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RESEARCH ARTICLE

Optimal Stocker Production Strategies for Spring and Fall Calving Cow Herd

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Abstract

We determine optimal stocker strategies based on calving season, herd size, and the number of days of retention before marketing weaned calves. We estimate a hedonic pricing model for feeder cattle and incorporate this into a simulation model that considers the variability of cattle prices and feed costs. The profit and utility-maximizing decision for fall calving herd would be to retain weaned calves for 150-day post-weaning. The producer marketing spring-born calves would prefer to sell these calves at weaning. The results are being utilized by extension to aid cattle producers in reducing their feed costs and increasing their profits.

Keywords: beef cattle; hedonic pricing; risk; simulation

JEL classifications: Q12

Introduction

Beef cattle production in the Southeastern United States (US) is commonly described as a forage-based, cow–calf operations that sell calves at weaning. The Southeast US has more beef cattle operations than any other region in the US, and it is the second-highest region in terms of total US beef cows (McBride and Mathews, 2011). These herds, however, are smaller than other regions when considering cattle per operation (McBride and Mathews, 2011). It is estimated that 70% of calves born in this region are sold at weaning, which is the highest of all regions, and calves were reported on average to be sold at a lighter weight (480 lb/head) than other regions (McBride and Mathews, 2011). A more recent survey by Asem-Hiablie et al. (2018) reported similar production practices for Southeast producers. The study reported most Southeast producers sold calves at weaning with an average age of 7.9 months old. Additionally, McBride and Mathews (2011) found the value of cattle production was lowest in the Southeast.

By selling at weaning, producers in the Southeast may be losing an opportunity to add value to their calves postweaning and increase revenue. Studies across the US, mostly the Northern Plains, North Central, and West regions, have shown preconditioning programs can add value to cattle (Coatney, Menkhaus, and Schmitz, 1996; Dhuyvetter, Bryant, and Blasi, 2005; Schumacher, Schroeder, and Tonsor, 2012; Williams et al., 2012, 2014; Zimmerman et al., 2012). While less attention has been focused on the economics of stocker production, which we define as weaned cattle grazing prior to going to the feedlot, in the Southeast, a few studies have found stocker production to be profitable in the Southeast (Anderson et al., 2004; Buccola, Bentley, and Jessee, 1980; Wang et al., 2001). Wang et al. (2001) examined the opportunities for Georgia beef cattle producers to earn additional profit from stocking cattle following seven different risk management strategies. The optimal outcome of their study depended on the scenario and producers risk preferences, but stocking cattle was profitable. Anderson et al. (2004) examined various contractual agreements for grazing stocker cattle compared to owning stocker cattle in the Southeast. Their study found that owning stocker cattle resulted in the highest profit while also being riskier than agreeing to allow stocker cattle to graze without ownership. The results also indicated stocker cattle production could be economically viable in the Southeast depending on the marketing strategy.

Several factors need to be considered when determining the management and marketing decisions for stocker cattle that will maximize profits and mitigate risk. One of the primary factors to consider is the cost of production, particularly feed cost. Feed costs commonly account for around half of the total variable costs in cow–calf production (Short, 2001; Henry et al., 2016). Hay is typically low-cost and chosen by cattle producers in the Southeast when forage production slows (Short, 2001; Boyer et al., 2020). Short (2001) reported that livestock operations in this region fed more harvested forage than operations in other regions, which could contribute to low net returns. Like hay, concentrate feed is another common source of supplemental nutrients for Southeast beef cattle producers (Prevatt et al., 2001; Henry et al., 2016). Corn silage and corn gluten are the most widely accessible feedstuffs for producers in the area. Rhinehart and Poore (2013) identified that the most efficient stocker production management system in the Southeast relies on low-cost, good-quality cool-season forages, such as tall fescue, with additional supplementation from concentrated grain feedstuffs.

One of the challenging components of stocker production in this region is the variation of calving season and forage production, that correlates to production and feed costs. Fall calving is more profitable than spring calving due to higher calf prices at weaning in the Southeast but feed costs increase due to nutritional needs of the cows (Caldwell et al., 2013; Henry et al., 2016; Smith et al., 2012). While previous studies on the profitability of stocker cattle in the Southeast are informative, studies have ignored key factors. Thus, research on seasonal impacts of calving season, forage production, feed cost, and feeder cattle prices on profitability across herd sizes and lengths of retaining ownership of weaned calves is needed.

Therefore, the objective of this study is to determine the profit-maximizing stocker length (i.e., days grazing) for fall and spring-born calves for herd sizes of 30, 60, 90 cows. Additionally, stocker periods of 30-, 60-, 90-, 120-, and 150-day postweaning and selling calves at weaning are considered. A simulation model is developed and considers stochastic feed prices, cattle weight, and cattle price to also determine a risk-averse producer optimal decision. These results can be used by producers in the region and help them make more informed and profitable decisions when they consider the multiple factors of an integrated cow–calf and stocker operation.

Economic Framework

Profit Maximization

Revenue from a cow–calf operation is received from selling steers, heifers, and culled cows. Cattle prices for steers and heifers typically vary based on weight, physical characteristics, and total weight of a lot of cattle sold (Garber et al., 2022; Martinez, Boyer, and Burdine, 2021; Williams et al., 2012, 2014; Zimmerman et al., 2012) and the average weight can vary across the calving seasons (Caldwell et al., 2013; Campbell et al., 2013). Therefore, revenue from an integrated cow–calf and stocker operation depends on calving season and the number of days stocking cattle with an uncertainty of the weight and price received. Production costs for a cow–calf operation will include pasture, feed, health, marketing, trucking, and others. Most of these production expenses do not vary significantly across calving seasons except for supplemental feed costs (Henry et al., 2016; Smith et al., 2012).

Assuming a producer is a risk-neutral and a profit-maximizer, the producer would select the number of days to retain weaned calves to feed or graze that would maximize their annual net

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returns per exposed female. In this research, several scenarios are analyzed to see how the optimal length of time to stocker cattle varies across herd size and calving season. Specifically, the herd sizes were assumed to be 30, 60, and 90 cow head herds, which are calving either in the spring or fall, with a stocker period of 30-, 60-, 90-, 120-, and 150-day postweaning. The producer's decision is expressed as

$$E[\pi_{ikl}] = p^s_{ikl} \times y^s_{ikl} \times \left(\frac{\mathrm{WR}}{2}\right) + p^h_{ikl} \times y^h_{ikl} \times \left(\frac{\mathrm{WR}}{2} - \mathrm{RR}\right) + p^c_i \times y^c_i(\mathrm{RR}) - \mathrm{PC}_{il} \quad (1)$$

were π_{ikl} are the expected annual net returns per exposed female (\$/head) for the ith calving season (i = spring, fall) for herd size k (k = 30, 60, 90 head) for stocker period l (l = selling at weaning, 30-day, 60-day, 90-day, 120-day, and 150-day); ${p_{ikl}}^s$ is the price of steer calves (\$/pound); ${y_{ikl}}^s$ is the weight of the steer calves (pound/head); WR is the weaning rate $0 \leq \mathrm{WR} \leq 1$; ${p_{ikl}}^h$ is the price of the heifer calves (\$/pound); ${y_{ikl}}^h$ is the weight of heifer calves (pound/head); RR is the replacement rate of the cowherd $0 \leq \mathrm{RR} \leq 1$; ${p_i}^c$ is the price of culled cows (\$/pound); ${y_i}^c$ is the weight of cull cows (pound/head), and PC_{il} is the annualized variable production costs (\$/head). The assumption was made that production cost could be varied in each calving season due to the differences in feed cost but calving and replacement rates would stay the same for both calving seasons (Henry et al., 2016; Smith et al., 2012), which is further discussed in the data section.

A key component to consider in this production system is uncertainty. Specifically, the uncertainty about weaning weight, cattle prices, and feed prices. Therefore, for each calving season, herd size, and stocker length, we simulate net returns considering this uncertainty. This allows the producer to make an optimal decision going beyond profits. Therefore, a producer's decision-making framework to select the optimal stocker period changes from profit maximization to utility maximization, defined as $U(\pi, r)$ where r is the producer's risk preference level (Hardaker et al., 2004).

Data

Annual net returns per exposed female were analyzed for six feeding periods for both the fall and spring calving season at three different herd sizes. This means results will be presented for 36 production scenarios (2 calving season × 3 herd sizes × 6 marketing opportunities). To build these scenarios, assumptions were made for the timing of breeding, calving, and weaning. Spring-calving cows are assumed to calve from January to March with re-breeding starting in April and ending in June, and lactation occurring from January to September. Calves from spring-calving cows will be weaned in the months of September and October, with stocking assumed to occur from October to March. Fall-calving cows are assumed to calve in the months of September through November with re-breeding starting in December and ending in February, and lactation being from September to May. The calves from a fall herd are assumed to be weaned in May and June, with the stocker period being from June to November. Table 1 showcases the timeline of production for both spring and fall calving herds.

Analyzing this decision will require data from various sources. The data section is divided into sections. First, cattle price data are discussed, followed by animal production data, and then, production costs are discussed.

Cattle Price

Price data were collected from the Lower Middle Tennessee Cattle Association (LMTCA) video sale spanning from 2016 to 2020, which is a bid-board auction occurring monthly. This consignment sale attracts cattle from several southeastern states. A sale catalog prior to the sale date includes cattle owner, number of head, estimated weight, sex, USDA feeder calf grades and flesh score, physical animal description, management practices, weighing conditions, shrink, and some

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Table 1. Time periods of cow breeding, calving, nursing, and weaning for the cowherd along with feeder cattle grazing for a spring and fall calving beef cattle herd

	January	February	March	April	May	June	July	August	September	October	November	December
Spring Calving Season												
Breeding				X	X	X						
Calving	X	X	X									
Nursing	X	X	X	X	X	X	X	X	X			
Weaning									X			
Feeder Cattle	X	X								X	X	X
Fall Calving Season												
Breeding	X	X										X
Calving									X	X	X	
Nursing	X	X	X	X	X				X	X	X	X
Weaning					X							
Feeder Cattle						X	X	X	X	X		

Table 2. Tennessee price data average prices across months and weight classes from 2016 to 2020 ($/cwt) (total observation equal 1,114)

	Weight Class					
Month	500–599	600–699	700–799	800–899	900–999	Monthly Average
January	*	*	134.00	134.77	133.41	134.05
February	136.63	136.63	130.97	129.75	130.00	135.60
March	*	*	135.27	131.24	130.68	133.70
April	162.67	162.67	134.74	124.44	128.21	141.72
May	139.50	139.50	132.06	129.72	126.99	133.44
June	133.88	133.88	133.09	134.50	132.26	136.83
July	*	*	135.66	131.69	130.01	136.84
August	*	144.08	139.33	137.23	137.00	140.02
September	130.33	133.33	135.38	131.58	128.15	131.61
October	143.00	143.00	136.29	137.82	134.05	138.04
November	137.94	137.94	133.70	139.06	135.55	135.30
December	*	*	138.86	133.40	137.55	135.78
Average	140.56	140.56	134.95	132.93	131.99	136.34

*Data does not exist.

other information. These cattle also have descriptions including information such as home raised (percent of cattle sold by the original producer), breed, percent with black hide, defects (scars, pinkeye, ringworm, horns), and if the lot has been tested for identification of being persistently infected with bovine viral diarrhea virus.

Cattle are sold through a public auction with bidders being present, on the phone, and through an online bidder platform. Table 2 illustrates average prices across months and weight classes. The seasonality of beef cattle prices and the relationship between price and weight is visible in this table. The lighter weight classes on average had the higher average sale prices. The sale months with the highest average sale prices were August and October. The range of head sold each month for each weight class ranged from 66 to 4,443.

Animal Production

These cattle production data for the spring and fall calving cowherds come from Ames Plantation Research and Education Center, located in Grand Junction, Tennessee from 1990 to 2008. Both calving herds were made up of commercial and purebred Angus cows. The commercial classified cattle were Angus-influenced that been crossbred with either Hereford or Simmental lines. Purebred Angus heifers were retained for replacements. Bulls were developed at Ames or purchased for the selection of genetic diversity.

The fall calving herd calved in the months of September through November, and the spring calving herd calved in the months of February through April. These herds grazed endophyte-infected tall fescue and received supplementation of mineral and corn silage as needed on a year-round basis. We do not have data on the amount of supplementation provided to these cows. Cows were culled from the herd if unable to re-breed or for low calf performance when compared with the total weight gained of other calves with dams of the same age. These data include spring herd consisting of 478 cows that totaled 1,534 calves born, and the fall herd totaled 474 cows with 1,727 calves born. Table 3 shows the summary statistics of the birth and weaning weights of calves

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Table 3. Summary statistics of birth weights (BW) (lbs) and actual weaning weights (WW) (lbs) by calving season and calf sex at Ames Plantation, from 1990 to 2008

	Average	Standard Deviation	Minimum	Maximum
Fall Calving				
Heifer BW	70	14	32	120
Steer BW	78	15	43	120
Heifer WW	497	71	257	704
Steer WW	527	78	171	788
Spring Calving				
Heifer BW	73	13	23	120
Steer BW	80	14	40	120
Heifer WW	498	77	208	717
Steer WW	531	85	171	763

in the spring and fall herds. These weaning weights were the assumed starting weight of retained weaned calves for feeding periods.

Calf death loss, cow death loss, calving rate, cull percentage, and culled cow weights were assumed from literature for our model. The assumed culled weaning rate was 90%, replacement rate of 10%, and cull cow average weight of 1,300 pounds for both spring-and-fall calving herds (Boyer, Griffith, and DeLong, 2020; Henry et al., 2016). For a herd size of 30 head, this equates to 27 total weaned calves, with 14 steers, 10 heifers, and 3 culled cows being sold. For a herd size of 60 head this equates to 54 total weaned calves, with 27 steers, 21 heifers, and 6 culled cows being sold. For a herd size of 90 head, this equates to 81 total weaned calves, with 41 steers, 31 heifers, and 9 culled cows being sold.

Nonfeed Production Cost

The production costs were determined from the University of Tennessee Department of Agricultural and Resource Economics Extension (2021) cow–calf and stocker budgets along with estimated feed cost rations based on cow nutritional needs and stocker growth rates. The budgets include production expenses of hay and pasture production, supplemental feed and minerals, veterinary and medication cost, labor, land, marketing as well as the expense of the bull. Feed and hay production expenses were removed from the cow–calf budget, and in the stocker budget, calf purchase cost including interest were removed from the estimate as well as pasture and hay production, and purchased feed, hay, and supplement feed cost. These feed costs were estimated separately for each animal unit by month based on forage production, which is discussed in more detail in the following sections.

Ration Development

Supplemental feed rations were developed and implemented to satisfy the nutritional requirements and demands for cow–calf production, following the National Research Council (NRC) guidelines for production phases. The NRC provides calculations containing the minimum nutrient demands for a cow based on the animal description, factors of the environment, forage and pasture quality, and feedstuffs implemented in the diet (NRC, 2000). The animal description includes factors of age, weight, body condition, calf birth weight, milk production, length of gestation, and the number of days in lactation. The feed program focuses on the appropriate balance

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of a cow's dry matter intake (DMI), energy (NEm), and metabolizable protein (MP) using the feedstuffs. Stocking rates as well as availability and quality of forage were assumed based on a tall fescue forage system in the Southeast. These rations utilize hay and feedstuffs when grazing is insufficient in maintaining the nutritional demands at various times of the year. These feed ingredients were selected due to availability to producers, simplicity, and nutrient quality (Poore, Johns, and Burris, 2002).

For spring calving, cows would need to be supplemented in the months of January, February, March, and December with average quality hay that was estimated to be 85% dry matter (DM), 52% total digestible nutrients (TDN), and 9% crude protein (CP). The amount of hay fed, on an as-fed basis, following the feeding season was 40 lb/head/day in December and January, 25 lbs/head/day in February and March. A 50:50 mixture of corn gluten feed and soybean hulls, accumulating to 90% DM, 71% TDN, and 15.6% CP, was needed. The amount needed, on an as fed basis, was 16 lb/head/day in both the months February and March. The fall-calving cows will receive supplementation from November to March. The hay fed on an as-fed basis was 25 lb/head/day for November, December, January, and February, and 40 lb/head/day in March. The amount of the 50:50 mixture fed was 16 lb/head/day from November to February.

Rations were also formulated for stocker calves born in the spring and retained past weaning. We targeted a 1.7 lb/day gain for weaned calves in developing these rations, which is a common ADG found in stocker production studies in this region (Crawford et al., 1989; Wang et al., 2001; Johnson et al., 2019). The literature suggests that there is a time post-weaning when calves can lose weight or not grow (Lynch, McGee, and Earley, 2019). Thus, it is assumed that for the first 20 days post-weaning that the ADG of the cattle is zero and after the first 20 days, cattle are assumed to gain 1.7 lb/day.

For the spring-born stockers, these cattle were fed 8 lb/head/day of hay and 12 lb/head/day of the 50:50 mixture in January. During February and March, stockers were given 9 lb/head/day of hay and 13 lb/head/day of 50:50 mixture. Supplementation resumes in October with 10 lb/head/day and 11 lb/head/day in November of 50:50 mixture. In December, these stocker cattle are fed 8 lb/head/day of hay and 11 lb/head/day 50:50 mixture fed. Fall stocker calves were supplemented with the 50:50 mixture from June to November. Hay is not required for fall stocker calves as pasture is a sufficient forage source during these months. The amounts needed for the 50:50 mixture is 10 lb/head/day in June, 11 lb/head/day in July and August, 12 lb/head/day in September, 13 lb/head/day in October and November.

Feed and Hay Costs

Hay and feed prices were used to develop ration costs. The US average hay price was $129/ton from 2016 to 2020 (USDA National Agricultural Statistics Service (NASS), 2021). However, hay prices are regional-specific, and the US hay prices do not always accurately reflect the regional hay price. That said, the seasonal changes in hay prices at the national level would be like a regional market in most years. Therefore, a seasonally adjusted, regional hay price was determined by developing a seasonal index created by using national hay prices. US monthly hay prices were collected from 2016 to 2020. An index was developed using January as a base month to show price fluctuation across months. This monthly price index was applied to a regional price of hay to build in a seasonal hay price to a local average market price. Due to limited reported transactions in the region, we selected an average price of $45/ton based on producer practice and conservations with Extension personnel.

USDA Agricultural Marketing Service (AMS) (2021) was the source for prices of corn gluten feed, and soybean hulls, from the Memphis, Tennessee reporting location. Table 4 shows monthly average feedstuff prices over the past 5 years (2016–2020) for corn gluten feed, soybean hulls, and hay. Most agricultural crops, such as those utilized for feedstuffs, have seasonality in their prices. Seasonality of feedstuffs is driven by supply and demand including price of substitutes,

Table 4. Monthly average feedstuff prices ($/ton) over the past 5 years (2016–2020) for corn gluten feed, soybean hulls, and hay ($n = 60$ for each price)

Month	Hay Cost[a]	Corn Gluten Feed	Soybean Hulls
January	$45.00	$146.18	$123.72
February	$46.03	$139.50	$124.53
March	$45.94	$140.22	$124.11
April	$45.96	$141.34	$123.79
May	$45.03	$142.04	$123.76
June	$43.51	$142.42	$123.55
July	$43.25	$142.43	$123.18
August	$43.19	$142.36	$122.74
September	$41.77	$142.79	$122.48
October	$43.79	$143.58	$122.31
November	$44.95	$144.45	$122.27
December	$44.37	$145.43	$122.36

[a]Hay Purchased at $45/ton.

complements, number of producers, expectations, and any other factor that affects crop productivity like weather (Griffith, 2013).

The total costs are found by combining the production cost with the feed cost. Table 5 illustrates both the cost of production and feed cost by segment as the stocker length and feed cost increase over time with purchasing feed as needed.

Empirical Modeling

Price Response Function

A hedonic pricing model was first estimated to determine price as a function of monthly, cattle weight, and lot weight impact prices. The estimated prices were used to simulate net returns shown in equation (1). All cattle are sold in groups, identified as lots, we estimate the model using the lot as the observation for the monthly sale, which accounts for seasonal price changes. The model is written as

$$\begin{aligned} \text{Price}_{clm} = \beta_0 + \beta_1 \log\,(W_{clm}) + \beta_2 \log\,(H_{clm}) + \beta_3 \text{HR}_{clm} + \beta_4 \text{MB}_{clm} + +\beta_5 S_{clm} \\ + \sum_{m=1}^{m=11} \gamma_m \text{SM}_m + \delta_1 \log\,(\text{CP}_{tm}) + v_t + u_c + \varepsilon_{clm} \end{aligned} \quad (2)$$

where Price_{clm} is the average price per cwt for cattle sold in lot c in year l during sale month m; W_{clm} is the average weight per head (pound/head); H_{clm} is the variable of the number of head sold in the lot; HR_{klm} is a binary variable for lots that were described as home raised; MB_{clm} is a binary variable for the lot being described as majority black hided; S_{clm} is a binary variable for sex of the cattle with the variable equal one if the lots were heifers; SM_m are a set of binary variable for the months the cattle are sold; CP_m is the nearby corn futures prices at the time of the sale; $\beta's$, $\gamma's$, and $\delta's$ are parameters to be estimated; $v_t \sim N(0, \sigma_v{}^2)$ is the year random effect; $u_c \sim N(0, \sigma_u{}^2)$ is the

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Table 5. Cost of production varied by stocker period length

Cost Segments	Fall ($/head)	Spring ($/head)
Production Costs		
Cow	$576	$576
Stocker – 30 days	$102	$102
Stocker – 60 days	$103	$103
Stocker – 90 days	$104	$104
Stocker – 120 days	$105	$105
Stocker – 150 days	$106	$106
Feed Costs		
Cow	$229	$154
Stocker – 30 days	$19	$33
Stocker – 60 days	$40	$67
Stocker – 90 days	$62	$74
Stocker – 120 days	$85	$111
Stocker – 150 days	$113	$141
Total Costs		
Cow – sell at weaning	$805	$730
Stocker – 30 days	$121	$135
Stocker – 60 days	$143	$170
Stocker – 90 days	$166	$178
Stocker – 120 days	$190	$216
Stocker – 150 days	$219	$247
Cow-Calf Combined Costs		
Cow – sell at weaning	$805	$730
Stocker – 30 days	$926	$865
Stocker – 60 days	$948	$900
Stocker – 90 days	$971	$908
Stocker – 120 days	$995	$946
Stocker – 150 days	$1,024	$977

sale lot random effect; and $\epsilon_{ilm} \sim N(0, \sigma_\epsilon{}^2)$ is the random error term. We assume independence on all four random variables.[1]

These models were estimated using maximum likelihood with the MIXED procedure in SAS 9.4 (SAS Institute, 2011). The parameter estimates of logged variables are converted to nominal dollar change in the sale price of cattle by multiplying the estimated parameter value by the average predicted selling price of the cattle (Wooldridge, 2013). Heteroskedasticity is tested for with respect to all covariates utilizing the likelihood ratio test (Wooldridge, 2013). If heteroskedasticity is present, it is corrected by implementing multiplicative heteroskedasticity in the variance

[1]We tested several specifications and taking the log of nonbinary independent variables was the best fit.

equation and the results are reported for the model that adjusts for the unequal variances (Wooldridge, 2013).

Simulation

The simulation was developed assuming cattle prices and feed price were stochastic. Hay prices were randomly drawn from the Gray-Richardson–Klose–Schumann (GRKS) distribution. The GRKS distribution is useful when minimal information is available about the distribution, requiring only minimum, midpoint, and maximum values as the bounds for the distribution (Richardson, 2006). The GRKS distribution is a two-piece normal distribution with 50% of the observations below the midpoint and 2.5% below the minimum value, while 50% of the observations are above the midpoint and 2.5% above the maximum value (Richardson, 2006) and frequently used in analyzing beef cattle net returns (Henry et al., 2016; McFarlane, Boyer, and Mulliniks, 2018). We select a minimum of \$25/ton and maximum of \$60/ton with the mid-point of \$45/ton. These prices were based on producer suggestions of hay prices. The corn gluten feed and soybean hull prices were assumed to be deterministic and the stochastic hay price results in the stochastic feed cost. We choose to only make hay price stochastic since it is most of the feed cost.

Calves weaning weights were randomly drawn from a truncated normal distribution with the lower and upper bound being the minimum and maximum of the data found in Table 4, respectively. These random weights feed into the price estimate to generate a random cattle price (equation 2). Finally, a truncated normal distribution was used to simulate price premiums for stocker cattle. There are several studies that suggest price premiums for preconditioned calves with a range of reports from zero to \$6 per hundred weights (Garber et al., 2022; Williams et al., 2012, 2014; Zimmerman et al., 2012). In this study, it is assumed producers could receive a price premium for cattle that were in a stocker phase before selling. The low and higher were selected from the literature as zero to \$6/cwt (Garber et al., 2022; Williams et al., 2012, 2014; Zimmerman et al., 2012).

For each herd size, stocker length, and calving season, the price will vary based on the number of calves being sold, month calves are sold, sex, stochastic weaning weight, and stochastic price premium. We assume all calves are black hided, home raised, and average corn price from these data. This is substituted into equation (1) along with the stochastic weaning weights, head sold, and stochastic production costs.

Stochastic dominance was then used to compare the distributions of net returns. In first-degree stochastic dominance, the scenario with cumulative density function (CDF) F dominates another scenario with CDF G if $F(\pi) \leq G(\pi) \forall \pi$ (Chavas, 2004). First-degree stochastic dominance often does not find one scenario to clearly be preferred to another; therefore, second-degree stochastic dominance adds the restriction that producers are risk averse, which increases the chance of finding a preferable scenario (Chavas, 2004). Second-degree stochastic dominance states the scenario with CDF F dominates another scenario with CDF G if G $\int F(\pi)d\pi \leq \int G(\pi)d\pi \forall \pi$ (Chavas, 2004).

Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to develop the distributions and perform the simulations (Richardson et al., 2008). A total of 1,000 net return simulated iterations were generated for each scenario.

Results

Price Response Function

Table 6 illustrates the estimated parameter value results from the regression. Various parameters are significant, and signs matched the literature. Heteroskedasticity was present for year, sex, and

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Table 6. Estimated parameter values for Tennessee price data from 2016 to 2020

Parameter	Estimate
Intercept	338.31***
Log Actual Weight	−32.4826***
Log Number of Head	1.461***
Home Raised	1.8456***
Majority Black Hided	2.6323**
Heifer	−10.9296***
January	−3.0872***
February	−3.4859***
March	−6.9903***
April	−7.4166***
May	−7.224***
June	−3.6993***
July	−1.0224
August	3.8637***
September	1.5866*
October	5.1823***
November	3.7231***
Log of corn futures	6.2714*

*, **, *** represent significance at the 10%, 5%, and 1% levels, respectively.

majority black hided variables and the model was corrected using multiplicative heteroskedasticity variance equation. Results are reported for the corrected model.

When the average weight per head increased, the sale price of the cattle decreased. A 100-pound increase in weight per head resulted in the sale price decreasing. Furthermore, an increase in lot size was found to increase the price of cattle. These directional relationships have also been reported in studies (Buccola, Bentley, and Jessee, 1980; Burdine et al., 2014; Dhuyvetter and Schroeder, 2000; Martinez, Boyer, and Burdine, 2021). Steer were sold for an estimated premium of $10.92/cwt over heifers. Cattle that had the hide color black received sale premiums of $2.63/cwt when compared to nonblack-hided cattle. Cattle that were home raised and sold by their original producer, holding all other factors constant, were expected to have an increased sale price of $1.85/cwt.

All months, with the expectation of July, were found to be significant relative to December. Cattle sale prices were on average the highest in October and the lowest in March. The months of August, September, October, and November resulted in an increase in the price of beef cattle sold in Tennessee. Contrastingly, selling cattle in the months of January through June results in a decline in the average sale price of beef cattle in Tennessee. The sale month of July is an insignificant variable in predicting the sale price of cattle.

Simulation

Table 7 shows the net returns for all the scenarios in this analysis. The spring calving herd was found to have a higher net return than the fall calving herd, which is different than others have

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Table 7. The average net returns (NR) ($/head) and standard deviations for the probabilities of positive profits in fall and spring calving herds of 30, 60, and 90 head herd sizes

	30 Head			60 Head			90 Head		
Production	**Mean NR**	**Standard Deviation**	**Probability of Positive Profits**	**Mean NR**	**Standard Deviation**	**Probability of Positive Profits**	**Mean NR**	**Standard Deviation**	**Probability of Positive Profits**
Fall Calving									
Weaning	−9	61	45%	−5	62	48%	−2	62	50%
30 days	−82	64	10%	−77	64	10%	−74	64	11%
60 days	−20	64	39%	−15	65	41%	−11	65	43%
90 days	1	62	52%	6	63	55%	10	63	58%
120 days	55	63	82%	60	63	83%	65	63	85%
150 days	70	61	87%	76	62	89%	81	61	89%
Spring Calving									
Weaning	115	67	95%	119	68	96%	122	68	96%
30 days	7	68	54%	12	69	57%	15	69	58%
60 days	7	65	54%	12	66	57%	16	66	59%
90 days	36	62	72%	41	62	75%	45	63	77%
120 days	45	61	78%	51	61	80%	55	62	82%
150 days	39	59	75%	44	59	78%	49	59	80%

found (Henry et al., 2016; Smith et al., 2012). The main difference in this study and these is we use sale price data from a sale while previous studies have used average state prices. Also, the fall calving herd had a higher cost of production due to higher feed costs. Additionally, as expected, net returns and probability of being profitabilitable increases as the herd size increases.

For the fall calving herd, the greatest probability for profit occurs when calves were sold after a 150-day stocker interval (87%), and the lowest chance for profit occurs when calves were sold after a 30-day retention period (10%). This was consistent regardless of herd size. The expected net returns were $70/head when retaining calves 150 days when you have 30 cows, and the net returns increase to $81/head for the same scenario, but the herd is 90 head. A profit- and utility-maximizing producer would select to retain weaned calves for 150 days.

For the spring calving herd, the likelihood of having a positive net return was highest when selling at weaning (95–96%). The net returns were also highest when selling at weaning ($115/head). Higher feed costs is a driver of decreased net returns to retaining calves post-weaning. Therefore, a profit-maximizing producer would sell their spring-born calves at weaning. Also, by first-degree stochastic dominance, the utility-maximizing producer would also sell their spring-born calves at weaning. This finding matches the common production system chosen by producers in the Southeast region. Additionally, studies have shown spring calving is the predominant calving season (Caldwell et al., 2013) and most producers sell spring-born calves at weaning (McBride and Mathews, 2011; Asem-Hiablie et al., 2018).

Conclusion

This study determined the profit-maximizing stocker length for fall and spring-born calves within herds of 30, 60, and 90 head of cows. The possible stocker lengths were 30, 60, 90, 120, and 150 days post-weaning along with selling calves at weaning. A simulation model was developed that considered stochastic feed prices, cattle weights, and price premiums for cattle to determine an integrated cow–calf and stocker producer's optimal decisions.

We find that factors such as per head weight, lot size, hide color, sex, and if cattle were raised on the farm which is selling the cattle impact the sale price. The spring calving herd was found to have a higher net return than the fall calving herd and the net returns and probability of being profitability increase as the herd size increases. For the fall calving herd, the profit and utility-maximizing decision would be retained weaned calves for 150-day stocker interval. On the other hand, the producer with the spring-born calves would prefer to sell these calves at weaning.

These results could be used by producers to allow for more informed decision-making that involves multiple aspects and considerations of successful beef cattle production and marketing. This study considers both risk and returns in the analysis of retaining calves. This methodology will allow for impactful extension education by presenting both these two critical considerations for relevant scenarios producers are confronted.

Data availability statement. The animal data that support the findings of this study are available on request from the corresponding author, C.N.B. The data are not publicly available due to these data coming from field work. The sale data is private and owned by the Lower Middle Tennessee Sale.

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