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Optimal Stocker Production Strategies for Spring and Fall Calving Cow Herds

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To the Graduate Council:

I am submitting herewith a thesis written by Cora Beth Key entitled "Optimal Stocker Production Strategies for Spring and Fall Calving Cow Herds." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural and Resource Economics.

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Optimal Stocker Production Strategies for Spring and Fall Calving Cow Herd

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Abstract

This thesis consists of two chapters discussing the economics of raising stocker beef cattle in the southeast United States. The objective of the first chapter is to estimate supplemental feed cost for spring-calving cows, spring-born stockers, cows calving in the fall, and fall-born stockers, while considering the seasonality of forage production and nutritional needs. The chapter explores ways producers can lower their feed costs and demonstrates the importance of managing hay expenses for cattle producers to control cost. The objective of chapter two is to determine the profit-maximizing stocker period in an integrated cow-calf and stocker operation with both fall- and spring- calving scenarios. Seasonal cattle prices are considered to determine optimal grazing periods and feeding lengths for fall- and spring-born weaned calves across different herd sizes. A simulation is developed to evaluate the probability of producers being profitable in background or stocker their cattle. These results may be used by Extension personnel to assist beef cattle producers in lowering feed costs, increasing profits, and managing price and production risk.

Table of Contents

List of Tables

List of Figures

Introduction

United States (US) beef production is a complex supply chain that includes several segmented phases of cattle production. These phases of production are typically defined as cow-calf, stocker/backgrounding, cattle feeders, and packers/processors (US Department of Agriculture [USDA] Economic Research Service [ERS] 2021a). Cow-calf production is defined as the management of cows through breeding, gestation, and calving as well as calves for at least six months or until the calves weigh 400 to 700 pounds (USDA ERS 2021b). Stocker production aims to add 200 to 400 pounds to weaned calves for a three to eight-month period, and feedlot or finishing is feeding calves to achieve a slaughter weight of 1,100 to 1,500 pounds (USDA ERS 2021b). Within each phase of production, producers are confronted with unique challenges related to market structures (e.g., auctions, formula pricing, forward contracts, cash negotiated) and regional conditions (e.g., cattle supply, distance to buyer), which impacts production and profitability.

The success and failure of these phases of production are also dependent on the region of the US the producer is located. McBride and Mathews (2011) showed the West, North Central, and Northern Plains regions of the US were primarily a mixture of cow-calf and backgrounding or stocker operations, while the Southern Plains and Southeast mainly participating in the cow-calf phases. They reported that 70% of all Southeast operations and 69% of all Southern Plains operations sold calves at weaning. It is worth recognizing this study also showed the Southern Plains and Southeast regions had the highest number of cattle but the lowest net farm income.

While the Southern Plains and Southeast are similar in production phases, the regions are different in terms of managing forage and feed costs. Much of the Southeast is well-suited for grazing cattle on tall fescue, which has two growing seasons in a production year (Wolf, Brown, and Blaser 1979). Thus, most of the beef cattle economic research in the Southeast primarily focuses on various farm management decisions on forage-based, cow-calf production operations. Less attention has been focused on the economics of stocker production in this region. However, a few studies have found stocker production can be profitable in the Southeast (Buccola, Bentley, and Jessee 1980; Wang et al. 2001; Anderson et al. 2004; Rankins and Prevatt 2013). Furthermore, studies across the US, mostly the Northern Plains, North Central, and West regions, have shown stocker programs can add value to cattle through preconditioning programs (Dhuyvetter, Bryant, and Blasi 2005; Coatney, Menkhaus, and Schmitz 1996; Schumacher, Schroeder, and Tonsor 2012; Williams et al. 2012; Williams et al. 2014; Zimmerman et al. 2012; Martinez, Boyer, and Burdine 2021; Garber et al. 2022). By selling at weaning, producers in the Southeast may be losing an opportunity to add value to their calves and increase revenue.

However, retaining weaned calves in a backgrounding or stocker operation can be a complicated decision that involves considering the increased production cost and seasonality of cattle prices. Chapter one of this thesis focuses on nutritional costs for an integrated cow-calf and stocker operation when calving in the spring and fall. Chapter two of the thesis will determine the optimal length of time to retain weaned calves to feed and graze, in an integrated cow-calf and stocker operation.

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Chapter One: Spring and Fall Calving Herd Feed Costs for an Integrated Cow-Calf and Stocker Operation

Abstract

The first chapter in this thesis set out to find the estimated feed cost for an integrated cow calf and stocker operation that retains calves after weaning. The feed costs are analyzed separately for a spring and fall calving cow herd as well as stockers as nutrition demands differ with production phase. Also, in the Southeast forage availability varies throughout the year, and can be a sufficient and cost-effective nutrient supply depending upon on the calving season. The objective of the chapter is to provide Southeast beef cattle producers with information that can be used to lower the feed cost on their operation which could potentially increase the net returns of beef cattle producers in the region. This chapter highlights the importance of reducing hay costs and the impact high hay prices have on cost by comparing the results of low and high hay price scenarios. These results will serve as a tool to aid Extension services in guiding and assisting local beef cattle producers who are looking to control the feed cost on their operations

Introduction

In the Southeast, cattle production is a pasture-based grazing system that relies on tall fescue *(festuca arundinacea).* Tall fescue is a hardy cool-season grass that grows from late February or early March to May with additional growth occurring late September to November (Wolf, Brown, and Blazer 1979) (Figure 1.1 in Appendix A). Along with the two growing seasons, tall fescue has the ability to grow under adverse weather conditions (Wolf, Brown, and Blazer 1979). Thus, tall fescue is the primary pasture and hay forage on over 35 million acres that accounts for 40% of cow-calf operations in the United States (US), which is commonly referred to as the Fescue Belt.[1] However, tall fescue is dormant during both the winter and summer months, which can make managing grazing during these time periods challenging for producers. One way to address this challenge is provide supplemental hay and feed.

Feed costs commonly account for around half of the total variable costs in cow-calf production (Short 2001; Gillespie et al. 2007; Henry et al. 2016). Ramsey et al. (2015) examined factors affecting beef cowherd costs, production, and profits utilizing standardized performance analysis data. They showed beef cattle operations with higher feed costs were associated with lower profits. They stated producers need to ensure the additional feed is generating more revenue through increased weights than the cost of the feed input itself. Thus, managing feed costs are vital for beef cattle profitability, particularly in the Southeast US where net returns to beef cattle production are low (McBride and Mathews 2011).

The challenge of managing grazing or minimizing feed costs can be exacerbated by other factors such as calving season within a cow herd. In the Southeast, typically calves are born in

[1] The Fescue Belt includes all or portions of 15 states: Alabama, Arkansas, Georgia, Illinois, Indiana, Kentucky, Mississippi, Missouri, North Carolina, Ohio, Oklahoma, Tennessee, South Carolina, Virginia, and West Virginia (Bussard and Aiken 2012).

either the spring or the fall (Caldwell et al. 2013; Campbell et al. 2013; Asem-Hiablie et al. 2018). Most cow-calf producers using a defined calving season in the Southeast US follow a spring calving season, beginning in January, and ending mid-March (Caldwell et al. 2013; Campbell et al. 2013). Cows are typically bred in late spring-early summer (May and June) and calves are weaned in the fall (September and October). On the other hand, fall calving occurs between mid-September and mid-November and fall-calving cows are bred in the winter (December and January) and calves are weaned in the spring (April and May) (Caldwell et al. 2013; Campbell et al. 2013).

Considering the timing of forage production and calving season is important when trying to reduce feed costs. Table 1.1 in Appendix A shows an example of the timing of cow breeding, calving, nursing, and weaning for a fall and spring calving season. For the fall calving season, a producer with an integrated cow-calf and stocker production system would have cows with nursing calves that are being re-bred along with feeder cattle from the previous calf-crop being fed during the winter. On the other hand, the spring calving herd will have cows re-breeding in the summer along with calves from the previous year's calf crop being fed as stocker cattle. Both periods of tall fescue growth are slow; thus, the cost of supplement feed could increase.

Hay is typically the low-cost supplemental feed chosen by producers in this region when forage production slows (Short 2001; Griffith et al. 2019; Boyer et al. 2020). Short (2001) reported that livestock operations in the tall fescue belt fed more harvested forage than operations in other regions, which could contribute to the low net returns. Boyer et al. (2020) reported that, on average, Tennessee cattle producers feed hay 143 days of the year, most of which occurred in the winter months. However, hay costs will depend on a range of factors like type of bale, bale weight, quality, waste, and regional supply and demand. McCullock, Davidson, and Robb (2014) estimated how hay price is impacted by various hay characteristics and found that quality grades and bale size impacted prices. Peake et al. (2019) evaluated the effect of attributes and quality on hay price in Kentucky. This Southeast study found that small square bales have a higher sale price than larger round bales in the region where beef cattle, specifically cow-calf production, is prevalent. They also note that quality has a lesser effect on price in large round bales, which are purchased by beef cattle producers. Rudstrom (2004) analyzed the importance of hay quality, bale size, and type/variety of hay on the market price. The study found that higher moisture levels could decrease price, but price premiums could be achieved from a higher relative feed value and an earlier cutting, resulting in less mature hay. They found small square bales had price premiums compared to large round bales. Besides the size and quality of hay, regional factors like drought can impact the supply and demand of available hay. Schaub and Finger (2020) reported a drought will increase hay prices by 15% and have a year-long effect on the market. Hay can be utilized as an important supplement to provide cattle with a cost-effective nutrition source, when purchased following these market fundamentals.

Like hay, grain feed is another common source for supplementation for Southeast beef cattle producers (Prevatt et al. 2001; Henry et al. 2016; Zumbaugh 2020). Henry et al. (2016) compared eight common feed ingredients found in Tennessee to determine the least cost rations for fall and spring calving herds. They reported the least-cost rations included the five feed ingredients of hay, corn gluten feed, corn silage, rice bran, and wheat middlings. However, corn silage and corn gluten were the most widely accessible feedstuffs for producers in the area. This study also reports that the fall calving herd had a higher feed cost than the spring calving herd (Henry et al. 2016).

While these studies are insightful for estimating Southeast cow feed costs when forage is limited, little is known about the feed costs in the Southeast for an integrated cow-calf and stocker operation. 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. Building on the idea of retaining weaned calves in a stocker operation to add value, a logical first step is to accurately estimate feed costs, considering seasonal feed prices, and analyzing ways to lower these costs.

Therefore, the objective of this chapter is to determine the feed costs for a spring and fall calving herd with an integrated stocker period for their retained weaned calves. This analysis considers monthly nutritional demands for cows and calves, based on production stage, along with pasture growth to develop supplemental feed rations that are targeted at a desired rate of gain. This analysis considers the seasonality of feed prices, thus, can show how producers could save feed costs by purchasing supplement feed when feed costs are at their lowest. The results will provide insight into implementing an integrated cow-calf and stocker production system and can serve as a guide to producers on developing a profitable system on their farm.

Data and Methods

Ration Development

The nutrient requirements for beef cattle range among a variation that can be predicted relative to the production cycle, which is, the time of breeding, weaning, and calving. The production cycle in a cow-calf operation follows a twelve-month season that affects the economic and natural methods of supplying the cattle with adequate nutrients to maintain successful production performance for growth, maintenance, and various other production levels.

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 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 from the literature. These rations utilize a hay and supplementation ration that is supplied when forage and hay are inefficient to meet the nutritional demands at various times of the year. Acreage for each of the three herd sizes is scaled up in the nutritional model to allow for appropriate stocking rates and forage availability according to the NRC. These scenarios are founded on a tall fescue forage system in the Southeast; with annual forages not planted. According to the literature, the typical ADG for the Kentucky 31 variety of tall fescue is 1.5 to 2.0 lbs/day (Stuedemann and Hoveland 1988; Crawford et al. 1989; Shoup, Kilgore, and Brazle 2010; Johnson et al. 2019). From this information we can calculate rations for cows and retained stocker calves for each calving herd.

Spring Rations

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 needed to be supplemented per head per day, on an as-fed basis, following the feeding season, would be 40 lbs/head/day in December, 40 lbs/head/day in January, 25 lbs/head/day in February, and 25 lbs/head/day in March. In addition to hay, a 50:50 mixture of corn gluten feed and soybean hulls, accumulating to 90% DM, 71% TDN, and 15.6% CP, would be needed. This ration and feed ingredients were selected due to availability to producers, simplicity, price, and nutrient quality (Poore, Johns, and Burris 2002). The amount needed for this feed in lbs/head/day, on an as fed basis, is 16 in both months February and March. This is under the assumption that appropriate stocking rates were followed and adapted throughout the year to allow cattle to consume the total amount of forage DM required by the NRC guidelines.

The next rations were formulated for stocker calves born in the spring calving herd and then retained past weaning. All stockers would need supplementation during six months (October, November, December, January, February, and March) of the stocker period. Rations are as follows: in January, the amount of hay needed to be supplemented, on an as-fed basis would be 8 lbs/head/day with an additional 12 lbs/head/day of the 50:50 mixture containing corn gluten feed and soybean hulls. The first month of supplementation after calves are weaned will be October with 10 lbs/head/day of 50:50 mixture and will increase to 11 lbs/head/day mixture in November as the cattle grow to a heavier weight. In December calves will need to be supplied with 8 lbs/head/day of hay and 11 lbs/head/day50:50 mixture fed. If calves are kept, during

February and March, the amount of hay needed to be supplemented, on an as-fed basis would be nine lbs/head/day with an additional 13 lbs/head/day of 50:50 mixture.

Fall Rations

Following the same protocol as the spring calving cows, the fall calving cows will receive supplementation for five months due to limited forage availability compared to the timing of production. The months that supplementation would be needed is January, February, March, November, and December. The amount of hay that would need to be supplemented, on an as-fed basis, following the feeding season is 25 lbs/head/day for both November, December, January, and February and 40 lbs/head/day in March,. The amount needed for the 50:50 mixture is 16 lbs/head/day in each of the months of November, December, January, and February.

Fall stocker calves will need to be supplied with supplementation of the 50:50 mixture from June to November for a total of six months, or until completion of their stocker period. Hay is not required for fall stocker calves as pasture is a sufficient forage source during these months. The amounts needed of the rations are 10 lbs/head/day in June, 11 lbs/head/day in July and August, 12 lbs/head/day in September, and 13 lbs/head/day in both October and November.

Feedstuff Cost

Feedstuff prices were collected to develop ration input costs. The US average hay price was \$129/ton for 2016 to 2020 (USDA National Agricultural Statistics Service (NASS) 2021). However, as mentioned, 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 seasonal adjusted, regional hay price was determined by developing a seasonal index created by using national hay prices (Figure 1.2 in Appendix A). US monthly hay prices were collected from 2016 to 2020. The index was developed using January as a base month to show price fluctuated across months. This monthly price index was applied to the regional price of hay to build a seasonal hay price that is specific to local average market prices. Due to limited reported transactions in the region, we selected two prices of $30/ton (low-cost scenario) and $60/ton (high-cost scenario) based on producer practice. 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 1.2 in Appendix A shows monthly average feedstuff prices over the past five years (2016 to 2020) for corn gluten feed, soybean hulls, and hay. The months with the highest prices are February for hay ($30.76/ton or $61.29/ton), January for corn gluten feed ($146.18/ton), and February for soybean hulls ($124.53/ton)

Production Scenarios

Feed costs are evaluated for several scenarios including spring and fall calving. The low hay price scenario is defined as when the base hay price of $30/ton and the high hay price scenario is defined when hay price is $60/ton. There are also scenarios of when a producer purchases hay as needed or in months when prices are the lowest. Finally, these costs are compared to the cost of producing hay. The University of Tennessee Extension budget assumes a hay cost of $162.11/head for a cow-calf operation, and a cost of $52.54/head for a stocker operation (University of Tennessee Department of Agricultural and Resource Economics 2021). Estimated purchased hay costs from the index are compared to these budget estimates of producing hay. Thus, the analysis has seven scenarios (2 calving seasons x 2 hay prices x 2 purchasing times x 1 produce on-farm hay). For these scenarios, this study considers a 90-day stocker period as a baseline stocker period.

Additionally, analysis is done to show how feed costs change as stocker periods changes. For the spring and fall calving season, we explore changes in feed costs for the 30-to-150-day stocker period in 30-day increments (e.g., 30, 60, 90, 120, 150). These results show both spring and fall calving seasons under the low and high hay prices scenarios for the 30 to 150 days stocker period, giving four additional scenarios (2 calving seasons x 2 hay prices).

Results

Low Hay Price Scenario

When purchasing feed as needed and when the base hay price is $30/ton, the annual feed cost for spring calving cows is $119.22/head and $186.60/head for fall calving cows. Assuming a 90-day stocker period, the average feed cost was $69.69/head for the spring born calf and $65.64/head for fall born calf (Table 1.3 in Appendix A). Fall calving cows have a higher feed cost of $67.38/head than the spring calving cows, which is comparable to the results other studies (Henry et al. 2016; Griffith, Boyer, and DeLong 2019; Boyer, Griffith, and Pohler 2020; Boyer, Griffith, and DeLong 2020; Griffith, Boyer and Pohler 2020). This is likely explained by the timing of breeding for fall calving cows and forage production. However, fall born calves entering a stocker program have a lower feed cost than spring born calves by $4.05/head. Fall born stocker cattle have a lower feed cost because the stocker period aligns with forage production, while spring born calves start their stocker period when forage production is slowing. The fall calving herd with an integrated cow-calf and stocker operation with a 90-day stocker period would have an average of $63.34/head higher feed cost than a spring calving herd.

The months with the lowest feed prices are September for hay, February for corn gluten feed, and November for soybean hulls. Assuming feed is purchased in these low-cost months, the annual feed cost for spring calving cows was $114.54/head and $179.45/head for fall calving cows. For a 90-day stocker period, the feed costs were $68.22/head for a spring born stockers and $64.71/head for fall born stockers. The same patterns were found here as when feed was purchased as needed. Compared to buying feed stuff as needed, feed costs declined $4.68/head for spring calving cows, $7.15/head for fall calving cows, $1.47/head for spring born stockers, and $0.93/head for fall born stockers. Overall, buying feed when prices are at the lowest a producer with an integrated cow-calf and stocker operation would save $6.15/head for spring calving operations and $8.08/head for fall calving operations.

High Hay Price Scenario

Feed costs were also estimated with a base hay price of $60/ton or the high hay price scenario. The annual ration cost when feedstuffs were purchased as needed was $177.81/head for spring calving cows and $249.52/head for fall calving cows. The 90-day stocker operation feed costs were $73.48/head for spring born stockers and $65.64/head for fall born stockers (Table 1.4). If the producer purchased feed in months when prices are at the lowest, the annual ration cost for spring calving cows was $169.01/head, $241.13/head for fall calving cows, and $71.80/head for spring born stockers, and $64.71/head for fall born stockers (Table 1.4 in Appendix A). Purchasing when feed prices were lowest reduced costs by $8.80/head for spring calving cows, $8.39/head for fall calving cows, and $1.69/head for spring born stockers, and $0.93/head for fall born stockers (Table 4). In total, a spring calving operation saves $10.49/head by purchasing feed when prices are lowest, and a fall calving operation saves $9.32/head. This is the opposite of the low hay price scenario.

Going from the low to high hay price scenario, feed costs increase by $58.59/head for spring calving cows ($177.81-$119.22), $62.92/head for fall calving cows ($315.17-$252.24), and $3.80/head for spring born stockers ($73.48-$69.69). There is no difference in the ration cost for fall born stockers since their ration does not include hay. Overall, when prices increase for hay, the annual feed costs increase $62.38/head for spring calving operation and $62.92/head for the fall calving operation, which relies less on hay as a feed source. These results demonstrate how vital reducing hay feed costs are to remaining profitable.

Buying vs Producing Hay

Compared to the feed cost when hay is produced on-farm while purchasing other feedstuffs as needed. The total annual ration cost, with feeding hay produced on-farm with purchased mixture feedstuffs as needed, was $222.74/head for spring calving cows and $285.78/head for fall calving cows. For a 90-day stocker period, the feed costs were $118.43/head for spring born stockers and $65.54/head for fall born stockers (Figure 1.3 in Appendix A). On-farm hay production has a higher cost than buying hay (Table 1.5 in Appendix A). Even when hay costs are $60/ton hay, buying hay had a lower feed cost than feeding your produced on-farm hay. However, these calculations do not consider the value of reducing feed cost risk from purchasing hay. There are risks associated with buying hay from outside sources including droughts leading to shortages and inflated prices, inappropriate moisture levels, and the unknown variability of the quality and content (Lacefield et al. 1998). However, due to limited hay testing in our region these same risks can be found when feeding hay produced on the farm.

Stocker Feed Costs

The analysis also considered the scenarios where the length of stocker period ranged from 30 to 150 days. Figures 1.4 and 1.5 in Appendix A show monthly feed costs for spring born and fall born stockers from 30 to 150 days, respectively. As expected, the increased the number of days the stocker period the higher the feed cost. When starting at a 30-day stocker length and adding an additional 30-day time (month) up to 150 days, the additional feed cost ranges from $20.61/head from zero to 30 days to $28.67/head from 120 to 150 days for the spring born stockers. Fall born stocker feed cost ranged from $19.95/head from zero to 30 days to $24.47/head from 120 to 150 days. Fall-born stockers have the lower additional feed cost and variability from adding days to the stocker period.

Assuming a 1.7 ADG for stocker calves, stocker cattle were expected to gain 51 pound/head every 30 days with a total weight gain of 255 pound/head for the 150-day period. The breakeven price of gain considering only the feed costs is calculated by dividing the monthly feed cost by the expected weight gain. These estimates represent the cost of gain per month. The monthly breakeven prices for both spring and fall born stockers increase from start date to end date (Table 1.6 in Appendix A). These calculations were made using a $30/ton hay price with hay and feed purchased as needed. The monthly breakeven prices range from $0.33/pound to $0.46/pound for the fall born calves and $0.34/pound to $0.48/pound for spring born calves. For example, if the price of stocker cattle is $1.25/cwt, $0.33/cwt of the price received for fall born stockers sold in June would be to cover the feed cost that month. That is, feed costs account for about 25% of the total sale price, with the remaining production costs including herd health management, vaccinations, land, labor, mineral, and other associated expense. These values demonstrate how costs of gain change over the months and increase over time.

Another way to evaluate these results is to consider the daily cost of feed for stocker cattle born in the spring or fall calving herd. That is, the cost of feed by month can be divided by the number of days to get a cost per head per day. Daily feed costs per head are shown in Table 1.7 in Appendix A. These calculations were made using a $30/ton hay price with hay and feed purchased as needed. The cost increases from start of the stocker period to end date. The costs range from $0.66/head/day to $0.89/head/day for fall born cattle and $0.71/head/day to $0.98/head/day for spring born calves. These values demonstrate the importance of managing grazing days to reduce costs. Extending grazing through various practices, including planting annual forages and stock piling tall fescue, will lower the number of days feeding and reduce feed costs. This research assumes a 120-day hay feeding season for both calving herds.

Conclusions

Feed costs for an integrated cow-calf and stocker operation have a large impact on the profitability of the operation. Reducing feed cost is a complex decision that involves considering calving season and many other production and management factors. As a result, ration amounts and cost, will vary for spring calving cows, spring born stocker cattle, fall calving cows, and fall born stocker cattle. Also, the length of the stocker period also affects the feed cost and breakeven point for stocker cattle. In the Southeast, feedstuff cost varies by season due to the growth and availability of forages when compared to the timeline of cattle production. The objective of this chapter was to evaluate feed cost by calving season for an integrated operation to determine what is more economically efficient for Southeast beef cattle producers; while, considering the timing of cattle and forage production, seasonality of feed prices, and the length of the stocker period.

The fall calving season has higher feed cost than the spring calving herd for cows. However, feed costs are higher for spring born stocker cattle compared to fall born stocker cattle. It is more cost effective in all scenarios to purchase feed in the lowest price month if on the farm storage is sufficient. The results show that relative to producing hay on-farm, purchasing hay might be more cost-effective.

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Appendix A

Table 1.1 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 1.2 Monthly average feedstuff prices over the past five years (2016 to 2020) for corn gluten feed, soybean hulls, and hay

Month	Hay Low-Cost[1]	Hay High-Cost[2]	Corn Gluten Feed	Soybean Hulls
January	$30.00	$60.00	$146.18	$123.72
February	$30.76	$61.29	$139.50	$124.53
March	$30.68	$61.20	$140.22	$124.11
April	$30.72	$61.20	$141.34	$123.79
May	$29.77	$60.28	$142.04	$123.76
June	$28.78	$58.53	$142.42	$123.55
July	$28.52	$57.98	$142.43	$123.18
August	$28.21	$58.16	$142.36	$122.74
September	$27.49	$56.04	$142.79	$122.48
October	$28.86	$58.71	$143.58	$122.31
November	$29.62	$60.28	$144.45	$122.27
December	$29.28	$59.45	$145.43	$122.36

[1]Hay purchased at $30/ton

[2]Hay purchased at $60/ton

Table 1.3 Purchasing feedstuffs assuming low hay cost scenario as needed compared to the lowest available price month ($/head)

	Purchased as needed	Purchased in Low Cost Month[1]	Difference
Spring Cows	$119.22	$114.54	$4.68
Spring Stockers	$69.69	$68.22	$1.47
Total	$188.91	$182.76	$6.15
Fall Cows	$186.60	$179.45	$7.15
Fall Stockers	$65.64	$64.71	$0.93
Total	$252.24	$244.16	$8.08

[1]Lowest cost months are September for hay, February for corn gluten feed, and November for soybean hulls

Table 1.4 Purchasing feedstuffs assuming high hay cost scenario as needed compared to the lowest available price month ($/head)

	Purchased as needed	Purchased in Low Cost Month[1]	Difference
Spring Cows	$177.81	$169.01	$8.80
Spring Stockers	$73.48	$71.80	$1.69
Total	$251.29	$240.80	$10.49
Fall Cows	$249.52	$241.13	$8.39
Fall Stockers	$65.64	$64.71	$0.93
Total	$315.17	$305.84	$9.32

[1]Lowest cost months are September for hay, February for corn gluten feed, and November for soybean hulls

Table 1.5 Total annual feed cost ($/head) comparisons of producing and buying hay in the month needed

	Hay Low-Cost[1]	Hay High-Cost[2]	Hay Production
Spring Cows	$119.22	$177.81	$222.74
Spring Stockers	$69.69	$73.48	$118.43
Total	$188.91	$251.29	$341.17
Fall Cows	$186.60	$249.52	$285.78
Fall Stockers	$65.64	$65.64	$65.64
Total	$252.24	$315.17	$351.42

[1]Hay purchased at $30/ton

[2]Hay purchased at $60/ton

Table 1.6 Stocker period length break even amounts by calving season ($/lb)

Month	Fall Breakeven ($/lb)	Spring Breakeven ($/lb)
January	-	$0.47
February	-	$0.48
March	-	-
April	-	-
May	-	-
June	$0.33	-
July	$0.38	-
August	$0.38	-
September	$0.41	-
October	$0.46	$0.34
November	-	$0.37
December	-	$0.45

Note: Hay purchased at $30/ton and feed and hay purchased as needed

Table 1.7 Daily cost for stocker period ($/head/day)

Month	Fall Breakeven $/head/day	Spring Breakeven $/head/day
January	-	$0.87
February	-	$0.98
March	-	-
April	-	-
May	-	-
June	$0.66	-
July	$0.74	-
August	$0.74	-
September	$0.81	-
October	$0.89	$0.71
November	-	$0.82
December	-	$0.82

Note: Hay purchased at $30/ton and feed and hay purchases as needed

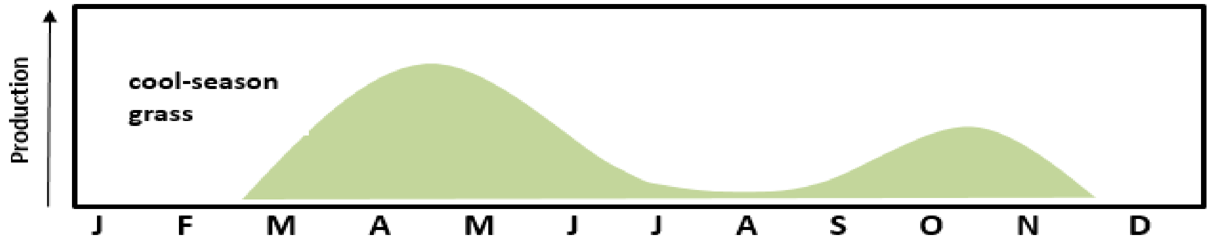

Figure 1.1 The average tall fescue growth curve in the Southeastern United States

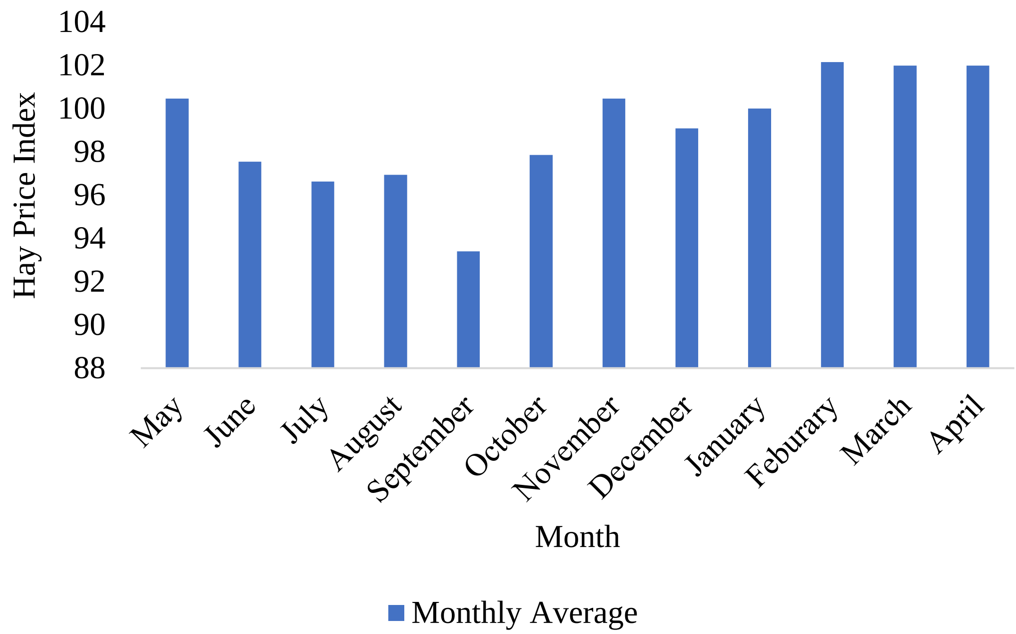

Figure 1.2 Seasonal hay price index with monthly average hay prices

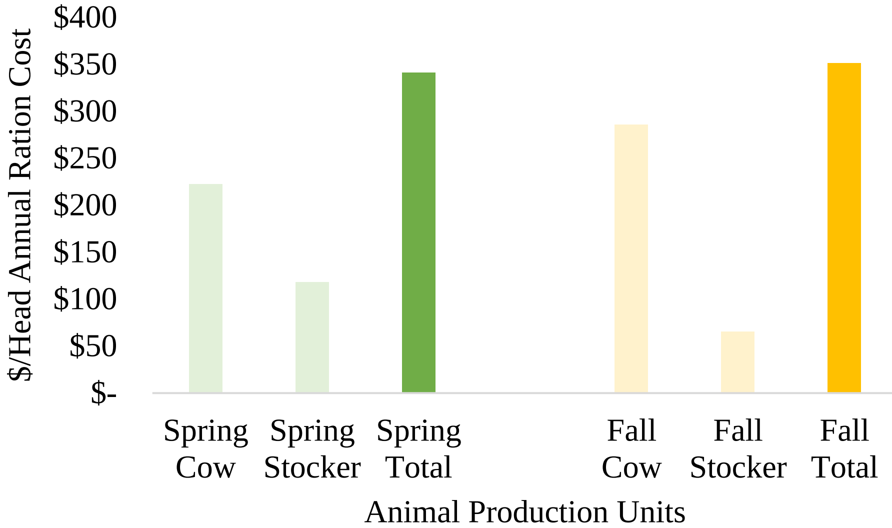

Figure 1.3 The total annual cost ($/head) of Southeast beef cattle rations with hay production

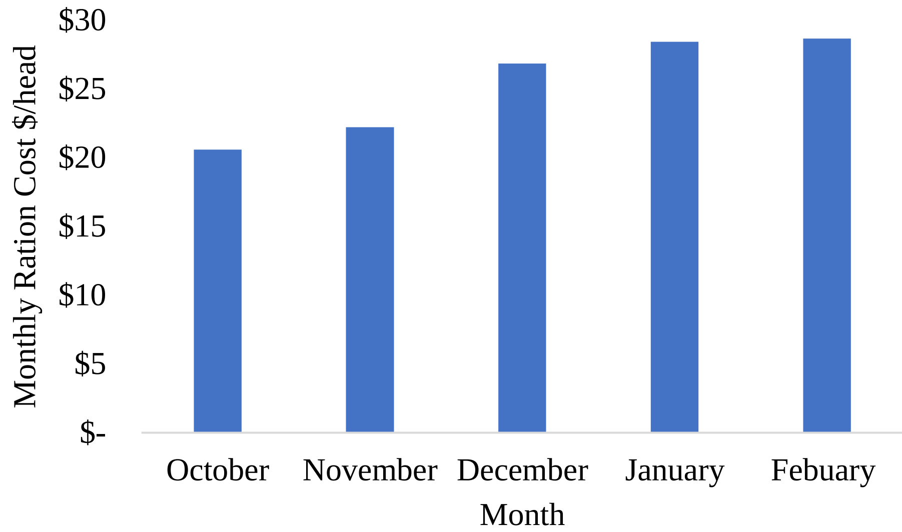

Figure 1.4 The cost of feeding spring stocker cattle over time (30 to 150 days)

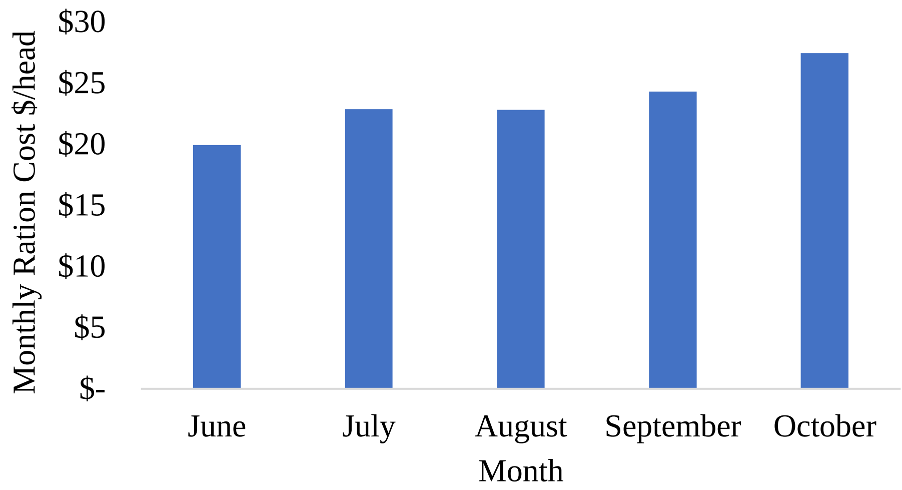

Figure 1.5 The cost of feeding fall stocker cattle over time (30 to 150 days)

Chapter Two: Optimal Integrated Cow-Calf and Stocker Operation Management

Abstract

Profit maximization was examined in an integrated cow-cow and stocker cattle operation in the Southeast United States. Beef cattle producers in the region that follow a spring or fall calving herd can make decisions on their calving season, herd size, and lengths to retained weaned calves before selling. This research then analyzes these scenarios along with the seasonality of feed and cattle prices to better understand the optimal lengths of stocker retention for both herds. This study uses a simulation model to account for seasonality and variability and then determines the probability of a producer's operation being profitable following the scenario. The results of this chapter can be utilized by Extension services to aid local beef cattle producers in reducing their feed cost, increasing the sale price of their cattle through price management and sale month, as well as increase he profits and net returns of the farm with neutral production risk.

Introduction

The Southeast United States (US) has more beef cattle operations than any other region in the US and it is the second-highest region in terms of percent of US beef cows (McBride and Mathews 2011). These herds, however, are smaller than other regions in terms of cattle per operation (McBride and Mathews 2011). These are primarily forage-based, cow-calf operations that sell calves at weaning. 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 lbs/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) reported the value of cattle production was lower in the Southeast than other regions.

There is likely a connection between producers selling calves at weaning and the value of cattle production being low. By selling at weaning, producers in the Southeast may be losing an opportunity to add value to their calves and increase revenue (Buccola, Bentley, and Jesse 1980; Wang et al. 2001; Anderson et al. 2004; Rankins and Prevatt 2013). However, stocker production can be complicated to manage risk and maximize profits. Peel (2006) described several key measurements for analyzing the economics of stocker production, which included the price-weight relation, the value of weight gained, and the cost of production. The price-weight relationship is the well-documented relationship of cattle prices declining non-linearly as weight increases (Dhuyvetter and Schroeder 2000; Burdine et al. 2014; Williams et al. 2012; Martinez, Boyer, and Burdine 2021). This means lighter cattle sell for a higher price than heavier cattle, but revenue could be higher for heavier calves because pounds sold also increased. Value of gain, the second key measurement, is found by dividing the gross margins by the total weight gain. Gross margins are found by multiplying the price of the cattle at the end of the stocker period by the ending weight minus the price at the beginning minus the beginning weight. This indicates the value of pounds gain for cattle during the stocker period. Last, the cost of production needs to be considered when make profitable production decision. Cost of production will depend on factors like health, forage, feed, and other expenses like interest and labor. These costs need to be compared to the value of gain to make sure the cost of gain is not greater than the value of gain. These three measurements need to be calculated to determine the profitability of a stocker operation.

Several studies have considered these measurements when conducting economic analyses of various stocker operations. Buccola et al. (1980) determined the profit-maximizing stocker operation, considering price-weight relationships and different weight gains. They found that when feeder cattle prices are high, it is optimal to sell calves at a lighter weight. 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 study analyzed these scenarios assuming a representative farm in Georgia that sold feeder cattle in May after a 181-day stocking period. The cattle were assumed to have a 1.65 lbs/day average daily gain (ADG) and started at 450 pounds. The optimal outcome of this study depended on the scenario and the riskiness of the producer, but stocking cattle was profitable. The study did find that implementing a risk management strategy along with stocker cattle operation could be optimal depending on their risk aversion levels.

Anderson et al. (2004) examined various contractual agreements for grazing stocker cattle compared to owning stocker cattle in the Southeast. This study used production data from

Mississippi and stocker cattle prices from Georgia to calculate net returns for each scenario. A stochastic simulation analysis was developed to compare the distribution of net returns. The study found that owning stocker cattle resulted in the highest profit but was 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.

While these studies are informative, they do not consider various lengths of time to graze feeder cattle and the subsequent month the calves are marketed. Studies have shown that cow-calf producers in the Southeast could calve in the spring and fall. Fall calving has been found to be more profitable than spring calving due to higher calf prices at weaning (Caldwell et al. 2013; Henry et al. 2016; Griffith, Boyer, and DeLong, 2019; Boyer, Griffith, and Pohler 2020; Boyer, Griffith, and DeLong 2020; Griffith, Boyer and Pohler 2020). Calving season and forage production are important when considering an integrated cow-calf and stocker production system. The previous work on stocker economics has not considered seasonal changes that accompany various calving seasons. More research is needed on seasonal impacts of calving season like forage production, feed cost, and feeder cattle prices impacting the profitability of a feeder cattle operation for various herd sizes and lengths of time of retaining ownership of weaned calves.

Therefore, the objective of this chapter is to determine the profit-maximizing stocker length for fall and spring born calves within herds of 30, 60, 90 cow herds. The possible stocker period of 30-, 60-, 90-, 120-, and 150-day post-weaning along with selling calves at weaning. A simulation model is developed that considers stochastic feed prices, cattle weight, and price premiums for cattle to also determine risk-averse producer optimal decision. These results could be used by producers to allow for better informed decision making that involves multiple aspects and considerations of successful beef cattle production and marketing.

Economic Framework

Profit Maximization

Revenue from a cow-calf operation is received from selling steers, heifers, and culled cows. Various factors can provide unexpected shocks to cattle prices, but historically, there are several factors that are expected to impact cattle prices. For example, the production cycle impacts when calves are typically marketed, and prices are expected to decline when supply increases. Also, prices will fluctuate by weight classes, physical characteristics, and total weight of a lot of cattle sold (Martinez, Boyer, and Burdine 2021). Weaning weights will vary across the calving seasons (Caldwell et al. 2013; Campbell et al. 2013) along with other factors. Therefore, revenue from an integrated cow-calf and stocker operation would depend on calving season and the number of days stocking cattle with uncertainty of the weight and price received at marketing.

Typical 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). Subtracting the cost from the revenue gives the annual net returns or profit per head.

Assume the producer is a risk-neutral, profit-maximizer, the producer would select the number of days to retain weaned calves to feed or graze that would maximize their annual net returns. 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 possible stocker period of 30-, 60-, 90-, 120-, and 150-day post-weaning. The producer's decision is generally expressed as:

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

were π_{ikl} are the expected annual net returns ($/head) for the i^{th} calving season (*i* = spring, fall) for herd size *k* (*k* = 30, 60, 90 head) for stocker period *l* (*l* = selling at weaning, 30-day, 60-day, 90-day, 120-day, and 150-day); p^s_{ikl} is the price of steer calves ($/pound); y^s_{ikl} is the weight of the steer calves (pound/head); WR is the weaning rate $0 \leq WR \leq 1$; p^h_{ikl} is the price of the heifer calves ($/pound); y^h_{ikl} is the weight of heifer calves (pound/head); RR is the replacement rate of the cowherd $0 \leq RR \leq 1$; p^c_i is the price of culled cows ($/pound); y^c_i is the weight of cull cows (pound/head), and PC_{il} is the annualized variable production costs ($/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).

Utility Maximization

A key component to consider in this production system is uncertainty. Specifically, the uncertainty about weaning weight, cattle prices, and feed prices. Monte Carlo simulation model was developed that considers these sources of uncertainty to estimate distributions of net returns. For each calving season and herd size, a simulate was conducted to compare the net returns to selling at weaning to retain weaned calves for the stocker lengths. 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).

Specifying a utility function, we can determine the certainty equivalent (CE), which is defined as the guaranteed net return a producer would rather take than taking an uncertain but potentially higher net return. A risk averse producer would be willing to take a lower expected net return with certainty instead of a higher expected net return with uncertainty. A risk averse producer would select the calving season and calving season length with the highest CE at a given risk aversion level. For our analysis, we used a negative exponential utility function, which specifies a constant absolute risk-aversion coefficient (ARAC) to calculate the CE (Pratt 1964). The ARAC is found by dividing the derivatives of the person's utility function $r_a(r) = -U''(r)/U'(r)$. Hardaker et al. (2004) discusses several advantages of using the negative utility function and recommends this functional form be used.

Data

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. 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. This video sale is hosted as a bid-board auction and occurs once monthly located in Columbia, Tennessee. This is a consignment sale, with most lots coming from Tennessee, Alabama, and North Carolina. This sale markets feeder calves in lots of 50,000 pounds, which is equivalent to a tractor-trailer load. The sale catalog is made available to the public before the sale date and includes owner, number of head, estimated weight per head, USDA feeder calf grades and flesh score, physical animal description, management practices, weighing conditions, shrink, and slide direction. Other information in the dataset includes date sold, lot number, if ownership was split, sex, weight, and price, as well as other factors. Cattle were delivered within 10 days after the conclusion of the sale, and if not were noted in the catalog as delayed delivery.

LMTCA partners with a certified marketing agency that advertises, hosts, and concludes the sale. An individual from the marketing agency is in correspondence with producers to accurately grade and describe the cattle prior to the sale. These descriptions include information such as home raised (this represents the percentage of cattle sold by the original producer), breed characteristics, black hided (percentage of cattle whose hide color was black), defects (scars, pinkeye, ringworm, horns, etc.), and if the lot has been tested for identification of being persistently infected with bovine viral diarrhea virus. Like the description section of the catalog the management practices are, where representatives can display as little as or as much information about how the cattle have been managed. Common examples include herd health information such as the amount and type of vaccinations given, feed rations, and if heifers are guaranteed to be pregnant.

LMTCA sells cattle through a public auction format with bidders being present, on the phone, and through an online bidder platform. The sale price and final weight of the cattle are determined at delivery. The final sale price and weight are received and reported as actual price and weight. Because of this, the price will include shrink or slide adjustments, including the lots that experienced delayed weighing.

Table 2.1 in Appendix B illustrates average prices across months and weight classes. The seasonality of beef cattle prices and the relationship between price and weight is visible from 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.

Animal Production

The animal production data for the spring and fall calving cowherds comes from Ames Plantation Research and Education Center, located in Grand Junction, Tennessee. The production data includes 18 years of records from 1990 to 2008. Both the spring and fall calving herds were made up of commercial and purebred Angus cows. The commercial classified cattle were Angus-influenced that been crossbred with either Simmental or Hereford lines for hybrid vigor. Purebred Angus heifers were retained for replacements and bulls were developed at the plantation, and bulls were purchased for the selection of genetic diversity. The bulls used in the commercial herd were originally purebred Angus. 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.

Both fall and spring herds grazed endophyte-infected tall fescue while receiving supplementation of mineral and corn silage as needed on a year-round basis. The amount of supplementation provided to the cattle was not recorded, which is a limitation to the dataset. Cows were typically culled from the herd if unable to re-breed. However, other cows were culled for low calf performance when compared to the total weight gained of other calves with dams of the same age. During the 19-year time span, the spring herd consisted of 478 cows that totaled 1,534 calves born, and the fall herd totaled 474 cows with 1,727 calves born. These totals of cows and calves represent the number of cows and calves included in the dataset at some point over the 19-year time span of the dataset.

The data on the cows included information of ID, breed, calving herd, sire, dam, and date of birth (DOB). The data on the calves included information of ID, DOB, sex, sire, cow parity, ADG, birth weight (BW), and weaning weight (WW). Weaning weight is typically used as a performance measure of calf growth to provide insight into the dam's mothering ability. However, weaning weights can be influenced by the calf's age, sex, and dam's age, therefore it is customary practice to adjust a calf's weaning weight. Cattle weights were determined by finding the average weaning weights for steer and heifer calves born in the spring and fall calving herds at Ames Plantation. Table 2.2 in Appendix B shows the summary statistics of the birth and weaning weights of calves in the spring and fall herds. These weaning weights were the assumed starting weight of retained weaned calves for feeding periods of 30, 60, 90, 120, or 150 days.

Calf death loss, cow death loss, calving rate, cull percentage, and culled cow weights were not included in these data, thus, 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 (Henry et al. 2016; Griffith, Boyer, and DeLong 2019; Boyer, Griffith, and DeLong 2020). For a herd size of 30 head this equates to 27 total weaned calves, with 14 steers, 10 heifers, and three culled cows being sold. For a herd size of 60 head this equates to 54 total weaned calves, with 27 steers, 21 heifers, and six culled cows being sold. For a herd size of 90 head this equates to 81 total weaned calves, with 41 steers, 31 heifers, and nine culled cows being sold.

Production Cost

The production costs were determined from the University of Tennessee (UT) Department of Agricultural and Resource Economics (AREC) 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 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. These scenarios are based on a tall fescue forage system in the Southeast; with annual forages not planted. These rations utilize a hay and feedstuffs when grazing is insufficient in maintaining the nutritional demands at various times of the year. This 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 lbs/head/day in December, 40 lbs/head/day in January, 25 lbs/head/day in February, 25 lbs/head/day in March. In addition to hay, 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 for this feed on an as fed basis, is 16 lbs/head/day in both months February and March. The fall calving cows will receive supplementation for five months: January, February, March, November, and December. The hay fed on an as-fed basis was 25 lbs/head/day for November, December, January, and February, and40 lbs/head/day in March. The amount needed for the 50:50 mixture was 16 lbs/head/day in each of the months of January, February, November, and December.

The next rations were formulated for stocker calves born in the spring calving herd and retained past weaning. Developing these rations required us to assume an ADG for the weaned and retained stocker calves of 1.7 lb/day. This ADG was based on what other studies have found from stocker cattle grazing in this region (Stuedemann and Hoveland 1988; Crawford et al. 1989; Wang et al. 2001; Shoup, Kilgore, and Brazle 2010; Johnson et al. 2019). This ADG is the target gain the cattle are being fed for according to the ration formulations. This is the assumed target growth rate, but this does not mean cattle will exactly grow at this rate. The literature suggests that there is a time post-weaning when calves can lose weight or not grow (Swiger et al. 1963; Loy 2003; 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, stocker gains and total weights by lot size are shown in table 2.3 in Appendix B.

For the spring-born stockers, rations on an as-fed basis per head per day basis. In January, stockers were fed 8 lbs/head/day of hay with an additional 12 lbs/head/day of the 50:50 mixture in January. During February and March, stockers were given nine lbs/head/day of hay with an additional 13 lbs/head/day of 50:50 mixture. Supplementation should resume in October with 10 lbs/head/day of 50:50 mixture and increase to 11 lbs/head/day 50:50 mixture in November. The final month of supplementation will be December with 8 lbs/head/day of hay and 11 lbs/head/day 50:50 mixture fed. Fall stocker calves were supplemented 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 of the 50:50 mixture is 10 lbs/head/day in June, 11 lbs/head/day in July, 11 lbs/head/day in August, 12 lbs/head/day in September, 13 lbs/head/day in October, and 13 lbs/head/day in November.

Feed and Hay Costs

Hay and feed prices were used to develop ration costs. The US average hay price was $129/ton for 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 seasonal 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.

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 2.4 IN Appendix B shows monthly average feedstuff prices over the past five years (2016 to 2020) for corn gluten feed, soybean hulls, and hay. Most agriculture 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, complements, number of producers, expectations, and any other factor that affects crop productivity like weather (Griffith 2013).

Total Costs

The total costs are found by combing the production cost with the feed and hay cost. Table 2.5 in Appendix B 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.

The production cost for cows was $576/head for fall and spring calving. The production cost of stocker cattle was $102/head for 30 days, $103/head for 60 days, $104/head for 90 days, $105/head for 120 days, and $106/head for 150 days. The annual supplemental feed and hay cost is $229/head for fall calving and $154/head for spring calving cows. The total combined expenses are $805/head for fall calving cows and $730/head for spring calving cows. The estimated supplemental feed and hay cost for fall born stockers is $19/head for 30 days, $40/head for 60 days, $62/head for 90 days, $85/head for 120 days, and $113/head for 150 days. The supplemental feed and hay cost for spring born stockers is $33/head for 30 days, $67/head for 60 days, $74/head for 90 days, $111/head for 120 days, and $141/head for 150 days. The total costs include the costs of production plus feed costs: fall born stockers are $121/head for 30 days, $143/head for 60 days, $166/head for 90 days, $190/head for 120 days, $219/head for 150 days. The total costs for spring born stockers are $135/head for 30 days, $170/head for 60 days, $178/head for 90 days, $216/head for 120 days, $247/head for 150 days. Combining the cow total costs with the stocker total costs gives us the cow-calf operation combined costs: fall born stocker operation is $926/head for 30 days, $948/head for 60 days, 971/head for 90 days, $995/head for 120-days, and $1,024/head for 150 days. Combined fall born stocker costs are $865/head for 30 days, $900/head for 60 days, $908/head for 90 days, $946 for 120 days, and $977 for 150 days.

Empirical Modeling

Annual net returns were analyzed for six feeding period for both the fall and spring calving season at three different herd sizes. This means results will be presented for 36 possible production scenarios (2 calving season x 3 herd sizes x 6 marketing opportunities). To build these scenarios, assumptions were made for the timing of breeding, calving, and weaning. Table 2.6 in Appendix B shows the timing of these decisions for each calving season. 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.

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

$$(2)\quad Price_{clm} = \beta_0 + \beta_1 log\,(W_{clm}) + \beta_2 log\,(H_{clm}) + \beta_3 HR_{clm} + \beta_4 MB_{clm} + +\beta_5 S_{clm} + \sum_{m=1}^{m=11} \gamma_m SM_m + \delta_1 \log(CP_{tm}) + v_t + u_c + \varepsilon_{clm}$$

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; SM_m is a binary variable for the months the cattle are sold; CP_m is the log of 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 sale lot random effect; and $\varepsilon_{ilm} \sim N(0, \sigma_\varepsilon^2)$ is the random error term. We assume independence on all four random variables.

These models were estimated using maximum likelihood with the MIXED procedure in SAS 9.4 (SAS Institute 2011). The parameter estimates can be converted to nominal dollar change in the sale price of cattle by multiply the estimated parameter value by the average predicted selling price of the cattle. Heteroskedasticity is tested for with respect to all covariates utilizing the likelihood ratio test (Woolridge 2013). If heteroskedasticity is present, it is corrected by implementing multiplicative heteroskedasticity in the variance equation and the results are reported for the model that adjusts for the unequal variances (Woolridge 2013).

Simulation

Then, the simulation was developed for Equation (1) assuming cattle weights, hay prices, feed prices, cattle prices, and price premium for stocker cattle were stochastic. Hay prices and feedstuff prices were randomly drawn from a 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; and Boyer et al. 2020). 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.

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, respectively. These random weights feed into the price estimate to generate a random cattle price. 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 (Williams et al. 2012; Williams et al. 2014; Zimmerman et al. 2012; Garber et al. 2022). 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 (Williams et al. 2012; Williams et al. 2014; Zimmerman et al. 2012; Garber et al. 2022). 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 observations were simulated for each scenario.

Stochastic dominance then used to compare the distributions of net returns. In first degree stochastic dominance, the scenario with 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). Stochastic dominance is an effective method of conducting a risk analysis of different production practices (Henry et al. 2016).

Results

Price Response Function

Table 2.7 in Appendix B illustrates the estimated parameter value results from the regression. Various variables are significant, and the anticipated signs were expected. Heteroskedasticity was present for year, sex, and 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. For every 100 pounds increase in weight per head, the sale price decreased by $4/cwt. This inverse relationship is consistent with previous research (Buccola 1980; Burdine et al. 2014; Dhuyvetter and Schroeder 2000; Martinez, Boyer, and Burdine 2021). Furthermore, an increase in lot size was found to increase the price of cattle, which is also consistent with previous research.

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 by $1.85/cwt. These results are also what Martinez, Boyer, and Burdine (2021) observed.

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 August, September, October, and November result in an increase in price of beef cattle sold in Tennessee. On the other hand, 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.

Estimated parameters were used to predict prices for black-hided and home-raised steer lots were estimated by stocker length, calving season, and herd size. These results were based on the average sale weight and the sale month of the cattle depending on calving season and length of stocker period (Table 2.8 in Appendix B). For spring born calves, the expected price for calves would be higher after a 30-day stocker but these calves were assumed to gain no weight the first 20 days. They might bring a higher price and have a slightly higher weight but have a higher cost. Expected prices decline after the 30-day stocker period, as expected. The expected price of spring born calves also increases slightly as the herd sizes increases, which is also expected since producers are getting closer to achieving a 50,000-pound lot of cattle.

Fall born calves have a similar trend to spring born calves for selling at weaning and at the 30-day stocker period. Expected prices increase from weaning to 30-day stocker period. After the 30-day stocker period, the expected prices continue to increase through 60-day stocker period and then declines. An interesting result is expected prices for fall born calves are higher for stocker periods 30 through 150-day than at weaning. Thus, heavier calves are bringing the same price or higher than lighter calves in the spring. This is an unusual result that needs future research to further understand what is happening. Like spring born calves, heavier lots of cattle (larger herd sizes) bring a higher price. Finally, Spring born calves brought higher prices on average than fall born calves at weaning. This is different from previous studies (Henry et al. 2016; Griffith et al. 2017; Hersom and Thrift 2018).

Simulation

Figures 2.1-2.6 in Appendix B shows the probability net returns being positive for the 36 scenarios in this analysis. Figure 2.1 shows the 30-head fall calving herd. For this 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%). The figure demonstrates selling at weaning gives a producer a 45% chance of making a positive profit. Similarly, net returns were highest when selling calves after a 150-day grazing period ($70 per head) and lowest for the 30-day grazing period (-$82 per head) (Table 2.9 in Appendix B). A profit- and utility maximizing producer would select to retain weaned calves for 150 days. Figures 2.2 and 2.3 show similar results for fall calving herd that is 60 and 90 head, respectively. Net returns increase as the herd size increases.

Spring calving herds also had similar results across herd sizes. The likelihood of having a positive net return was highest when selling at weaning (95-96%). The net returns were also highest for this selling period (Table 2.9 in Appendix B). 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.

When compared, the spring calving herd was on average more profitable than the fall-calving herd. These results are different from the conclusions found by Henry et al. (2016) but Henry et al. (2016) did not consider price slides for weight classes. Producers with defined calving season in this region typical calve in the spring and sale calves at weaning, thus, the results align with producer practices.

Conclusion

This chapter determined the profit-maximizing stocker length for fall and spring born calves within herds of 30, 60, 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.

Calving season, stocker length, and herd size are the main variable determinants of the profitability of an integrated cow-calf and stocker operation. Calving season impacts feed prices and the price seasonality of when the cattle will be potentially sold. The fall-calving herd has the higher feed and total combined costs compared to the spring calving herds. However, the month when the cattle are sold also depends on the length of the stocker period. The two months with the highest cattle price seasonality are August and October. Therefore, fall-born cattle stocked for 60-days and sold in August and spring-born cattle stocked 30 or 60 days and sold in October or November have the highest selling prices. However, profitability of the operation depends on other factors like weight of the cattle. The spring calving season results in heavier cattle that have a lower feed cost, where the fall calving season results in selling cattle when price seasonality is higher depending on the stocker length. In Tennessee, most producers following a defined calving-season calve in the spring months, which is more profitable according to this research. The fall calving herd has the higher production cost, due to increased need for supplemental feed. When considering an optimal length of a stocker period 30 days and 60 days had the lowest probabilities for positive profits in both the spring and fall calving herds.

These results could be used by producers to allow for better informed decision making that involves multiple aspects and considerations of successful beef cattle production and marketing.

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Appendix B

Table 2.1 Tennessee price data average prices across months and weight classes from 2016 to 2020 ($/cwt)

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	*	*	139.33	137.23	137.00	140.02
September	130.33	130.33	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
Slide Average	140.56	140.56	134.95	132.93	131.99	136.34

*data does not exist

Table 2.2 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	704	257
Steer WW	527	78	171	788
		Spring Calving		
Heifer BW	73	13	23	120
Steer BW	80	14	40	120
Heifer WW	498	77	717	208
Steer WW	531	85	763	171

Table 2.3 Expected weight (lbs) for stockers and lot total weight (lbs) at each stocker period by calving season and herd size

Production	Head Weight	30-head herd (24-Lot)	60-head herd (48-Lot)	90-head herd (72-Lot)
		Fall		
Weaning	512	12,354	24,677	37,030
30-days	529	12,762	25,493	38,254
60-days	580	13,986	27,941	41,926
90-days	631	15,210	30,389	45,598
120-days	682	16,434	32,837	49,270
150-days	733	17,658	35,285	52,942
		Spring		
Weaning	514	12,410	24,787	31,197
30-days	531	12,818	25,603	38,421
60-days	582	14,042	28,051	42,093
90-days	633	15,266	30,499	45,765
120-days	684	16,490	32,947	49,437
150-days	735	17,714	35,395	53,109

Table 2.4 Monthly average feedstuff prices ($/ton) over the past five years (2016 to 2020) for corn gluten feed, soybean hulls, and hay

Month	Hay Cost[1]	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

[1]Hay Purchased at $45/ton

Table 2.5 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

Table 2.6 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 2.7 Estimated parameter values for Tennessee price data from 2016 to 2020

Parameter	Estimate	$ Change/cwt
Intercept	338.31***	
Log Actual Weight	-32.4826***	$(3.99)
Log Number of Head	1.461***	$0.31
Home Raised	1.8456***	
Majority Black Hided	2.6323**	
Heifer (Sex 0)	-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.

Table 2.8 Predicted monthly sale prices ($/cwt) of beef cattle in Tennessee based on herd size and length of stocker period

	Weaning	30 days	60 days	90 days	120 days	150 days
	Sale Month					
	October	November	December	January	February	March
Spring 30-Head	$145	$147	$140	$135	$132	$126
Spring 60-Head	$146	$148	$141	$135	$133	$126
Spring 90-Head	$146	$148	$142	$136	$133	$128
	Sale Month					
	June	July	August	September	October	November
Fall 30-Head	$136	$142	$144	$140	$141	$137
Fall 60-Head	$137	$143	$145	$140	$142	$138
Fall 90-Head	$138	$144	$146	$141	$142	$139

Table 2.9 The average profits ($/head) and standard deviations for the probabilities of positive profits in fall and spring calving herds of 30, 60, and head herd sizes.

Herd Size	30 head		60 head		90 head	
Production	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
			Fall Calving			
Weaning	-9	61	-5	62	-2	62
30-days	-82	64	-77	64	-74	64
60-days	-20	64	-15	65	-11	65
90-days	1	62	6	63	10	63
120-days	55	63	60	63	65	63
150-days	70	61	76	62	81	61
			Spring Calving			
Weaning	115	67	119	68	122	68
30-days	7	68	12	69	15	69
60-days	7	65	12	66	16	66
90-days	36	62	41	62	45	63
120-days	45	61	51	61	55	62
150-days	39	59	44	59	49	59

Figures

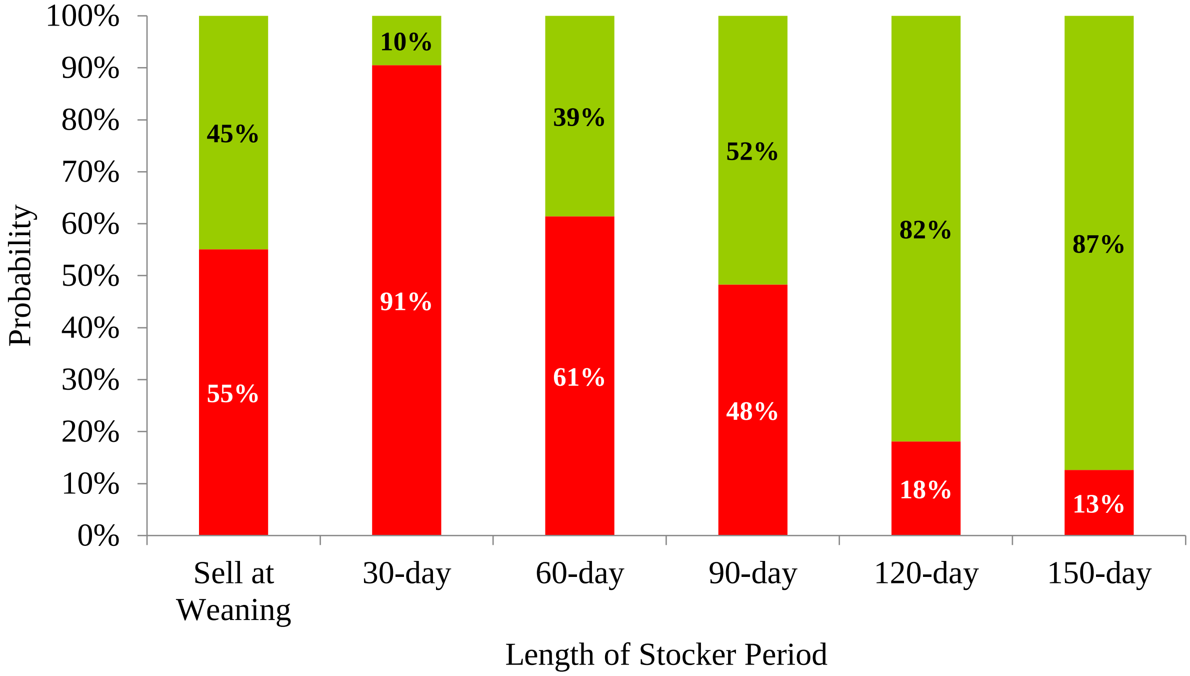

Figure 2.1 The probability of net returns being positive (shown in green) and negative (shown in red) for a 30-head fall calving herd by length of stocker period

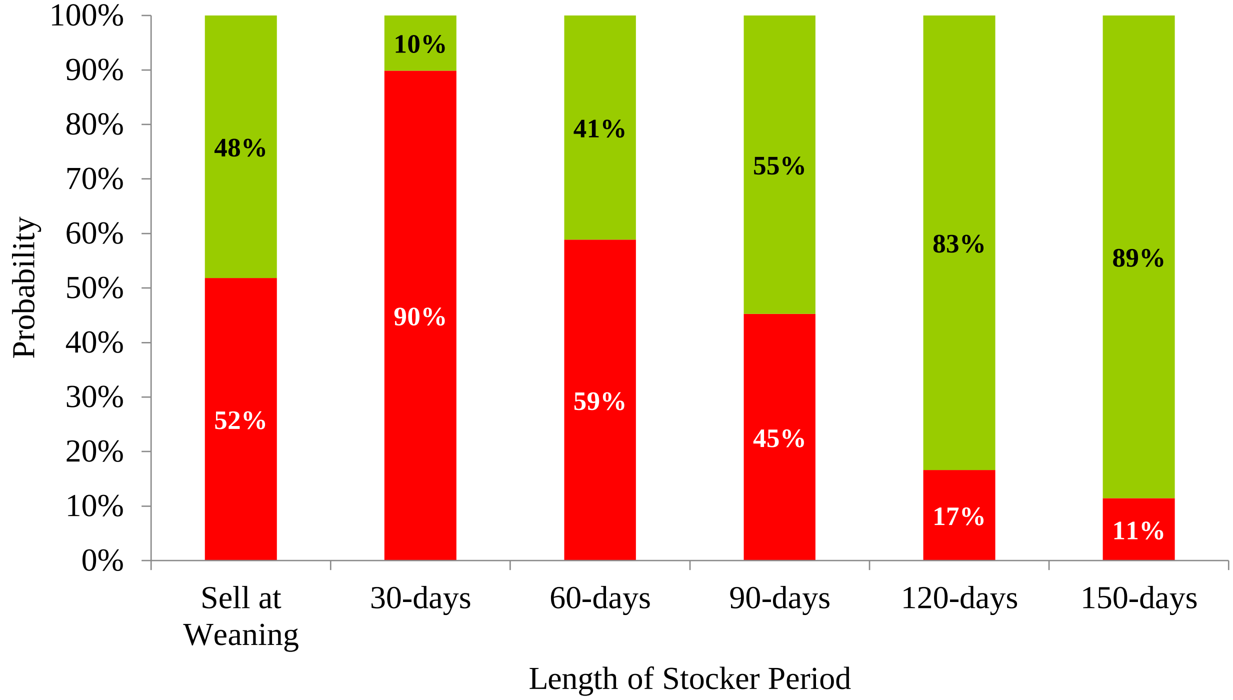

Figure 2.2 The probability of net returns being positive (shown in green) and negative (shown in red) for a 60-head fall calving herd by length of stocker period

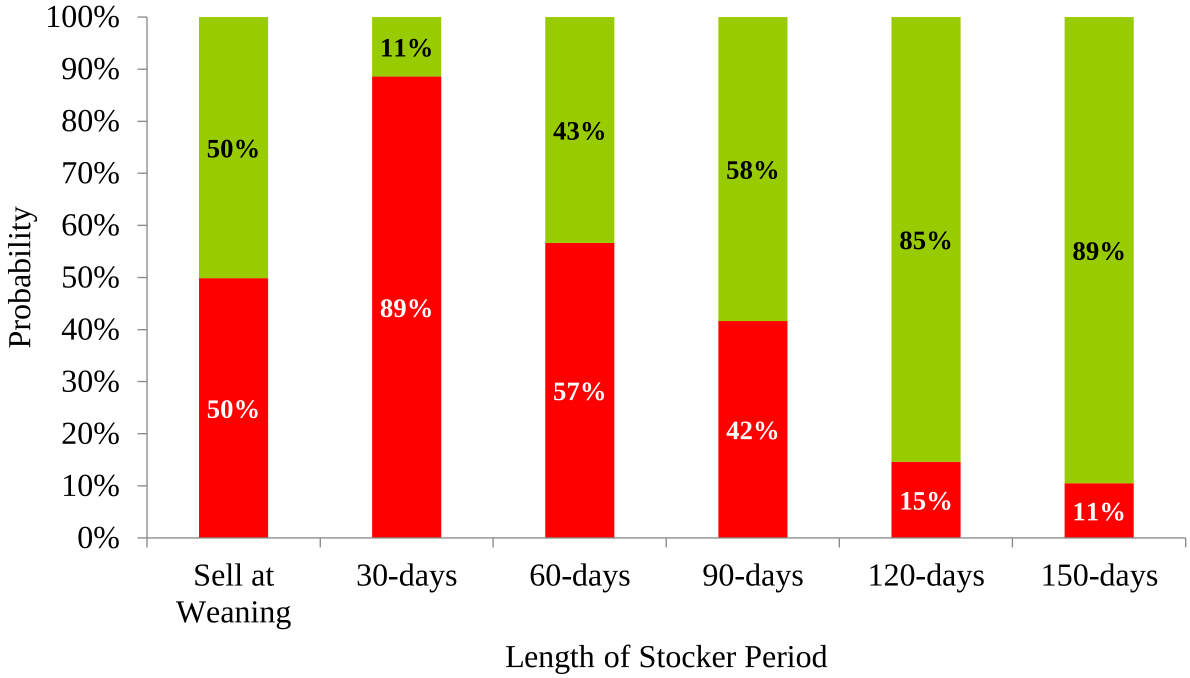

Figure 2.3 The probability of net returns being positive (shown in green) and negative (shown in red) for a 90-head fall calving herd by length of stocker period

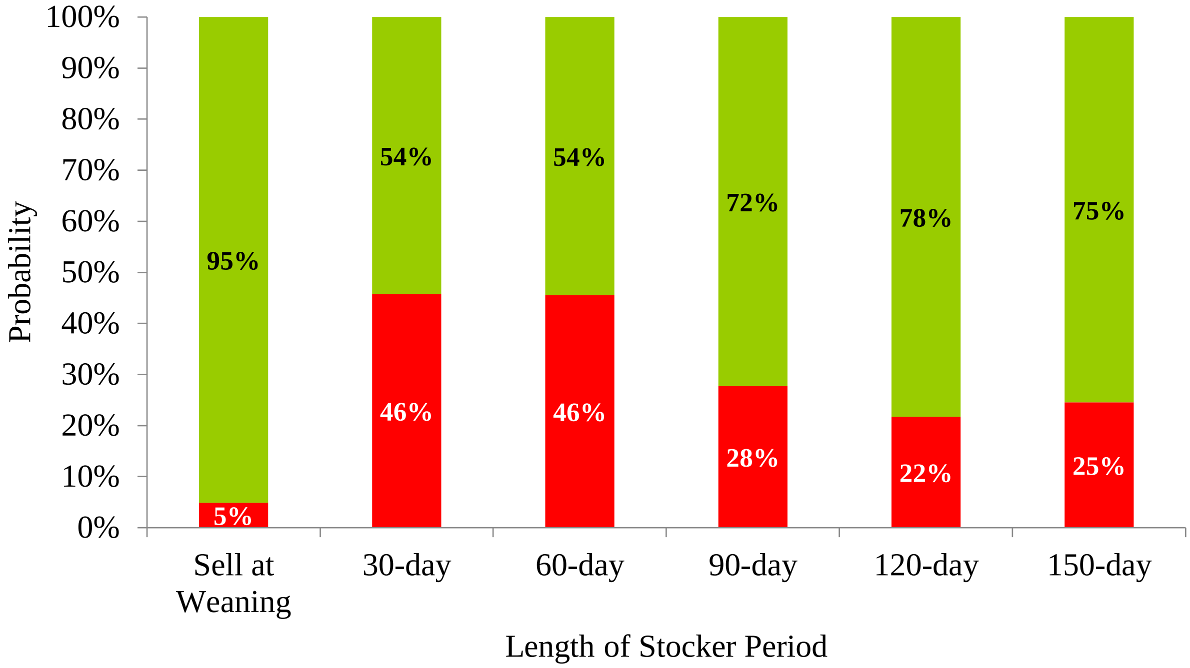

Figure 2.4 The probability of net returns being positive (shown in green) and negative (shown in red) for a 30-head spring calving herd by length of stocker period

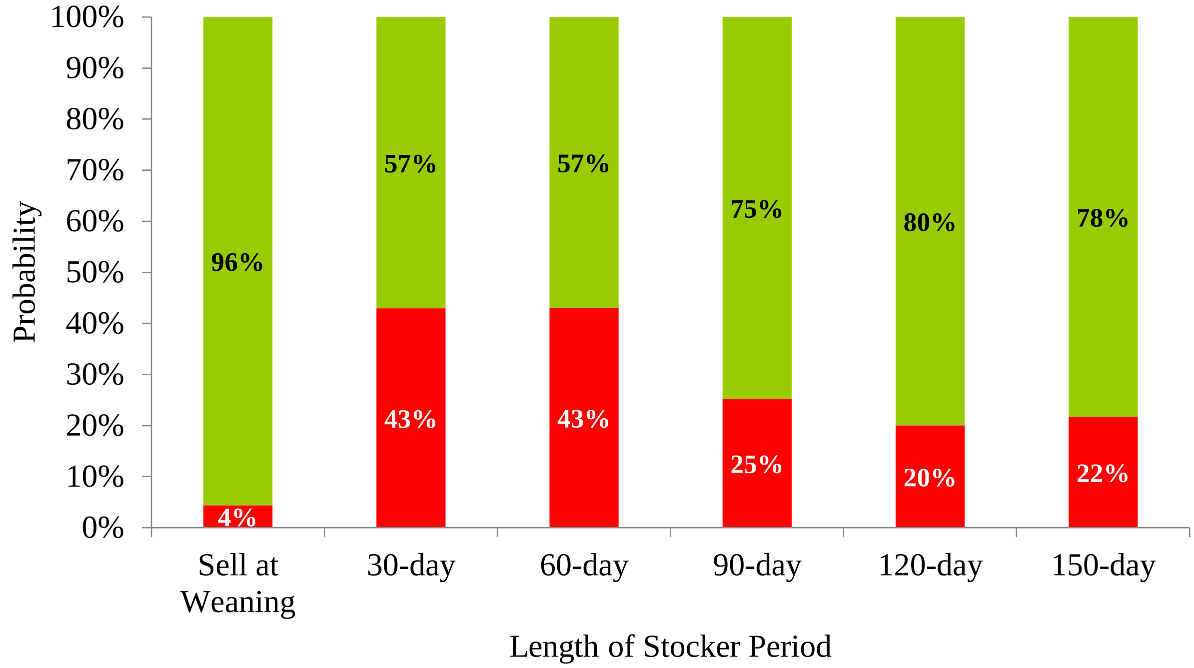

Figure 2.5 The probability of net returns being positive (shown in green) and negative (shown in red) for a 60-head spring calving herd by length of stocker period

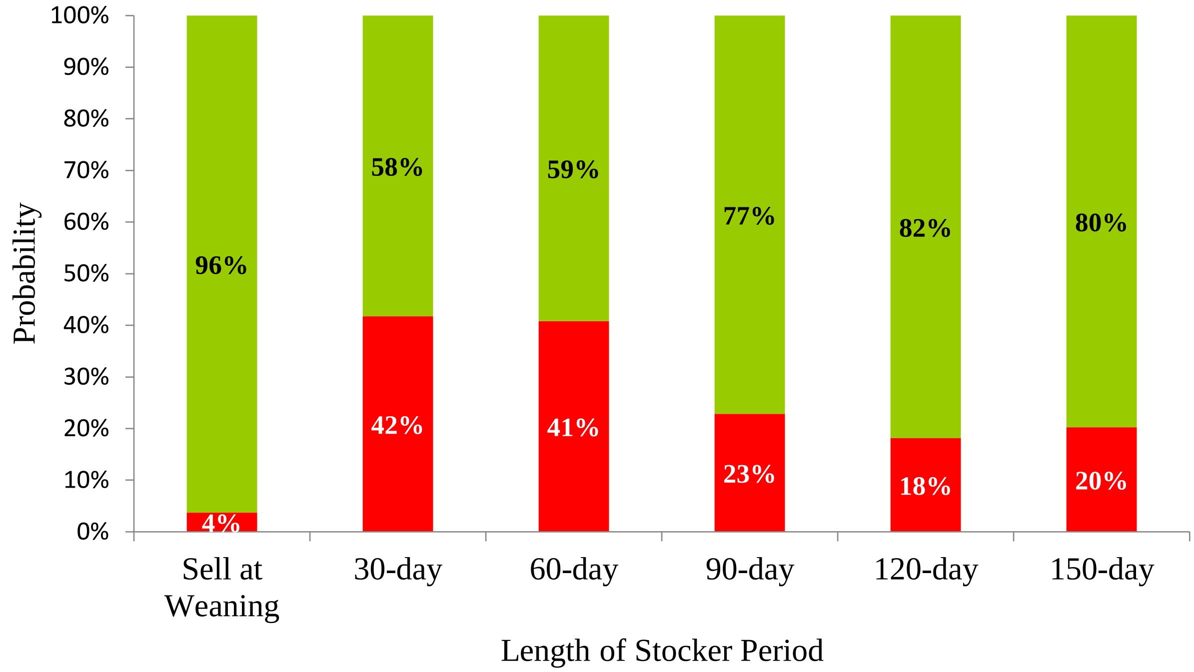

Figure 2.6 The probability of net returns being positive (shown in green) and negative (shown in red) for a 90-head spring calving herd by length of stocker period

Conclusions

The first chapter of this thesis analyzed producer decisions surrounding feed cost to meet nutritional demands of beef cattle in an integrated cow-calf and stocker operation in the Southeast. In order, to reduce feed cost a producer must consider many factors including when calves are born, when they will be weaned and begin to graze, and month of sale. The amounts of supplemental feed and hay fed will vary for spring calving cows, spring born stocker cattle, fall calving cows, and fall born stocker cattle. Also, the length of the stocker period will also affect the feed cost, the longer the cattle are kept the higher their feed cost will be. In the Southeast, the costs of feedstuffs exhibit seasonality because of the forage growth curves and availability when compared to the cattle production timeline. This researched determined that feed cost is greater for a fall-calving season when a producer practices an integrated operation in the Southeast by considering the timing of cattle and forage production, seasonal feed prices, and the length of the stocker period.

The second chapter of this thesis determined the profit-maximizing stocker length for fall and spring born calves by herd size with ranges from 30 to 90 head. The potential stocker lengths to retain calves were 30-, 60-, 90-, 120-, and 150-days post-weaning. Chapter two also considered the possibility of selling calves at weaning, which reduces feed cost but decreases cattle weight. A simulation model was developed for stochastic feed prices, cattle weights, and price premiums to aid an integrated cow-calf and stocker producer in decisions.

The time of year when cattle are sold is determined by the length of the stocker period. Cattle sale prices are highest in Tennessee in the months of August and October. As a result, a producer with a fall-calving season should consider retaining his calves for a 60-day period to sale them at the highest price in August. A producer with a spring-calving herd should keep his calves either 30 or 60 days and sell them in October and November to receive higher sale prices. The profitability of the operation depends on many factors, such as, the weight, sex, lot size, corn prices and hide-color of the cattle, to receive price premiums. In Tennessee producers that follow a defined calving-season typically calve in the spring months, which is more profitable according to this research. The fall calving herd has the higher total cost, due to increased need for supplemental feed. When considering an optimal length of a stocker period 30 days and 60 days had the lowest probabilities for positive profits in both the spring and fall calving herds.

These results could be used by producers to allow for better informed decision making that involves multiple aspects and considerations of successful beef cattle production and marketing.

Vita

Cora Key grew up actively involved in 4-H and FFA and showed livestock competitively across the country and served as a Middle Region FFA Treasurer. She comes from a small town known as Celina, Tennessee that does not have an entire red light in the whole county, and from a graduating class of approximately 30 students (also the only high school in the county). It was also a dream of hers to attend The University of Tennessee and pursue a career in the livestock industry and give back to the agricultural lifestyle that gave many opportunities to her growing up. During her undergraduate career she was involved in just about everything she could get my hands in from being a farm credit scholar, to being on the collegiate livestock and horse judging team, to leadership roles in a professional agricultural sorority, and even an officer in block and bridle, and a student speaker at the December 2020 graduation, Cora kept herself busy. The start of 2020 marked the beginning of COVID-19 which impacted many lives across the world, however she continues to push for success and dedication to her career and not let that circumstance stop her, as she completed an online internship with Farm Credit Mid America, began her master's degree, and served as the assistant livestock judging coach during what "free" time she had as a graduate student. In August of 2021 she began the next step on her career path and became a 4-H Extension agent in her home county starting December 1st of 2020 while completing her thesis dissertation. The most important part of Cora's life is agriculture, the industry that fuels, feeds, and clothes the world.