965; Bentley, Waters, and Shumway, 1976; Melton, 1980; Trapp, 1986; Mathews and Short, 2001; Mackay et al., 2004). Several factors impact the profitability of the investment in raising a replacement heifer, but cattle prices and cost structures have been identified as a primary contributor (Mathews and Short, 2001; Ibendahl, Anderson, and Anderson, 2004; Mackay et al., 2004). Mackay et al. (2004) explored several marketing strategies for female cattle as cattle prices changed. They generally reported that in times of high cattle prices, returns increased by selling bred yearlings and retaining heifers to develop. Conversely, when cattle prices were low, returns were maximized by selling open heifers and retaining yearlings. Cattle prices can cause the profit-maximizing average age of the herd to fluctuate. Ibendahl, Anderson, and Anderson (2004) showed how the cost of developing and production can influence the timing of selling an open cow. They reported that keeping open cows would be advantageous to developing heifers to replace cows during times of high feed costs.

Despite most producers indicating in a survey that open/late calving cows had a significant economic impact on their operation (U.S. Department of Agriculture, 2009), little research has investigated the impact of reproductive failure by a raised replacement heifer on the profitability of the herd. Reproductive failure through failed pregnancy, abortions, and calf death result in producers incurring expenditures to maintain open cows while not receiving any revenue for that year, decreasing the lifetime profitability of the raised replacement heifer. When a cow or heifer fails to produce a calf, the decision must be made to cull or retain her for a chance of producing a calf in the following year. Mathews and Short (2001) analyzed how missing a calf impacted NPV for the cow and found that missing one calf resulted in a negative NPV for the cow's productive life. This implies that if a cow/heifer fails to produce a calf during its breeding cycle, the producer is better off culling the animal than keeping it in the herd. Similarly, Ibendahl, Anderson, and Anderson (2004) investigated how reproductive failure impacts the profitability of the herd under a various price and cost scenarios.

These studies are relevant and offer insight into the impact of reproductive failure on profitability for a raised replacement heifer, but more research is needed to extend these analyses. Both of these studies use unique datasets to assume average weaning weights of cows at various ages. Mathews and Short (2001) stated that weaning weights are vital to estimating a cow's NPV, but this information is not typically readily available for a herd over time. Thus, limited data has remained a shortcoming of these studies; using actual production data would be an extension of the research. Additionally, southeastern United States beef cattle production consists primarily of forage-based cow–calf production (McBride and Mathews, 2011), which relies on tall fescue (TF) for pasture and hay (Stuedemann and Hoveland, 1988). TF has many desirable qualities, but cattle grazing endophyte-infected TF during the summer can be affected by fescue toxicity, increasing the frequency of reproductive failure and lower weight gains (Looper et al., 2010). Thus, managing reproductive failure can be a critical and common issue for producers in this region. Finally, these studies analyze various scenarios, but a simulation model might allow us to analyze how actual production and price data impact the distributions of NPV.

Therefore, the objective of this research was to determine how reproductive failure impacts the profitability of raising replacement heifers in Tennessee. Profitability was measured as the NPV of the raised replacement heifer over an assumed 11-year production life. We also calculate breakeven prices for each calf born over the production life and how many weaned calves are needed to recoup the investment cost of the heifer (i.e., payback period). Data come from a 19-year study in Tennessee of cow–calf herds that grazed TF and calved in the spring and fall. We estimate a calf-weaning-weight response function given the dam's age and set up Monte Carlo simulation models to find distributions of NPV, breakeven prices of calves sold at weaning, and the payback period. These models were simulated when a cow produced a calf every year of her production life, failed to produce one calf, and failed to produce two calves over her production life. Results will benefit producers by showing the economic implications of selecting replacement heifers based on fertility and ability to remain in the herd.

Economic Framework

An appropriate measurement to estimate profitability of raising a heifer to replace a culled cow is NPV, which is the sum of the discount value of future net returns (Burt, 1965; Bentley, Waters, and Shumway, 1976; Melton, 1980; Trapp, 1986; Mathews and Short, 2001; Ibendahl, Anderson, and Anderson, 2004; Mackay et al., 2004). The initial investment in the heifer begins when the cow that produces the heifer is bred (i.e., year 0) (McFarlane, Boyer, and Mulliniks, 2018). After birth, costs such as cow maintenance during nursing, forage, land, animal health, labor, and feed after weaning accumulate over the next 2 years before the heifer produces a weaned calf and generates revenue. Assuming that producers market calves after a short weaning period, the animal's revenue is generated from the selling of the steer and/or heifer calves as well as the value of the culled cows. Revenue is determined by factors such as cattle prices, weaning weights, and the number of cows culled.

Annual net returns to raised replacement heifer are determined by subtracting production costs from revenue, which are expressed as

$$(1) \qquad E[\pi_{it}] = p_{it}^s y_{it}^s \left(\frac{CR}{2}\right) + p_{it}^h y_{it}^h \left(\frac{CR}{2} - RR\right) + p_{it}^c y_{it}^c (RR) - PC_i,$$

where π_{it} is the expected annual net returns (\$/head) for the ith calving season ($i =$ spring, fall) in period t ($t = 0, \ldots, 11$); $p_{it}^s$is the price of steer calves (\$/lb); y_{it}^s is the weight of the steer calves (lb/head); CR is the calving rate $0 \leq CR \leq 1$, p_{it}^h is the price of the heifer calves (\$/lb); y_{it}^h is the weight of heifer calves (lb/head); RR is the replacement rate of the cow herd, $0 \leq RR \leq 1$, p_{it}^c is the price of culled cows (\$/lb); y_{it}^c is the weight of cull cows (lb/head); and PC_i is the annualized production costs for each calving herd (\$/head). We assume cost of production varies by calving season due to different feed requirements, but calving and replacement rates do not vary by calving season (Henry et al., 2016).

The annual net returns over the 11-year production life are discounted to find the NPV of replacement heifers in spring- and fall-calving herds. The opportunity cost and the cost of developing the heifer to replace a cow is also included in the NPV. The opportunity cost of develop a raised heifer is equal to the revenue the producer could receive from selling the heifer calf at weaning. The development cost is assumed to be the cost of cow maintenance during pregnancy, nursing, and weaning along with the cost forage, land, animal health, labor, and feed until that heifer is bred. NPV is generally expressed as

$$(2) \qquad E[NPV_i] = \sum_{t=2}^{11} \pi_{it}/(1+R)^t - [p_{it}^h y_{it}^h \left(\frac{(1-CR_i)}{2} - RR_i\right) + PC_i]/(1+R) + DC_i,$$

where NPV_i is the sum of the discounted annual net returns; R is the risk-adjusted discount rate; the opportunity cost, $p_{it}^h y_{it}^h \left(\frac{(1-PR_i)}{2} - RR_i\right)]$ is discounted back one period because this is a onetime cost that occurs in period 1, and DC_i is the cost of developing a heifer to replace a culled cow that is assumed to be in year 0. Annual productions are included in year 1 to account for costs from the time the heifer was bred to when it produces a calf. We select an 11-year useful life of the raised replacement heifer and assume that she will produce the first calf at age 2, based on assumptions made in other studies (Mathews and Short, 2001; Ibendahl, Anderson, and Anderson, 2004; Mackay et al., 2004; Shane et al., 2017).

Payback period is also estimated and is defined as the age at which the discounted annual net returns from the replacement heifer become greater than the investment cost (Kay, Edwards, and Duffy, 2012). This calculation is found by dividing the sum of the annual discounted net returns by the initial investment cost of developing the heifer (Schulz and Gunn, 2016):

$$(3) \qquad PB_t = \frac{\sum_{t=2}^{11} \pi_{it}/(1+R)^t}{DC_i},$$

where PB_t is the payback period and is calculated for each year. When $PB_t > 1$, then the heifer has recovered the investment. We present the average year in which $PB_t > 1$ for each reproductive scenario. We present the expected year when this ratio becomes greater than 1. An investment with the shortest payback period is preferred (Kay, Edwards, and Duffy, 2012).

We also determine the price a producer would need to make 0 profit for each calf, commonly referred to as a breakeven price (Kay, Edwards, and Duffy, 2012). Equation (1) can be rearranged to show the price producers would need to break even with each calf produced over the production life. The breakeven price is the same for heifers and steers since the cost of production to raise these calves will be the same. Any price the producer receives above the breakeven price is profit; if the price received is below the breakeven price, profits will be negative. Greater costs of production will result in a higher breakeven price, limiting the chances of economic profits. However, a lower cost of production will decrease the breakeven price, and the producer would have a greater opportunity of making economic profits.

Methods

Statistical Analysis

Since this is a lifetime production analysis that calculates NPV for the raised replacement heifer, we estimate calf weaning weight as a function of dam age and calf sex for each calving herd. This response function was used in the NPV calculation to estimate weaning weight for each year in the production life. A quadratic functional form for age of dam was selected based on a visual inspection of the data and previous research (Bentley, Waters, and Shumway, 1976; Mathews and Short, 2001) (Figure 1). We hypothesize that weaning weights increase to a certain age of dam and then begin decreasing. Calf sex is a binary variable that shifts the average weight for steer or heifer calves. These random effects that control for unobserved heterogeneity are included for year and sire. The response function was specified as

$$(4) \qquad y_{ilk} = \beta_{0i} + \beta_{1i}AGE_i + \beta_{2i}AGE_i^2 + \beta_3 S + v_l + u_k + \varepsilon_{itk},$$

where y_{itk} is calf weaning weight (lb/head) for calving season i in year l from sire k; Age_i is age of the dam (year) when the calf was weaned; S is an indicator variable for sex ($S = 1$, steer; $S = 0$, heifer); $\beta_0, \ldots, \beta_3$ are coefficients to be estimated; $v_l \sim N\left(0, \sigma_v^2\right)$ is the year random effect; $u_k \sim N\left(0, \sigma_u^2\right)$ is the sire random effect; and $\varepsilon_{itk} \sim N\left(0, \sigma_\varepsilon^2\right)$ is the random error term. Independence is assumed across all three random components. This equation was estimated using the maximum likelihood with MIXED procedure in SAS 9.4 (SAS Institute, Inc., 2013). We test weaning weights for heteroskedasticity with respect to cow age, year, and sex using the likelihood ratio test (Wooldridge, 2013), which compares the difference in log-likelihood values between a restricted model (variance does not vary) and an unrestricted model (variance can change across cow age, year, and sex) with a χ^2 test statistics. If heteroskedasticity is present, we correct it using multiplicative heteroskedasticity in the variance equation and report the results for the model that adjusts for the unequal variances (Wooldridge, 2013).

The dam age that maximizes weaning weight (AGE^*) can be found by taking the first-order conditions of equation (3) with respect to dam age and solving for AGE, which is expressed as $AGE_i^* = (-\beta_{1i})/2\beta_{2i}$. Since the annual cost of production is assumed to not vary by dam age, the dam age that maximizes weaning weight also maximizes profits.

Simulation

Uncertainty about animal performance such as weaning weight and fertility ALONG with changes in cattle prices makes raising replacement heifers a risky investment (Mathews and Short, 2001).

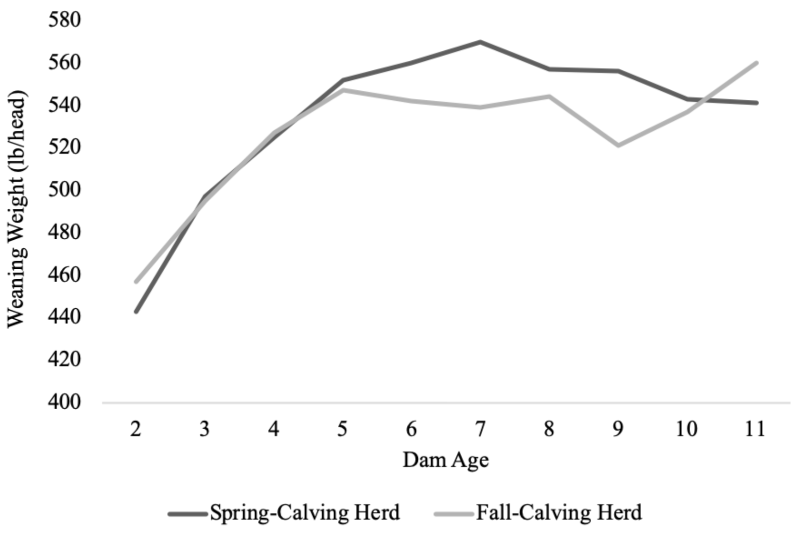

Figure 1. Expected Weaning Weights (lb/head) for Spring- and Fall-Born Calves by Dam Age (years)

Therefore, to consider uncertainty in this decision, we developed Monte Carlo simulation models to estimate distributions of NPV, payback periods, and breakeven prices by calving season. For each calving herd, we simulate the models when the replacement heifer produces a calf in every breeding season (no missed calves), fails to produce a calf (one missed calf), and fails to produce two calves (two missed calves) over the 11-year production life. We assume failure to produce a calf would occur for the second calf (or 3 years of age) and failure to produce two calves would occur for the second and third calf (or 4 years of age). These periods are when a cow is most likely to experience reproductive failure because the cow is still growing, trying to produce milk for the first calf, and trying to conceive. Reproductive failure could also occur as in the final years of her productive life, but failure at this stage will likely have a much smaller impact on profitability of the investment than early in the cow's life since she has produced calves for many years. An interesting follow-up analysis could be to investigate the trade-off of keeping an open older cow verse investing in a replacement heifer.

For each year of production life, the weaning weight is randomly assigned based on the dam's age during that breeding cycle. We did this by considering the weaning-weight response function parameters found in equation (3) to be stochastic. The response parameters were drawn from the multivariate normal (MVN) distribution:

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

where “ ” denotes a randomly drawn parameter from the MVN distribution; the mean of the distribution is the vector of the estimated yield response function coefficients $\left[\hat{\beta}_{0i}, \ldots, \hat{\beta}_{3i}\right]$; $\hat{\sigma}^2_{\beta_{0i}}$ are variance estimates of the parameters; ρ is the correlation coefficient in the four-by-four covariance matrix of parameters; and $\hat{\rho}_{ab}\hat{\sigma}_a\hat{\sigma}_b$ are estimated covariances between the parameters. This method of considering production risk has successfully been used for crop yield response functions (Cuvaca et al., 2015; Harmon et al., 2017; Boyer et al., 2018), but it has never been implemented for livestock-weight response functions.

Prices for culled cows, steers, and heifers were randomly drawn from a multivariate empirical distribution derived using historical Tennessee price data from 2000–2017. Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to develop the distributions and perform the simulations (Richardson, Schumann, and Feldman, 2008). A total of 5,000 net return observations were simulated for each calving herd and the three reproductive scenarios.

Data

Data were from spring- and fall-calving herds 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. Spring-born calves arrived from January 1 through mid-April, and fall-born calves arrived from early September through mid-November. Cows were not rotated between the spring- and fall-calving herds.Both herds primarily grazed endophyte-infected TF and were supplemented with free-choice mineral and corn silage year-round as needed. We assume that all raised replacement heifers were developed on endophyte-infected TF and were supplemented with free-choice mineral and corn silage during the winter months. Cows were culled due to failure to rebreed, poor calf performance (i.e., below-average weaning weights), and age. The spring-calving herd totaled 478 cows with 1,534 calves born over the 19 years, and the fall-calving herd included 474 cows with 1,727 calves born over the 19 years.

Data collected include identification number, calving herd, sire, dam, and date of birth. Records were not kept for cows that did not calve; thus, calving rate and replacement rate could not be calculated. We follow Henry et al. (2016) and assume that the calving rate was 85% and the replacement rate was 15%. Data for the calves include calf number, date of birth, sex, sire, number of calves the cow has calved, average daily gain, birth weight, and weaning weight. Table 1 reports weaning weight summary statistics for the spring- and fall-calving herd as a function of dam age during the associated breeding cycle. More information on the summary statistics for these herds can be found in Campbell et al. (2013) and Henry et al.. Production costs on a per head basis came from the University of Tennessee Extension livestock budgets (2018) and supplemental feed costs for spring- and fall-calving herds were found using McFarlane, Boyer, and Mulliniks (2018). Total annual variable production costs (PC_i) for the spring- and fall-calving herds were \$590 and \$595 per head, respectively. Cost of developing a replacement heifer (DC_i) was \$889/head for the spring-calving herd and \$894/head for the fall-calving herd, similar to what McFarlane, Boyer, and Mulliniks reported for developing heifers on TF in Tennessee. The development cost included all the costs from when cow is bred to when the heifer calf from this cow is bred, such as cow maintenance during pregnancy, nursing, and weaning along with the cost forage, land, animal health, labor, and feed until that heifer is bred. Costs were assumed to be consistent on an annual basis.

Monthly Tennessee beef price data for steers, heifers, and culled cows were collected from 2000 to 2017 (U.S. Department of Agriculture, 2017). All beef prices were adjusted into 2017 dollar values using the U.S. Bureau of Labor Statistics Consumer Price Index (2017). Calves born in the spring were assumed to be sold at weaning between September and November. Calves born in the fall were assumed to be sold at weaning between March and May. Table 2 reports price summary statistics for 500–600 lb steers, 500–600 lb heifers, and culled cows during these two timeframes. Revenue from culled cows was found by multiplying cull cow price by an average cull cow weight of 1,300 pounds. We use a discount rate (R) of 5.5% to calculate NPV.

Table 1. Summary Statistics for Weaning Weights (lb) for each Calving Season and Age of Cow

Cow Age (years)	*N*	Minimum	Median	Maximum	Mean
Spring-calving herd					
2	321	171	447	669	443
3	293	254	495	685	497
4	231	338	528	735	525
5	175	262	556	720	552
6	133	386	562	722	560
7	96	415	564	763	570
8	74	421	566	707	557
9	62	382	559	670	556
10	38	392	555	708	543
11	18	356	555	629	541
Fall-calving herd					
2	355	257	452	766	457
3	284	248	501	788	495
4	229	310	523	819	527
5	183	369	546	730	547
6	168	289	547	692	542
7	145	284	544	716	539
8	114	291	546	690	544
9	91	372	514	694	521
10	53	400	542	692	537
11	23	390	570	702	560

Results

Weaning-Weight Response Function

Table 3 shows the parameter estimates for weaning-weight response to dam age for the spring- and fall-calving season. For both calving seasons, parameter estimates for dam age were positive ($p < 0.001$) and dam age squared were negative ($p < 0.001$). This indicates weaning weights were increasing at a decreasing rate as a dam got older until the weaning-weight-maximizing age, after which weaning weights decreased as dam age increased. The weaning-weight-maximizing age for a dam in the spring- and fall-calving herd was 7 years old. This result matches what Mathews and Short (2001) found and is similar to previous work by Bentley, Waters, and Shumway (1976) and Bourdon and Brinks (1987), who found that the profit-maximizing dam age was 8 years old. While Núñez-Dominguez et al. (1991) found the optimal age to be between 6 and 9 years old, and Mackay et al. (2004) reported the profit-maximizing age of dams to be 4–9. Steer calves were found to weigh on average 33 lb/head more than heifer calves born in the spring ($p < 0.001$). For fall-born calves, steers were on average 25 lb/head heavier than heifer calves ($p < 0.001$).

Simulation

Table 4 presents the expected values of the simulated distributions of NPV and payback period for the spring- and fall-calving herd. The expected NPV was positive for dams that do not miss a calf and that miss one calf for both calving herds. However, missing one calf over the 11-year useful life decreased profitability by \$472/head (\$671 – \$199) for spring-calving dams and \$483/head

Table 2. Summary Statistics of Cattle Prices ($/lb) in Tennessee from 2000–2017 in 2017 Dollars by Calving Season

Commodity	Mean	Standard Deviation	Minimum	Maximum
Spring-calving herd				
Steer price	1.44	0.36	1.04	2.41
Heifer price	1.31	0.34	0.96	2.23
Culled cow price	0.67	0.17	0.46	1.11
Fall-calving herd				
Steer price	1.50	0.38	1.13	2.62
Heifer price	1.34	0.34	0.99	2.35
Culled cow price	0.70	0.17	0.52	1.12

Table 3. Parameter Estimates for Weaning Weight (lb/head) Response to Dam Age for Spring and Fall Calving

Parameter Estimates	Spring Calving Season	Fall Calving Season
Intercept (β_0)	353.48***	402.25***
AGE (β_1)	65.53***	41.76***
AGE^2 (β_2)	−4.52***	−2.91***
S (β_3)	32.72***	25.48***
Weaning-weight-maximizing dam age (AGE^*) (years)	7	7
-2 log-likelihood	16,150	18,435
Aikake information criterion (AIC)	16,164	18,449
Bayesian information criterion (BIC)	16,171	18,456

Notes: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.

Table 4. Summary Statistics of the Simulated Distributions of Net Present Value ($/head), and Payback Period (years of age) by Calving Season

Measurement	Zero Missed Calves	One Missed Calf	Two Missed Calves
Spring-calving herd			
Net present value	$671	$199	-$279
	(1,029)	(932)	(833)
Payback period[a]	6.03	8.21	9.77
	(2.45)	(2.37)	(1.84)
Fall-calving herd			
Net present value	$683	$200	-$279
	(1,035)	(935)	(837)
Payback period[a]	6.14	8.18	9.61
	(2.88)	(2.54)	(1.91)

Notes: Standard deviations are reported in parentheses.
[a]Payback period reports the number of calves the cow would need to produce to pay off the investment of retaining the heifer.

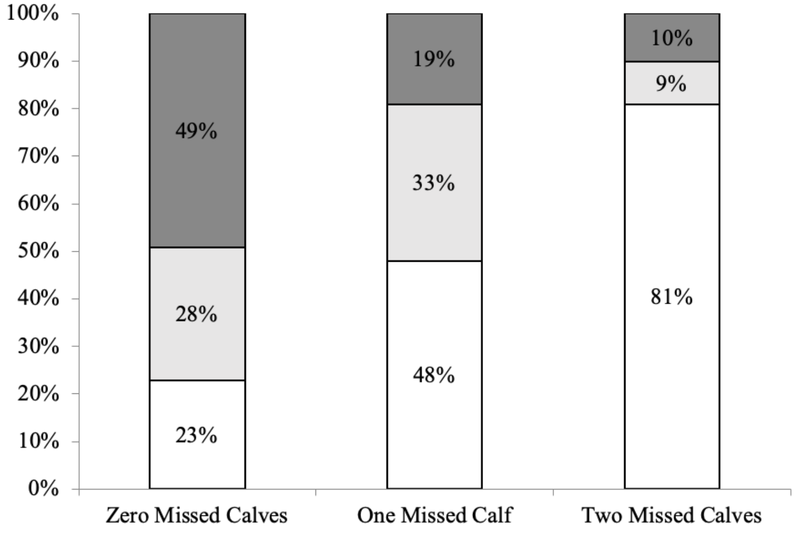

Figure 2. Probability of Net Present Value

Notes: Probability that the net present value is less than $0 (white), between $0 and $500 per head (light gray), and greater than $500 per head (dark gray) for the spring-calving herd..

($683 – $200) for fall-calving dams. If a raised replacement heifer misses two calves, the expected NPV was negative for both calving seasons. Mathews and Short (2001) reported missing one calf results in a negative NPV for the cow, which is different from what we observed in this analysis. This could likely be due to the fact that the cattle prices used in this study included prices from 2014 and 2015, when feeder cattle prices were at a historic high. For each reproductive scenario, the fall-calving herd had a higher expected NPV than the spring-calving herd, consistent with Henry et al. (2016).

Figure 2 shows the probability of the simulated NPV being below $0 (shown in white), between $0 and $500/head (light gray), and above $500/head (dark gray) for the spring-calving herd. There is a 49% chance that a raised replacement heifer that never misses a calf over the production life would have an NPV greater than $500/head, and a 23% chance of a negative NPV. This shows that even if the raised replacement heifer produces a calf every year of their production life, a producer could lose money on the investment depending on cattle prices. Missing one calf increases the likelihood of NPV being negative to 48% and decreases the probability of NPV being greater than $500/head to 19%. Missing two calves creates an 81% probability of a negative expected NPV and a 19% probability of a positive NPV. Figure 3 shows the probability of the simulated NPV being below $0 (shown in white) and above $500/head (dark gray) for the fall-calving herd. Results for the fall-calving herd also show that expected NPV for a raised replacement that misses two calves was most likely negative; if one calf is missed, the investment in the raised replacement heifers has a 50% probability of being profitable.

These results indicate that a raised replacement heifer that misses one calf could be profitable to keep in the herd, but missing two calves would mean the producer would likely lose money. To give a raised replacement heifer another chance at calving after missing a calf would likely result in a negative NPV for the dam, even if there were no more missed calves. Therefore, selling an open dam after missing one calf would likely be a better management decision than keeping the open dam in the herd for another year. This indicates that selecting replacement heifers based on fertility and maintaining environmental conditions for heifer/cows to reproduce is vital for maintaining a profitable cow–calf operation.

Table 4 also shows the payback period for raised replacement heifers in a spring- and fall-calving herd. Results for the payback period were similar across the spring- and fall-calving seasons. Even

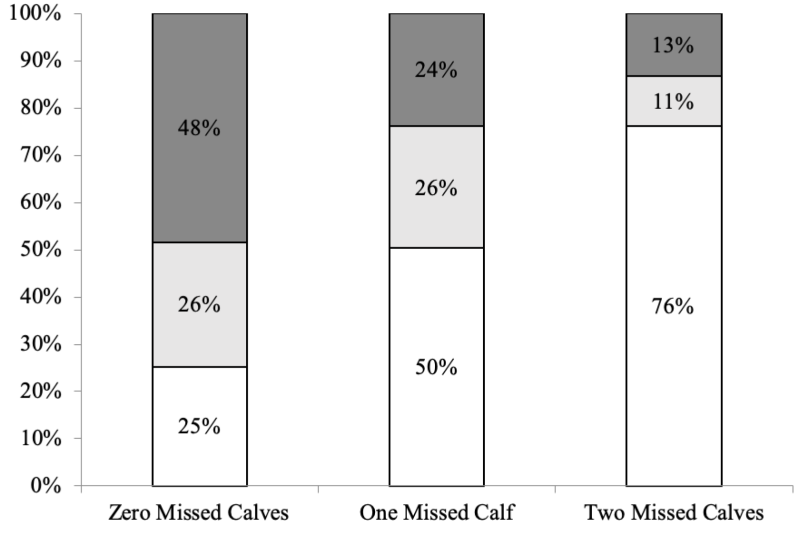

Figure 3. Probability of Net Present Value

Notes: Probability that the net present value is less than $0 (white), between $0 and $500 per head (light gray), and greater than $500 per head (dark gray) for the fall-calving herd.

if no calves were missed over the productive life, the dam needs to produce six calves before the returns to the investment were greater than the cost of development for both calving herds. The sixth calf would come at age 7 for the dam, which is the weaning-weight-maximizing dam age for both calving herds. If one calf is missed, the ninth calf weaned pays off the initial investment, which means the cow was 11 years old. Two missed calves results in the payback period occurring after the tenth calf was weaned.

Table 5 reports the expected breakeven prices for each calf produced by the raised replacement heifer by calving season. Breakeven prices are lower on average for the fall-calving herd than the spring-calving herd for all reproductive scenarios. The first three calves produced by the dam will not likely be profitable for either calving herd. However, by the fourth calf weaned, the breakeven price is less than the average price for steer and heifer calves born in either the fall or the spring (see Table 2). Missing a calf will increase the breakeven price to $4.05/lb, and the breakeven price does not go below the historical average prices until the seventh calf is weaned. The breakeven price results reinforce the conclusion that keeping a dam that has failed to wean a calf in the herd decreases the profitability of the herd and likely results in the return on investment from developing the dam being negative.

These results illustrate the value of selecting heifers based on fertility and the importance of managing cows to annually wean a calf. In the Fescue Belt,[1] managing summer forage to avoid fescue toxicosis, which is estimated to result in $1 billion in lost revenue per year to cattle producers, is vital in ensuring reproductive success (Smith et al., 2012). One possible solution is to incorporate grazing warm-season grasses along with TF. Several species are suited for this region, including the native perennials such as switchgrass and big bluestem; nonnative perennials like bermudagrass; and annual grasses such as crabgrass. Studies have shown that steers grazing warm-season grasses have positive gains and net returns (Lowe et al., 2015, 2016). While warm-season grasses could be a viable solution, there is limited research on integrated warm- and cool-season grazing systems in cow–calf production. More research is needed to determine the species and acres of warm-season grasses to incorporate with TF to increase cattle production and profitability.

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[1] The Fescue Belt includes all of or portions of Alabama, Arkansas, Georgia, Illinois, Indiana, Kentucky, Mississippi, Missouri, North Carolina, Ohio, Oklahoma, Tennessee, South Carolina, Virginia, and West Virginia Bussard and Aiken (2012).

Table 5. Summary Statistics of the Distribution of Breakeven Prices ($/lb) of Calves by Cow Age and Calf Number for Spring- and Fall-Calving Herds

	Zero Missed Calves		One Missed Calf		Two Missed Calves	
Age (years)	Spring-Calving Herd	Fall-Calving Herd	Spring-Calving Herd	Fall-Calving Herd	Spring-Calving Herd	Fall-Calving Herd
2	3.06	3.00	3.06	3.00	3.06	3.00
	(0.073)	(0.074)	(0.073)	(0.074)	(0.073)	(0.074)
3	1.98	1.97	–	–	–	–
	(0.034)	(0.038)				
4	1.56	1.57	4.05	4.05	–	–
	(0.024)	(0.026)	(0.076)	(0.081)		
5	1.32	1.35	2.35	2.37	5.08	4.98
	(0.114)	(0.021)	(0.036)	(0.043)	(0.083)	(0.091)
6	1.16	1.19	1.75	1.78	4.13	4.05
	(0.014)	(0.017)	(0.023)	(0.026)	(0.076)	(0.081)
7	1.05	1.08	1.44	1.48	2.67	2.72
	(0.012)	(0.015)	(0.018)	(0.021)	(0.035)	(0.042)
8	0.95	0.99	1.23	1.29	1.92	1.98
	(0.011)	(0.013)	(0.014)	(0.017)	(0.230)	(0.029)
9	0.88	0.92	1.09	1.14	1.67	1.61
	(0.010)	(0.012)	(0.012)	(0.015)	(0.023)	(0.022)
10	0.82	0.85	0.99	1.04	1.54	1.38
	(0.009)	(0.011)	(0.011)	(0.013)	(0.018)	(0.018)
11	0.77	0.80	0.91	0.96	1.31	1.21
	(0.009)	(0.010)	(0.010)	(0.012)	(0.015)	(0.016)

Notes: Standard deviations are reported in parentheses.

Conclusions

Identifying beef cows to cull and heifers to replace these culled cows is a complex decision that can have a major impact on profitability. Economic research has focused on factors that can drive the profitability of culling and replacing culled cows. However, little knowledge exists about the effects of reproductive failure by a raised replacement heifer on herd profitability. Thus, the goal of this study was to determine how reproductive failure impacts the NPV, payback period, and calf breakeven prices of raising replacement heifers in Tennessee.

Data were from a 19-year study in Tennessee of cow–calf herds that grazed TF and calve in the spring and fall. We estimate a weaning-weight response function to animal age and conduct Monte Carlo simulation models to find NPV distributions, breakeven prices of calves, and payback periods. These models were simulated when a cow calves each year of her productive life, fails to produce one calf, and fails to produce two calves over her productive life. Results will benefit producers by showing the implications of selecting replacement heifers based on fertility and on the profitability of the investment in raising replacement heifers.

For both calving seasons, weaning weights increases until the dam is 7 years old and then begins to decrease. On average, the expected NPV is positive for dams that do not miss a calf and that miss one calf but negative if the dam misses two calves. While the expected NPV is positive for a raised replacement heifer that misses one calf, the probability of the dam being profitable over the 11-year production life is approximately 50% for both calving herds. The payback period is six calves if no calves are missed, nine calves if one calf is missed, and 10 calves if two calves are missed. Giving the dam another chance at calving after missing a calf would likely result in the investment being unprofitable, even if there were no more missed calves. This implies that a producer might be better off selling the open dam than giving it another chance. These results illustrate the value of selecting heifers based on fertility and the ability to remain in the herd longer.

While the simulation approach considers variation in prices and production, one shortcoming is the results are conditional to the period considered in this study. Several factors—such as changes in development costs and cattle prices—could change these results under different economic scenarios.

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