

ANALYSIS OF THE ECONOMIC VALUE ASSOCIATED WITH THE ADOPTION
OF BEEF REPRODUCTIVE TECHNOLOGIES

A thesis presented to the Faculty of the
Graduate School at the University of Missouri

In Partial Fulfillment of the Requirements
for the Degree Master of Science

by

EMMA DOWNING

Dr. Scott Brown, Thesis Supervisor

JULY 2019

The undersigned, appointed by the Associate Vice Chancellor of the Office of Research
and Graduate Studies, have examined the thesis entitled

ANALYSIS OF THE ECONOMIC VALUE ASSOCIATED WITH THE ADOPTION
OF BEEF REPRODUCTIVE TECHNOLOGIES

presented by Emma Downing,

a candidate for the degree of Master of Science,

and hereby certify that, in their opinion, it is worthy of acceptance.

Associate Extension Professor and Director of Strategic Partnerships – Dr. Scott Brown

Professor and State Beef Extension Specialist – Dr. David Patterson

Cowden Professor and Director of FAPRI – Dr. Patrick Westhoff

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Dr. Scott Brown. We met when I was an 18-year-old agriculture economic freshman who held passion in hopes of making a positive impact but was in need of a great deal of guidance. In no way could I repay your massive contribution of time teaching me economic mindsets, showing me occupational opportunities, and connecting me with industry leaders. You have repeatedly exhibited an example of how to apply economic analysis in a way in which industry and producers can learn from and implement - the most important lesson I've learned in the past four years. I will not miss writing this thesis, but I will miss being able to give you a hard time daily. Thank you to my committee members - Dr. Patrick Westhoff and Dr. David Patterson. Dr. Westhoff, I feel honored to have been taught by you. Thank you for teaching me to consider all points of the argument and the degree quantitative measurements can impact policy. Dr. Patterson, as my time learning about your research at the Thompson Research Center grew, I was continually blown away by your positive contribution to the beef cattle industry. Thank you for the immense time spent on extensively editing this work. It was an honor to work on this project, and I hope it helps quantify added value potential and provides helpful information as producers decide to adopt innovative technologies and practices.

I want to thank additional members of Dr. Brown's team who worked hours providing assistance on this project. Daniel Madison, thank you for helping brainstorm analytical approaches and tracking down relative data sources. Darlene Kruse, thank you for the vast amount of work you've done to see this project to the finish line. From helping transition the dataset to perfecting the finalized draft, and everything in between, I would've been lost without your guidance. Additionally, a couple of others spent hours

helping me process over 13,000 pages of data. Without your efforts in creating this database, it would not have been possible to conduct analysis so quickly.

Lastly, thank you to the immense kindness of family and loved ones who were part of this whirlwind of a year. I will never be able to accurately express how appreciative I am for all the patience exhibited, phone calls made, support expressed, food delivered, podcasts suggested, endurance encouraged, coffee breaks taken, and love showered. This thesis was a team effort.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
LIST OF FIGURES	v
LIST OF TABLES	v
ABSTRACT	vi
Chapter 1: Introduction	1
Chapter 1.1 Domestic Cattle Production Cycle	2
Chapter 1.2 The US Cattle Industry	4
Chapter 1.3 US Beef Exports	11
Chapter 2: Evolution of AI and Supporting Technologies.....	14
Chapter 2.1 Estrous Synchronization and Fixed Time AI.....	15
Chapter 2.2: Structure of the Cattle Industry.....	17
Chapter 3: Review of the Literature	20
Chapter 4: Show-Me Select Heifer Program.....	29
Chapter 5: The Thompson Research Farm.....	32
Chapter 5.1 Thompson Farm Data Analysis	34
Chapter 5.2 Description of Thompson Farm Inventory	36
Chapter 5.3 Descriptive Statistics.....	37
Chapter 5.3 Part A Birthweight and Weaning Weights.....	40
Chapter 5.3 Part B Death Loss	42
Chapter 5.4 Analysis Methodology	43
Chapter 5.5 Measuring the Value of Thompson Farm Offspring.....	46
Chapter 5.5 Part A Thompson Farm Feedlot Steers	47
Chapter 5.5 Part B Replacements/Bred Heifers	54
Chapter 5.5 Part C Residual Auction Market Calves	58
Chapter 5.6 Weighted Average Value Comparison for Thompson Farm	59
Chapter 5.7 Top Utilized Sire Evaluation	63
Chapter 5.8 Additional Research Opportunities	66
Chapter 6: Conclusion.....	67
Bibliography	69

LIST OF FIGURES

Figure 1 US Beef Cattle Inventory and Oklahoma Feeder Steer Price Comparison	5
Figure 2 US Annual Commercial Beef Production per Number of Beef Cows	6
Figure 3 US Beef Quality Grade Percentages.....	9
Figure 4 US Annual Average Boxed Beef Cutout Values.....	10
Figure 5 Number of Cows in Thompson Farm Herd Annually	37
Figure 6 Percentage of Thompson Herd Offspring Categorized by Fate	38
Figure 7 Percentage of Thompson Farm Offspring in Top 3 Fates	39
Figure 8 Thompson Farm Birthweights and Weaning Weights	40
Figure 9 Thompson Farm Birthweights and Weaning Weights - Females.....	41
Figure 10 Thompson Farm Birthweights and Weaning Weights- Males	42
Figure 11 Death Loss Rate of Thompson Herd	43
Figure 12 Percentage of Sale Price Assumptions Compared to Offspring Counts.....	44
Figure 13 Value of Difference of Thompson Farm Fed Steer and May t+1 AMS Steer Values 2008-2017	47
Figure 14 Thompson/US Values Ratio Averaged Annually for Fed Steers 2008-2016..	48
Figure 15 Thompson/US Values Ratio Averaged Annually for Fed Steers 2008-2017..	51
Figure 16 Thompson/US Fed Steer Values Individually by Year	53
Figure 17 Difference of OK Bred Heifer Values and Premium Heifers Annual Average Sale Values for 2003-2017.....	55
Figure 18 Thompson/OK City Value Ratio Averaged Annually for Premium Heifers 2003-2017	56
Figure 19 Thompson/US Values Ratio Averaged Annually for Weaned Calves 2004-2017	58
Figure 20 Weighted Average Values Thompson Farm and US 2004-2017	60
Figure 21 Thompson/US Values Ratio for Offspring 2004-2017	61
Figure 22 Thompson/US Values Ratio Weighted Averages for Offspring 2004-2017...	62
Figure 23 Top Utilized Sires of Fed Steers and Premium Heifers	65

LIST OF TABLES

Table 1 Percentage of Operations by Reproductive Technology Used and by Herd Size 19	
Table 2 Natural Service and FTAI Performance Comparison.....	21
Table 3 Cost of Retaining Bulls at Western Beef Development Centre.....	22
Table 4 Estimated Costs for Fixed Time Artificial Insemination per Cow	23
Table 5 Sales Average for Show-Me-Select Replacement Heifers Based on Service-Sire and Tier	31
Table 6 Patterson and Team Research Timeline at Thompson.....	33
Table 7 Assumption Calculation Methodology	46
Table 8 Percentage of Observations that Performed Above the Average Thompson/US Fed Steer Values by Year	53
Table 9 Top Utilized Sires of Fed Steers and Premium Heifers.....	65

ABSTRACT

Beef cattle herd improvement to meet growing demand for higher quality beef has been an aspiration within the cattle industry since inception. Throughout the heartland, progressive cow-calf producers invest and adopt research-proven practices striving to continually improve their herds, resulting in premium cattle and beef products. Advantages to modifying management practices and applying advanced genetics could aid modern cow-calf producers by minimizing calf loss, unifying calving windows, increasing weaning weights, raising daily feedlot gains, and improving carcass quality grades. This research evaluates aggregate data from the University of Missouri Thompson Research Center with a focus on realized values of offspring born from 2004 to 2017. By evaluating the difference in aggregate average values of offspring when compared to US averages over time, this research strives to quantify realized added value achieved through the adoption of innovative beef cattle reproductive management practices. The goal of this research is to provide producers suspect of using newer production methods an additional decision aid to measure potential added revenue.

Chapter 1: Introduction

From the time cowboys drove herds from the southwestern United States (US) to cities in the northeast, beef cattle production has embodied the American Heartland. Cattle markets promoted a livelihood for establishing settlement towns throughout the Midwest. By 1860, the invention of the refrigerated railcar revolutionized the US cattle industry as herds from Texas could now be fattened on midwestern prairies before slaughter and shipment to population centers. With increased accessibility, expectations of quality beef production grew. Midwestern cattle feeders encouraged western cattle producers to improve herds, searching for British bulls to increase heartiness.

Cattle herd improvement to meet growing demand for higher quality beef has been an objective within the cattle industry since that time. Throughout the heartland, progressive cow-calf producers invest and adopt research-accredited practices striving to continually improve their herds, resulting in premium cattle and beef products. Advantages to modifying management practices and applying advanced genetics could aid modern cow-calf producers by minimizing calf loss, unifying calving windows, increasing weaning weights, raising daily feedlot gains, and improving carcass quality grades.

Today, various segments of the beef industry including: cow-calf producers, local auction markets, feed yards, and processors, all play important roles in the beef production system. Exchange of information stemming from product attributes demanded by customers through market channels to cow-calf producers is vital to promote a superior product for domestic and export markets. The adoption of grid pricing, assigning values tied to carcass grades, has begun to provide information on consumer demand for premium-quality beef to cow-calf producers debating whether to invest in reproductive

technologies and adopt management practices necessary to consistently produce higher quality beef. However, to capture the value of this information, cow-calf producers usually must retain ownership of calves through the feedlot and harvest phase, which few producers choose to do citing added risk that arises from feeding cattle.¹

This research strives to quantify realized added value achieved through the adoption of innovative beef cattle reproductive management practices. The goal of this research is to provide producers suspect of using newer production methods an additional decision aid to measure potential added revenue. This research evaluates aggregate data from the University of Missouri Thompson Research Center with a focus on realized values of offspring born from 2004 to 2017.

Over the last 20 years, the Thompson Research Center has been a center of applied beef cow reproductive research conducted by University of Missouri animal scientists. This study assembled data from the Center and analyzed this dataset to compare performance of offspring produced at the Center over time against US averages. This research center operates similarly to a commercial beef cow-calf operation and findings will likely provide long-term evidence to support the adoption of genetic improvement and herd management practices that increase the value of calves.

Chapter 1.1 Domestic Cattle Production Cycle

Beef cattle production occurs throughout the US. The beef cattle industry includes cow-calf producers, local auction market operators, cattle and boxed beef haulers, feedlot

¹ Fraiser-Pope, Kelsey et al., “Cow-Calf Producers Risk Preference Impacts on Retained Ownership Strategies” *Journal of Agricultural and Applied Economics* no. 43 (November 2011):497-513.

operators, processors and retailers. Cow-calf producers are responsible for the beef cow herd in which case cows typically produce one calf annually. Cow-calf producers purchase bulls to naturally breed beef cows or procure semen straws for technicians to artificially inseminate cows when they display estrus or heat. One natural service sire, bull used for breeding purposes, generally can service about 25 females per breeding cycle.² The market value for bull semen is a function of bull characteristics: color, birthweight, age, expected progeny differences (EPD) as well as the degree of competition in semen markets. EPDs are measurements that provide genetic information about the sire—birth weight, weaning weight, calving ease, carcass traits, etc. Each cow-calf producer selects a reproductive strategy based on many factors including herd size, labor requirements, cattle prices, available capital, farm terrain, etc.

Cow-calf producers breed beef cows and heifers to produce offspring in the spring or fall. Typically, calves are weaned as a group at an average age of 6-8 months at a minimum of 400 pounds. Once calves are weaned, cow-calf producers decide whether to sell weaned calves through a local auction or alternative market, retain them longer on feed, select heifers for replacements, or transport calves to feedlots and retain ownership through finish and slaughter.

Between 2007 and 2011 North Dakota's herd performance data suggests producers typically replace 15.1 percent of the cow herd annually.³ Cow-calf producers consider

² Lardner, Bart et al., "Comparison of Fixed-time Artificial Insemination vs. Natural Service in Beef Cows: Reproductive Efficiency and System Cost" (2015).

³ Hughes, Harlan. "Raised Replacement Heifers: Some Economic Considerations" *Management Considerations in Beef Heifer Development and Puberty* (November, 2013): 643-52.

herd replacements to maintain a perpetual herd, to increase herd size, or to repopulate herd numbers after droughts or high bred-heifer price periods. Replacement selection is extremely important as it represents a longer-term investment in the cow herd. Operations that choose to sell replacement heifers after one calving cycle because of poor reproductive results, lament the cost they have in spending two years raising the female without receiving an offspring.

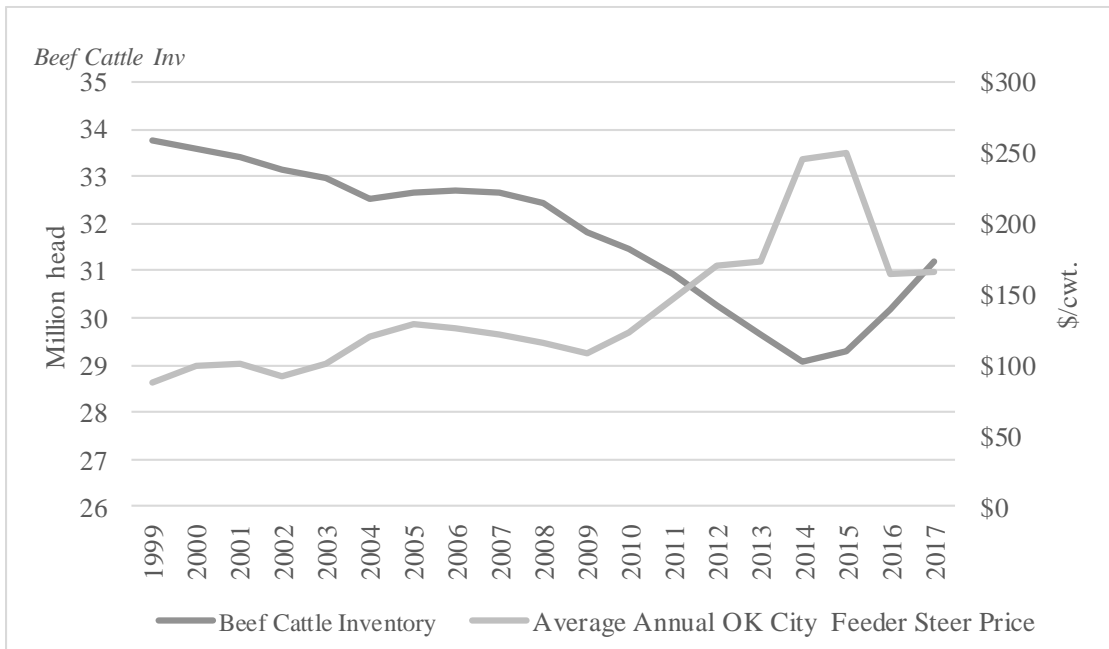
Whether it is choosing a calving season or selecting which heifers to retain as replacements, cow-calf producers must evaluate the financial balance between risks and returns. Retaining ownership through the feedlot process could increase animal value, and thus revenues received; all of which may be realized through increased carcass weight, capturing performance information post weaning, and collecting added value from health programs and superior genetics. For example, if a producer retains ownership, producers are able to analyze carcass reports and capture added value on superior carcass performance. However, risk of death, variability in feed costs, or lower cattle prices may deter risk-adverse producers.

Chapter 1.2 The US Cattle Industry

From 2007-2014 US cattle inventory steadily declined due to drought and high feed costs. As shown below in Figure 1, lower cattle inventories usually increase calf prices. Because producers regularly perceive current market conditions as long term, heifer retention climbed as prices rose. Cow-calf producers likely wished to expand herd size aiming to maximize the number of calves sent to sell as high prices were thought to continue.

However, gauging calf market shifts poses difficulty. As Figure 1 shows, inventories began an uptick an entire year before USDA ERS Oklahoma Feeder Steer Prices peaked in 2015 then fell drastically. This example underlines the delicate balance between risk and returns for cow-calf producers. Market behavior is an exogenous factor beyond the control of a cow-calf producer. Therefore, endogenous factors such as herd health, death loss, and calving distributions should be emphasized on an operation.

Figure 1 US Beef Cattle Inventory and Oklahoma Feeder Steer Price Comparison

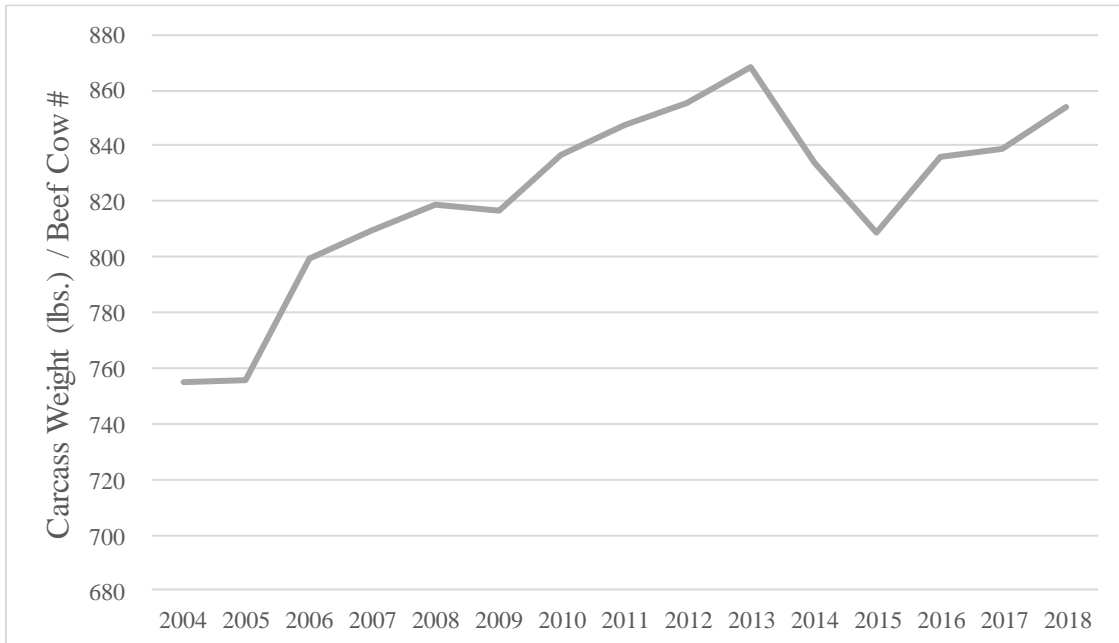


Source: USDA

Figure 2 below displays the USDA ERS US Annual Commercial Beef Production per the number of beef cows in the US for the respective year. During the time periods 2013 through 2015, high heifer calf retention lessened the number of calves sent to slaughter causing a decline in beef harvested. Apart from this period, the graph displays a continual climb in industry efficiency. The beef industry is producing more efficient animals and therefore larger and larger carcasses. It is important to note that the analysis presented in

this thesis compares performance of cattle produced at the Thompson Research Center to the US average; in other words, a comparison applied to an improving industry.

Figure 2 US Annual Commercial Beef Production per Number of Beef Cows



Source: USDA

In the early 2000's the beef industry began to adopt grid pricing in response to concerns and consumer demand trends that some identified with inconsistencies with beef quality. Grid pricing allows each animal to receive a specific value based on carcass merit and can include both premiums and discounts depending on the individual animal. Before grid pricing was more widely adopted, procurers of fed cattle typically purchased cattle by allotted pens. Cattle were valued on a pen average basis. Grid pricing uses value-based marketing determinants to price individual carcasses based on marbling, maturity, yield grade, and carcass weight. The process allows producers of high merit carcasses to

receive premiums while below average carcasses receive discounts. Cow-calf producers that retain ownership through the feedlot process are able to use grid pricing as a pathway to receive information on carcass performance. Superior carcass performance, a direct result of genetic herd improvement, can result in premiums for fed calves that would otherwise not be apparent if calves were sold at weaning. The 2007 National Cattlemen’s Beef Association (NCBA) National Meat Case Study found that the percentage of branded retail package beef cuts increased from 42 percent and 51 percent in 2004 and 2007, respectively.⁴ This increase is likely a result of producers responding to market signals that allowed for premiums through the use of grid pricing.

As the industry is focused on rewarding cattle producers that produce higher quality calves, cow-calf producers are looking for alternative marketing channels or branded certifications to capture more added value. For example, Certified Angus Beef (CAB®) is a certification program for beef cattle that meet specific marbling, yield grade, carcass weight, and quality standards. Producers are striving to move away from the commodity “price takers” role and obtain premiums for superior quality. For fiscal year 2018, CAB® brand sales topped 1.21 billion pounds, representing an 8.1 percent growth over the past year, and continuing a 14 year-over-year run of growth.⁵ In the export division, CAB® exported 207 million pounds, an 18.6 percent increase over 2017, to South Korea, Canada, Japan, Hong Kong and Mexico in descending order. As shown in the

⁴ National Cattlemen’s Beef Association. “National Meat Case Study.” (November, 2007) Accessed February 2019. Available at: <https://www.beefitswhatsfordinner.com/sales-data/retail-insights>.

⁵ Certified Angus Beef, “Partners Propel Sales to New Heights,” *Certified Angus Beef Brand Update 2018* volume 22(1), November 2018, 6.

certification's continued growth, consumers, domestic and abroad, are responding and willing to pay more for superior quality beef.

The USDA's Agricultural Marketing Service (AMS) grades carcasses, resulting in market price differentials, based on defined criteria of yield and quality. Yield grades estimate beef carcass cutability to aid in determining amount of lean, edible meat per carcass. To determine grade, USDA inspectors evaluate fat thickness over the ribeye area, estimate percentage of kidney, pelvic and heart fat, and hot carcass weight.

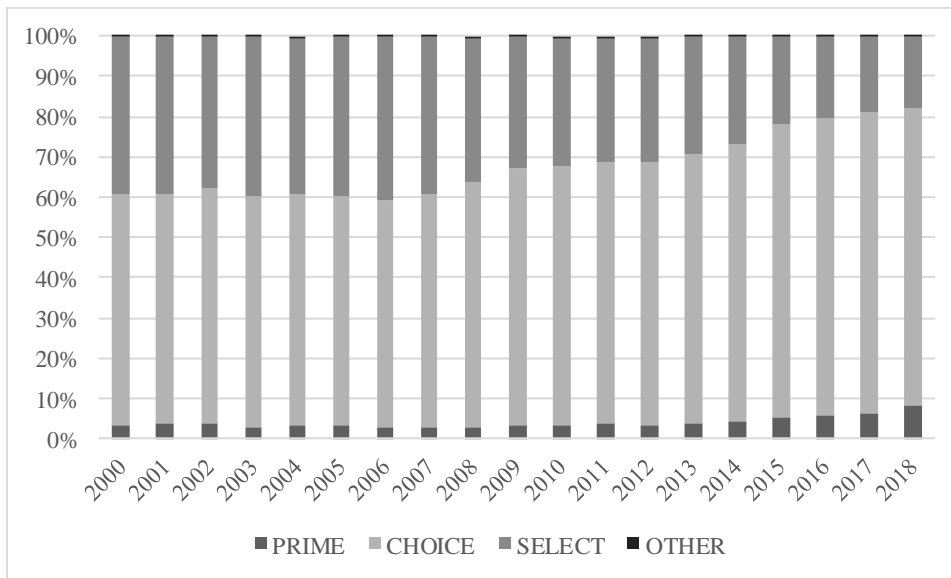
Inspectors grade yield on carcasses on a 1 to 5 scale. A carcass with a USDA Yield Grade of 1 provides the greatest quantity of saleable beef. Although usually overlooked by consumers, carcass reports containing yield grade information are especially helpful to producers by providing descriptive reports that measure quantity of meat the carcass produced which ultimately impacts carcass value.

USDA Quality Grades are recognized by most consumers in the retail space and consist on a range beginning with the best marbling and maturity scoring—Prime, Choice, Select, and Standard. Marbling consists of the measure of intramuscular fat that directly relates to tenderness, juiciness, and flavor. Maturity is an age measurement of the slaughtered animal. As cattle progress in age, meat toughness increases. Cattle receiving the quality grade of Prime usually depict a carcass from a younger age animal that is high in intramuscular fat and likely finished on a grain-based ration.

Consumers purchase beef based in part on palatability. Premiums or discounts in beef retail market prices are associated with consumers' palatability assessments. Quality grades identify differences in palatability factors such as tenderness, juiciness, and

flavor.⁶ Marbling and maturity are the most important attributes evaluated in quality grading that affect palatability. Beef quality grades establish a common denominator to distinguish carcasses based on accredited attributes associated with palatability and consumer preference.

Figure 3 US Beef Quality Grade Percentages



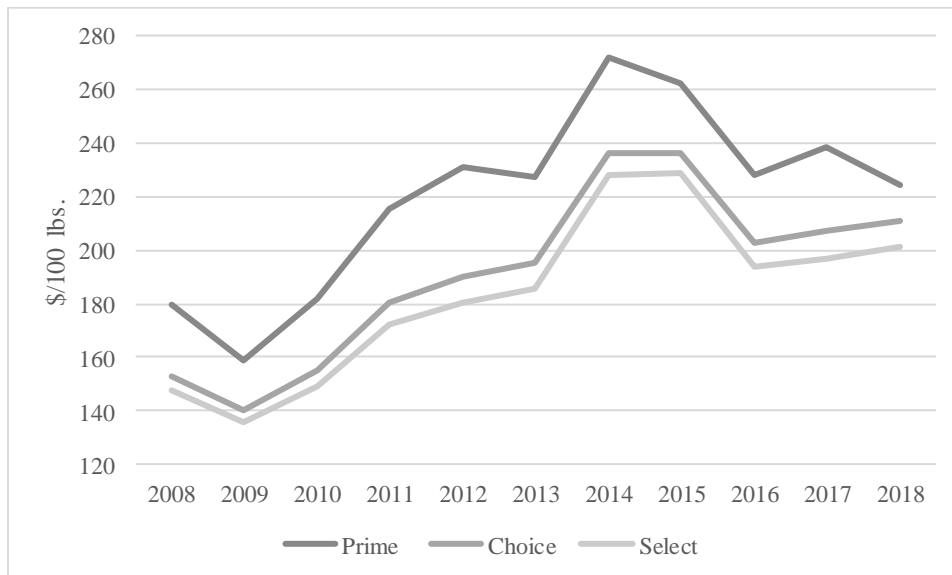
Source: USDA, AMS

As Figure 3 illustrates, the percentage of cattle receiving Prime and Choice quality grades has grown over time compared to cattle receiving lower quality grades. From 2000 to 2018, Prime carcasses showed a compound average growth rate of 4.7 percent. From 2013 to 2018, the compound average growth rate for Prime’s share of US graded beef increased to 13.4 percent. As shown in the data, the use of higher-quality genetics by the

⁶ Pierce, John. “The Federal Grading System for Animal Products.” Fat Content and Composition of Animal Products: Proceedings of a Symposium, Washington, D.C. December 1974.

US beef industry has enhanced carcass quality, resulting in an increase in carcass premiums. However, many producers still market their calves through local auction markets that make it difficult to transfer information and capture value. Lambert et al. hypothesized low adoption of retained ownership was due to high levels of risk aversion, cash flow constraints, satisfaction with current marketing methods, and physical or labor constraints.⁷

Figure 4 US Annual Average Boxed Beef Cutout Values



Source: USDA Market News

Figure 4 shows the annual average boxed beef cutout values for the 2008 to 2018 timespan. Although the Prime-Choice spread contracted in 2018, Prime boxed beef consistently captures a premium. From April 2018 through March 2019, average Prime graded cutout values were 5.7 percent higher over carcasses that graded Choice and 10.7

⁷ Lambert, D.K. "Calf Retention and Production Decisions Over Time." *Western Journal of Agricultural Economics*, no. (1989)14: 9.

percent higher over carcasses that graded Select.⁸ With the possibility of receiving 10 percent or more value for the Prime grade, the cost of incorporating better genetics in the herd can be economically viable when the added value is taken into account. If producers retain ownership through feedlot to slaughter, they would be made more aware of market signals demanding higher-quality beef.

When differentials in cutout values are considered, even with the production share of carcasses grading Prime or Choice increasing, consumer demand for higher quality products is growing. As Figure 3 illustrates, the supply of Prime-graded beef continues to grow. Although the Prime-Choice spread cutout value declined in 2018, the beginning of 2019 shows recovery.⁹ These increases in cutout values for Prime show consumer demand surpassing the supply growth. As consumer tastes and preferences develop toward higher-quality beef, lower supplies of carcasses grading Prime run the risk of consumers searching out alternative meats and suppliers.

Chapter 1.3 US Beef Exports

The beef industry in the US represents one of agriculture's top export sectors, and the US maintains the highest market share of higher-quality beef exports on a global basis. It is important to note, however, that more beef-exporting countries are entering this top-tier export market.¹⁰ As the middle class continues to expand within southeast Asia's growing population, beef, especially higher-quality US-produced beef, will grow in demand if the

⁸ USDA Market News, Livestock Marketing Information Center Report (LMIC). Accessed April 2019.

⁹ Ibid. USDA Market News (2019).

¹⁰ Patterson, David J. et al., "Management Strategies for Adding Value to Replacement Beef Heifers: A Working Model" *Management Considerations in Beef Heifer Development and Puberty* (November 2013), 653-666.

US is able to retain and continues to build its reputation for high quality beef in these markets. Japan is the US's largest beef export market followed by South Korea and Mexico. Japan imported 826 million pounds of beef in 2017.¹¹

However, due to the US exit from the Tran-Pacific Partnership (TPP) trade agreement, remaining countries including Japan, Australia, Canada and New Zealand went forward with the agreement, under the Comprehensive and Progressive Agreement Trans-Pacific Partnership (CPTPP). The newly enacted compact between CPTPP countries competitively challenges US beef export market access to Japan. Under CPTPP, Japan has currently lowered beef tariffs to 27.5 percent for participating CPTPP countries compared to the 38.5 percent rate US beef exports face.¹² Under this new agreement, Japan will continue to lower tariff rates to participating CPTPP countries, dropping them to 9 percent by 2033 and creating an increased advantage for many US beef export competitors. Kent Bacus, Director of International Trade and Market Access for the National Cattlemen's Beef Association encourages the industry to address tariff differentials that provide an advantage to beef export competitors over the US, including Canada, Mexico, and New Zealand.

With increased demand for beef, China's beef and veal imports increased from 63.9 million to 919 million pounds from 2011 to 2014.¹³ From 2000-2013, Chinese prices for beef have increased 390 percent as reported by Chinese government officials. In 2010,

¹¹ USDA, ERS Livestock and Meat International Trade Data. Accessed February 2019.

¹² USDA Foreign Agricultural Service Global Agricultural Information Network (GAIN) *CPTPP Changes to Japanese Beef Market*. December 2018.

¹³ Mao, Yanwei et al., "Consumption Patterns and Consumer Attitudes to Beef and Sheep Meat in China." *American Journal of Food and Nutrition Research*, no. 4(2016): 30-39.

Chinese beef production growth stagnated, while consumer demand continued to expand, increasing the reliance on imports. Only 67.5 percent of Chinese consumers cite satisfaction with current cooked beef quality and 50 percent stated they would increase beef consumption if quality improved. International demand for safe and superior quality beef is apparent, and international consumers are willing to pay a premium for higher quality beef.

Chapter 2: Evolution of AI and Supporting Technologies

The introduction of artificial insemination (AI) allowed producers that adopted the technology to more quickly improve genetics of their herds. Producers use fewer bulls by purchasing semen for use in inseminating cows and heifers. Artificial insemination allows producers access to superior genetics more affordably than purchasing higher-quality bulls that may only service 25 cows or heifers annually. Through current breeding management, AI conception rates rival conception rates of females bred using natural service. Applying superior genetics, calves produced through AI are likely to experience higher average daily gains creating a larger weaned heifers or steers when sold locally or sent to the feedlot.

Using artificial insemination, cow-calf producers have the flexibility to select for specific sire traits given characteristics of the cow herd that result in more rapid improvements in quality of offspring produced. For example, a producer would likely select a calving-ease sire to produce smaller calves at birth for use on first-calf heifers in comparison to placing less emphasis on calving ease and more emphasis on growth for sires used on mature cows. Without implementing AI practices, limitations due to biological lags may prove too lengthy and costly for herds to provide offspring that consistently hit current market specifications.

Reproductive failure is a major source of economic loss for cow-calf producers. If a calf is lost at birth the producer paid a year's worth of costs-vaccinations, mineral, feed, sire costs, and labor-for no return from the cow for that year. Producers are now able to reduce calving loss by selecting calving ease traits of sires to breed to heifers and at the same time increase expected weights of calves from those sires at weaning. AI allows

producers to personalize sires based on the status of the dam and mitigate a percentage of risk as a cow-calf producer.

Adoption of reproductive technologies may be perceived as confusing and too expensive to adopt. Although AI technologies provide increased offspring performance, only 7.6 percent of US beef producers currently utilize AI applications.¹⁴ Beef producers cite not using AI because it is too labor intensive, they lack adequate facilities, the technology is too time consuming to implement, concern over reduced conception rates, and general lack of knowledge about the procedure. Producers are slow to adopt technologies they do not at times fully understand, but also when faced with the potential for reduced conception rates. With the lack of time producers already face, transforming production practices may be a difficult decision when added benefits may not be realized and level of risk remains unknown.

Chapter 2.1 Estrous Synchronization and Fixed Time AI

Detecting estrus, using estrus-detection aids can be difficult and time-consuming. Failure to detect estrus or detecting estrus mistakenly can result in significant economic losses. Because of these challenges, adoption of AI technologies has been slow. Producers in many cases believe that using natural service sires requires less time and reduces risks compared to detecting estrus. These considerations supported the development of estrous synchronization protocols that facilitate fixed-time AI (FTAI).¹⁵ With estrous

¹⁴ USDA National Animal Health Monitoring System. *Reference of Beef Cow-Calf Management Practices in the US*. Fort Collins Colorado: Animal and Plant Health Inspection Service, February 2009.

¹⁵ Patterson, David J. and D. Scott Brown. "Rebuilding the US Beef Herd: Rethinking the Way Industry Develops" *Management Considerations in Beef Heifer Development and Puberty* (November 2013): 470-476.

synchronization, estrous cycles of groups of females are synchronized to enable all females to exhibit estrus around the same time. Rorie et al. found that when estrus was detected in 500 Angus females, by applying Heat Watch detection aids, the length of estrus averaged only 10 hours and fewer than 26 percent of females exhibited estrus for less than seven hours.¹⁶ With such a narrow window of time to accurately inseminate females based on estrus expression, inseminating females based on observed estrus becomes challenging. Estrous synchronization followed by FTAI overcomes these challenges.

Improved methods of estrous synchronization have increased the adoption of AI resulting from the development of more successful, user-friendly protocols. Estrous synchronization combined with FTAI is a great option for producers managing cows and bulls. When combined, the limitation of number of cows and heifers a bull can service disappears. Benefits include shorter calving seasons, increased weaning weights, and more improvements in genetic merit.

Estrous synchronization and FTAI allow all females to be inseminated in a single day resulting in earlier conception. Since most weaning decisions are based upon timing conducted and as a single group, bred heifers that calve early in the first calving season perform higher in lifetime calf production compared to those that calve later.¹⁷ The more females that conceive earlier in the breeding season, the more calves will weigh for weaning, capturing a greater value than lighter-weight younger-age calves. Additionally,

¹⁶ Rorie, R.W. et al., "Application of Electronic Estrus Detection Technologies to Reproductive Management of Cattle." *Theriogenology*, no. 57 (2002): 137-148.

¹⁷ Ibid. Patterson., (2013).

with the purchase of semen, feed and labor costs to maintain bulls throughout the year is reduced.

Cows only cycle naturally three times during a 65-day breeding season. However, cows which have been synchronized and display estrus in the early days of the breeding season have as many as four opportunities to conceive during the same time frame, greatly increasing potential success rates.¹⁸ Concentrating on detail with special consideration related to health, nutrition, and other management factors is vital for successful results in AI programs.

Chapter 2.2: Structure of the Cattle Industry

Unlike other livestock sectors, the cow-calf segment of the US beef cattle industry has remained dominated by small and medium size independent producers. Once offspring are weaned, marketing channels to sell weaned offspring include conventional livestock auction markets, private sales, or brand marketing sales. In conventional livestock auction markets feeder calves are viewed as a commodity with sale prices differentiated in large measure based on weight, color, age etc. instead of carcass performance, genetics, maternal grandsire EPDs, etc. Over 60 percent of small-scale cow-calf operations, containing 100 cows or less, report targeting conventional marketing channels for their calves.¹⁹

¹⁸ Perry, G.A. et al., "Management Factors Influencing Fertility in Synchronized and Natural Breeding Programs," *South Dakota State University* (2008).

¹⁹ USDA National Animal Health Monitoring System. *Small-Scale US Cow-Calf Operations*. Fort Collins Colorado: Animal and Plant Health Inspection Service, April 2011.

Regardless of size of operation, 62.8 percent of the cow-calf enterprises used production practices that targeted conventional livestock markets. Survey results indicate that small-scale producers are less likely to utilize specific production practices to target breed-influenced programs and age-and-source verification programs compared to larger operations. This creates difficulties as small operations, and part-time producers, in many cases lack economic incentives to invest in genetics.

Table 1 shows the percentage of cow-calf producers that are adopters of reproductive technologies. Adopters have not focused on estrus synchronization or AI, but instead pregnancy diagnoses, body condition scoring, and semen evaluation across all herd sizes. Body condition scoring is a herd management tool that utilizes a numeric system to distinguish nutritional needs for a beef cow.²⁰ The percentage of operations that utilized reproductive technologies increased with herd size. Non-adopters cited labor and time constraints most often followed by cost of the technology and difficulty in implementation a technology when questioned as to why they failed to adopt reproductive technologies. Estrus synchronization and artificial insemination received only a 7.9 percent and 7.6 percent adoption rate, respectively, across all operations that reported adoption of reproductive technology. Even as advances in reproductive research have simplified estrous synchronization protocols and minimized time and labor requirements to implement an AI program, producers across all herd sizes are still hesitant to adopt the technology.

²⁰ Eversole, Dan E. et al., “Body Condition Scoring Beef Cows,” *Virginia Cooperative Extension* (2009).

Table 1 Percentage of Operations by Reproductive Technology Used and by Herd Size

Reproductive Technology	Percent Operations									
	Herd Size (number of beef cows)									
	1-49		50-99		100-199		200 or more		All Operations	
	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error	Pct.	Std. Error
Estrus synchronization	5.7	(0.9)	10.5	(1.8)	14.9	(2.1)	19.3	(1.9)	7.9	(0.7)
Artificial insemination	5.6	(0.8)	8.4	(1.6)	16.3	(2.1)	19.8	(2.0)	7.6	(0.7)
Palpation for pregnancy	10.8	(1.2)	25.8	(2.6)	41.2	(2.8)	58.3	(2.6)	18.0	(1.0)
Body Condition Scoring	10.5	(1.1)	19.1	(2.3)	26.8	(2.5)	34.4	(2.5)	14.3	(0.9)
Same Evaluation	10.9	(1.1)	33.2	(2.7)	45.9	(2.8)	56.8	(2.5)	19.5	(1.0)

Source: USDA Animal and Plant Health Inspection

Strategies to develop superior female replacements has one of the greater long-term effects upon profitability compared to other decisions made by a cow-calf producer.

Since most calves are weaned at a time than a weight constant, calves born late in the calving season tend to be lighter weight and likely sell for a lower value. This decreases the dam's total lifetime revenue stream.

Cow-calf producers invest in herd genetics through two approaches. Producers have the choice of focusing on sire and maternal grandsire EPDs or focus on retaining heifers from high performing dams that produce offspring of superior quality. Higher-performing dams are usually retained the maximum amount of time on the farm. Heifers typically produce offspring when they are two years old. If a dam consistently conceives annually producers save money by not needing to purchase replacements or retain heifer calves as future replacements as often.

Chapter 3: Review of the Literature

Technological advances are currently available for cow-calf producers to improve herd genetics, create uniform calf crops, reduce the annual calving window, increase conception rates and weaning weights, and improve carcass grades. However, the question that producers must answer is whether the investment in reproductive technology is profitable. The National Animal Health and Monitoring Survey (2007) reported US small-scale cow-calf operations represented 90.4 percent of beef cattle farms and accounted for 45.9 percent of all beef cows.²¹ As discussed previously, it remains vital for the US beef industry to continue investment in reproductive technologies that contribute to greater quantities of higher-quality beef to demand and increase marketing opportunities for beef in the US and worldwide. Smaller sized operations that partially rely on off-farm income, are slower to invest in technology due to the lack of economies of scale needed to adopt the technology. However, these operations represent almost 46 percent of beef cattle produced in the US, and ultimately the industry can't move forward as quickly without participation from smaller cow-calf operations.

To evaluate economic profitability of technological adoption, past research has analyzed various aspects ranging from simple cost benefit analysis of FTAI and natural sire performance comparisons to retail sector price differentials. Participants throughout the beef cow production cycle absorb risks ranging from weather to feed costs to disease. Reproductive loss is the greatest contributor to economic loss for a cow-calf operation making producers work hard to ensure that a large percentage of females produce

²¹ Ibid. USDA National Animal Health Monitoring (2007).

offspring annually. Livestock economists have worked to provide tools and information for producers that remain unsure about investment in technology.

The Western Beef Development Centre (WBDC) compared reproductive efficiency and associated costs for 80 black Angus five-year-old cows following fixed-time AI or natural service. The study applied estrous synchronization and FTAI protocols to 40 females followed by clean-up bulls. The remaining 40 females were exposed to natural service sires at a 25:1 female to bull ratio. Results showed in Table 2 display a 3.4 percent and 12.5 percent improvement in average birthweight and calving rate, respectively, when estrous synchronization and FTAI protocols were applied compared to natural service protocols.²² Although adjusted weaning weights were lower, the weaning rate, number of calves weaned per exposed female, was 12.5 percent higher, meaning more calves on the ground from in the FTAI group.

Table 2 Natural Service and FTAI Performance Comparison

Production Measure	NS	FTAI
Number of Cows	40	40
Pregnancy Rate, % of total cow	92.5	97.5
Calving span, d	69	64
Calving rate, %	80	92.5
Calf birth weight, lbs	85	88.4
Calving distribution, % of total		
1-21 d	84.8	81.1
22-42 d	9.1	10.8
43-63 d	6.1	8.1
Wean rate', %	77.5	90
Calf 205-d adjusted weaning weight, lbs	629	606
Total lbs of calf weaned (205-d adjusted)	18,253	22,422

Source: Lardner et al., Western Beef Development Centre

²² Ibid. Lardner et al., (2015).

The difference in weight between calves resulting from FTAI versus natural service equaled 4,169 pounds. Assuming a fall 2014 weaned calf price of \$2.90 per pound, the increase in pounds of weaned calf amounted to \$12,090 in added revenue that resulted from calves produced from the FTAI group.

Table 3 Cost of Retaining Bulls at Western Beef Development Centre

Costs	Total \$	Assumptions
Hay	\$ 245.41	<i>Fed 45 lb/d for 185 d, valued at \$65/tonne</i>
Pasture	\$ 162.00	<i>On grass for 180 d; grazing worth \$0.90/hd/d</i>
Bedding	\$ 15.00	<i>Source: WBDC Fact Sheet #2010-04</i>
Grain	\$ 64.76	<i>Fed 7 lb/d for 120 d, valued at \$170/tonne</i>
Minerals/Salt	\$ 15.00	<i>Source: WBDC Fact Sheet #2010-04</i>
Vet/Medicine	\$ 20.00	<i>Source: WBDC Fact Sheet #2010-04</i>
Semen testing	\$ 100.00	
Total direct costs	\$ 622.17	
Yardage	\$ 216.45	<i>\$1.17 per d x 185 d (WBDC's 2012 COP Study)</i>
Bull depreciation	\$ 685.81	<i>Based on WBDC's actual average purchase price (\$4000) less salvage value (WBDC cull bull sales in early 2014- \$1.05 x 1850 lbs.) divided by 3 years of use (WBDC's average # of years bulls used)</i>
Risk of loss	\$ 600.00	<i>15% chance bull will need to be replaced during breeding season</i>
TOTAL	\$ 2,124.43	
\$/Cow	\$ 84.98	<i>per cow (assuming 25 cows serviced)</i>

Source: Lardner et al., Western Beef Development Centre

Table 3 displays the cost breakdown of retaining breeding bulls on the operation in this study. Applying assumptions pertaining to feed intake and utilizing past WBDC data, the study calculated an average annual cost of \$2,124 to maintain a breeding bull and assumed that each bull serviced 25 females. Therefore, to service 40 females, the average sire costs would be \$3,399.

Table 4 calculates FTAI costs to service 40 females at \$5,166. This would suggest that applying FTAI protocols compared to natural service protocols cost about \$1,767 more for 40 females based on the designated assumptions in the study. However, when revenue

gains were applied, net gain totals amounted to \$10,323 for the 40 females that were assigned to the FTAI group compared to those exposed for natural service.

Table 4 Estimated Costs for Fixed Time Artificial Insemination per Cow

Item	Total \$ on 40 cows	\$/cow
FTAI supplies		
Prostaglandin	\$ 207.48	\$ 5.19
GnRH (2 doses)	\$ 243.45	\$ 6.09
CIDR	\$ 680.11	\$ 17.00
Syringer, applicator	\$ 36.67	\$ 0.92
Semen	\$ 1,064.00	\$ 26.60
Total supply costs	\$ 2,231.70	\$ 55.70
AI technician		
AI fee	\$ 420.00	\$ 10.50
Mileage	\$ 119.28	\$ 2.98
Labour charge	\$ 175.14	\$ 4.38
Total AI technician costs	\$ 714.42	\$ 17.86
Ranch Labour		
2 Ranch labourers ¹	\$ 360.00	\$ 9.00
Clean up bull		
Clean up bull ²	\$ 1,699.55	\$ 42.49
Overhead		
Handling system ³	\$ 160.00	\$ 4.00
Total costs	\$ 5,165.67	\$ 129.14

Source: Lardner et al., Western Beef Development Centre

It is important to note that this study was based on a relatively small sample size and results are only for one given year. The report was designed to provide a glimpse of potential returns for adoption of a FTAI protocol. All prices are subject to change as fall of 2014 was an exceptional year for weaned calf prices. Several assumptions and generalizations were applied to natural service sires and FTAI protocol costs and may not be accurate across operations.

White et al. highlighted the growing value of information as the beef industry evolves to a more integrated value chain. These authors recommended that all profit maximizing producers strive to collect data on each level of production, including preweaning, backgrounding, feeding, carcass performance, and implementation costs related to specific management practices based on analysis of the data.²³ With expanded information, farm managers are better equipped to respond to market signals and evaluate the magnitude of increased risks.

Parcell et al. reported heifer procurers categorized economic characteristics including pen uniformity, AI to calving ease bulls, synchronized calving, and heifer weight and condition as important, and conveyed a significant willingness to pay.²⁴ This research also highlighted the importance of replacement heifer selection, citing it as the top significant long-term effect on a beef herd's production efficiency and profitability. Yet, in many cases managers are limited by the availability of premium male and female seed stock to accelerate genetic improvement in their herds.

Brown evaluated marketing opportunities for AI bred heifers and AI sired progeny citing determinants of how market returns are increased, and/or economic risks are reduced through use of genetic information.²⁵ Timing of future market situations reward those producers that expand before a market boom while punishing those that expand shortly before facing economic pressure. Brown referenced economic theory when suggesting

²³ White, Brad et al., "The Cow-Calf Operation Retained Ownership Decision" *Professional Animal Scientist* no. 23 (2007): 18-28

²⁴ Parcell, Joe. L. et al., "Buyers' Perceptions of Importance and Willingness-To-Pay for Certain Attributes of Source and Production Verified Bred Heifers" *Agricultural Economics* no. 41 (2010): 463-470

²⁵ Brown, D. Scott "Marketing Opportunities for AI Bred Heifers and AI Sired Progeny" *USDA Added Value Beef Study* (2014): 148

that cow-calf producers should invest in herd expansion when the expected net present value (NPV) of future returns is greater than current market values of females.

Brown prompted consideration of the differences in price or value between AI bred heifers compared to heifers carrying natural service sired pregnancies. Producers should consider economic gains from a more predictable genetic base. Although exogenous risks, such as volatile cattle prices and weather, are impossible to accurately predict and potentially determinantal for economic returns, technological advances better equip management of reproductive risks. Reduction of calf loss risk is viable with a focus on calving-ease genetics for bred heifers. Analyses suggested that loss of a cow's second calf could reduce her NPV by \$967 compared to loss of her sixth calf, reducing her NPV by \$556. Due to discount rates, return on investment is more pertinent in the short term; younger age females typically experience a higher incidence of calving difficulty so calf loss in the early years of a cow's productive life could be harmful to economic viability of an operation.

Hughes et al. reminded producers to properly analyze measures used to determine costs of raising replacement heifers. Applicable cost measures include accounting costs, cash costs such as interest and principle payments, and economic costs such as opportunity costs. The paper cited the largest costs associated with retention and development of heifers results from the opportunity costs of not selling heifer calves at weaning.²⁶

²⁶ Ibid. Hughes (2013).

Fraiser-Pope et al. evaluated cow-calf producer risk impacts related to retained ownership decisions. The findings concluded that producers displayed risk aversion and that many producers sold calves post weaning despite market incentives to retain heifer calves.²⁷ The study highlighted the importance of risk aversion as it impacts longer term calf retention. Findings concluded risk-adverse producers have more than a 60 percent probability of selling calves shortly post weaning while risk-tolerant producers showed less than a 20 percent probability of doing so. Fraiser-Pope et al. relayed survey results of Kansas cow-calf producers that reported 40 percent of producers always sell calves at weaning while 44 percent and 13 percent retain ownership through backgrounding or finishing, respectively.

McDonald et al. determined the relative effects on price, quality, and feeding performance on profit per head for fed cattle marketed through a grid structure. Grid base price and feeder cattle price were found to be the top determinants of profit over time.²⁸ However, pen quality should not be overlooked, as it also serves a role in profitability. For those utilizing grid pricing, the Choice-to-Select spread is the most important price risk when compared to those selecting traditional live weight marketing. The paper suggests intense management of stated price factors offers the largest opportunity for management of profit risk over time.

Fausti et al. discussed grid pricing and the issues and trends facing the slaughter cattle market. They cited adoption of value-based marketing technologies as vital to increase

²⁷ Ibid. Fraiser-Pope et al., (2011).

²⁸ McDonald, Allen and Ted C. Schroeder. "Fed Cattle Profit Determinants Under Grid Pricing" *Journal of Agricultural and Applied Economics* no. 35 (April 2003).

production efficiency.²⁹ Through production efficiency, producers are consistently rewarded when grid pricing is applied. Fausti et al. highlighted literature reporting marketing fed cattle through grid systems increases price variability relative to average pricing and recommended that producers not sell through grid pricing programs if they lack knowledge related to the quality of their cattle.

Steiner and Brown assessed the role beef quality grade should play in the strategy of differentiated beef demand. Findings concluded Prime-graded beef and Certified Angus Beef (CAB®), as more own-price elastic when compared to other quality grades at -2.33 percent and -2.26 percent, respectively.³⁰ These elasticities mean as Prime beef price increases by one percent consumption demand falls by 2.33 percent.

Traveling down the quality grade spectrum, analysis by Steiner and Brown found that beef graded as Select faces an own-price lower elasticity of -1.24 percent. When price flexibility measures were applied, findings concluded a -.43 percent for Prime, -.44 percent for CAB®, and -.81 percent for Select. Thus, meaning a one percent increase in Prime beef supply could result in a 0.43 percent decline in price, but that Select beef price would decline 0.81 percent with the same supply increase. Beef prices of lower quality grades, such as Select, are more susceptible to shifts in supply compared to prices of higher quality grades such as Prime.

²⁹ Fausti, Scott W. et al., "Value-Based Marketing: Discussion of Issues and Trends in Slaughter Cattle Markets" *Journal of Agribusiness* no. 28 (Fall 2010): 89-110.

³⁰ Steiner, Jillian and D. Scott Brown. "Should Beef Quality Grade be a Priority?" *USDA Value-Added Beef Study* (2014): 155.

Brown and Patterson evaluated the development of high-quality marketing for Missouri cow-calf producers where ownership was retained through the feedlot process. Results showed carcasses that graded Prime presented the largest added income and held steady regardless of average daily gain.³¹ Findings concluded difficulty in convincing Missouri cow-calf producers to modify their marketing strategies partially due to associated changes timing related to cash flow.

Previous literature highlights carcass-quality focused price differentials and grid pricing's importance in acquiring information. Past studies found that implementation of artificial insemination technologies can increase value and deter other risks. Additionally, research on implementing technology applied cost comparisons and noted opportunity costs of investing in cow-calf reproductive technologies.

There is much to be evaluated on the value of implementing cow-calf reproductive technologies from a producer perspective. Current academic literature lacks analysis of the long-term measure of value when reproductive technologies are applied throughout several breeding cycles on an entire operation. As cow-calf producers consider adoption, they will likely consider potential increases in value of applying reproductive technologies to their entire operation over the long term.

³¹ Brown, D. Scott and David J. Patterson "Development of High-Quality Marketing Program for Missouri Cow-Calf Operators" USDA Value-Added Beef Study (2014):2.

Chapter 4: Show-Me Select Heifer Program

In 1996, Missouri extension specialists, beef producers, veterinarians, and beef industry firms cooperated to develop and implement a plan that would promote long-term sustainability of Missouri's beef cow herds. The program focused on the importance of heifer selection and development and involved five steps:

1. Create an understanding of the importance of heifer development based on reproductive outcomes.
2. Implement changes in heifer development that will eventually spill over into the cow herd.
3. Expand producer focus on genetic improvement.
4. Emphasize the importance of reproductive management, which becomes apparent as changes are implemented.
5. Emphasize to participating herds that creation of a value-added product requires a re-evaluation of marketing strategies.³²

The same group initiated the Show-Me-Select Replacement Heifer (SMS) Program in 1996 piloted in the southwest and northeast regions of Missouri involving 33 farms and 1,873 heifers.³³ Over time the SMS program expanded and increased its recognition, with SMS program heifers now having sold into 20 states, spreading superior genetics throughout the industry. The program is designed to improve long-term reproductive

³² Ibid. Patterson and Brown (2013).

³³ Ibid. Patterson and Brown (2013).

efficiency of cow-calf operations. Privatized as a non-profit in 2004, participation in the SMS program continues to grow.

Improved heifer development programs through a total quality management approach increased the value of heifers by establishing accreditation that is recognized in the marketplace. Participating program cow-calf operations created reliable sources of superior heifers based on quality genetics, reproduction and health. Requirements for candidacy in the SMS program include health and vaccination guidelines, expanded service sire requirements, minimum body condition score requirements, pre-breeding examinations, and certified screening from the Missouri Department of Agriculture.³⁴

Recently, the SMS program established an additional level of minimum requirements to be qualified for Tier 2 status. This entailed minimum sire accuracies for calving ease, weaning weight, carcass weight, and marbling. When sale performance was compared between AI and natural service bred heifers within the same time period, heifers carrying AI sired pregnancies outperformed the natural service sired group. As shown in Table 5, a Tier 1 natural serviced bred heifer sale value average totaled \$1,549 while a Tier 1 AI bred heifer averaged \$1,841.³⁵ Tier 2 qualified heifers received additional premiums. Tier 2 bred heifers carrying natural service sired pregnancies averaged \$2,023 and Tier 2 AI bred heifers averaged \$2,263. Undoubtedly, price differentials are present within the various SMS qualifying tiers.

³⁴ Ibid. Parcell et al., (2010).

³⁵ Ibid. Brown (2014).

Table 5 Sales Average for Show-Me-Select Replacement Heifers Based on Service-Sire and Tier

	Tier One Show-Me-Select Heifer (\$)	Tier Two Show-Me-Select Heifer (\$)
Natural Service-Sired Pregnancy	1549	1786 + 237
AI-Sired Pregnancy	1695 + 146	1906 + 357

Sales average reflect sales of heifers from the fall of 2010 through the fall of 2012

Source: Patterson et al., (2013)

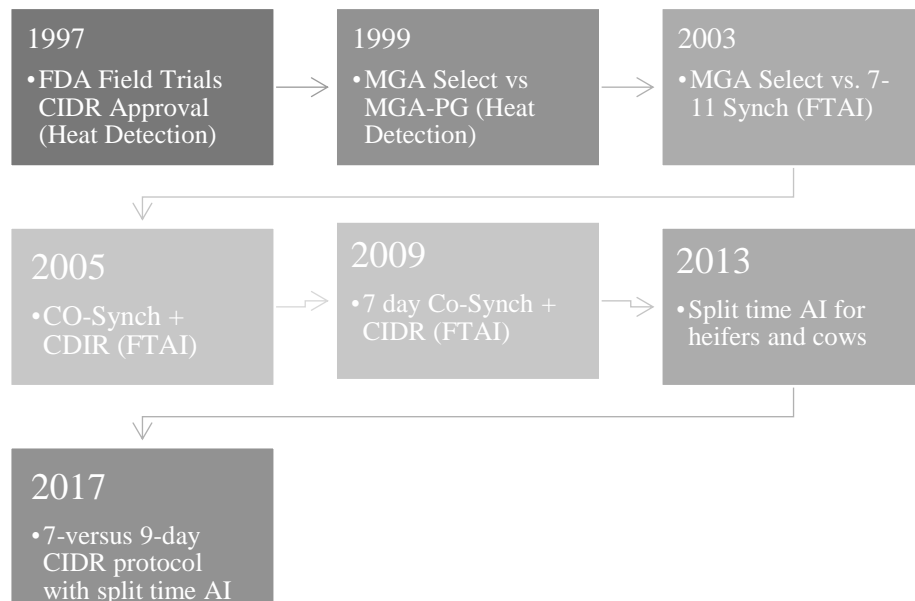
Chapter 5: The Thompson Research Farm

In 1956, George Drury donated 1,600 acres near Spickard, Missouri to the University of Missouri. The donation, known as the Thompson Research Center, focused on crop management and beef cattle production systems. The research center transitioned from crop production research to beef cattle research during the 1970's. The Thompson Research Center focuses on cow-calf research related to reproductive efficiency and evaluates management practices that include backgrounding and finishing options. Currently, the research center maintains approximately 200 commercial Black Angus cows.

Beginning in 1997, Dr. David Patterson, University of Missouri State Beef Extension Specialist and Professor of Animal Sciences, and his team conducted extensive reproductive research including experiments applying estrous synchronization and artificial insemination utilizing expected progeny differences (EPD) to improve genetic merit of the herd. As shown in Table 6, from 1997-2002, Patterson and team utilized heat detection aids to determine estrus.³⁶ From 2003 on the team progressed to FTAI applications, developing programs for beef cows and heifers. Table 6 shows the detailed timeline of Patterson and his team's research at the Center.

³⁶ Patterson, David J., Personal Interview to Emma Downing, April 2019.

Table 6 Patterson and Team Research Timeline at Thompson



Source: Dr. David Patterson Personal Interview
(2010)

With the primary goal of producing premium quality “white table cloth” beef, the Thompson Research Center not only stands at the fore front of cow-calf reproductive discovery in the industry, but bridges research and extension by demonstrating opportunities for producers in the Midwest intent on improving their herds. As a member of the Missouri Agriculture Experiment Station, the Thompson Research Center facilitates a proactive extension role with local producers. Producers from the region serve on the Center’s board, field days are open to the public in which university personnel present research findings and discuss application of technology to the industry, and onsite training for graduate students in animal science.

Breeding programs led by Dr. Patterson have utilized AI programs to improve contributing reproductive performance of the herd, while at the same time enhancing the genetic merit of the herd over time. The research focused on reproductive and performance of the females and carcass merit based on quality grade and marbling of the steers. Carcass data from Thompson fed steers consistently performed well, with steer groups averaging between 25 and 30 percent Prime and over 90 percent grading Choice or higher with only minimal discounts for yield grade.³⁷ Thompson carcass data is extremely impressive when compared to an average of only 8.31 percent of all US carcasses that graded Prime in 2018.³⁸

Brown analyzed performance of Thompson steers compared to USDA- AMS reported St. Joseph, Missouri feeder steer prices during mirrored time periods. Brown found no Thompson Farm Prime-graded steers that were worth less at slaughter than the feeder price value during the post-wean time period.³⁹ Analysis showed that Thompson steers were worth an additional \$148.37 per head when compared to the average feeder calf price if sold as such.

Chapter 5.1 Thompson Farm Data Analysis

Research question: *Has the investment in genetics and management over time improved the value of offspring produced at the Thompson Research Center compared to US average performance?*

³⁷ Ibid. Brown, (2014)

³⁸ Ibid. USDA AMS

³⁹ Ibid. Patterson and Brown, (2013)

The aim within this project was to create a useable database of collected Thompson Farm data, including, animal identification, birth dates and weights, weaning weights, sale prices, marketing outlets, carcass grades, offspring associated with dam and sires, etc.- throughout a 20-plus-year span. Over 13,000 pages of data were processed, formatted, and organized to create a database involving detailed information on over 4,000 calves. This process led to the creation of electronically accessible information available to update and to be utilized by Thompson Research Center interested parties, including, economists, farm managers, and reproductive technicians.

A database of this magnitude, time span, and size is rare. These detailed quantitative data and results can now be used by beef extension specialists at the Center and across the state and nation. Local producers that consider ways in which to advance the genetics of their herds through reproductive technologies are now able to learn from research outcomes from the Center as quantitative economic results become available.

Once the data was formatted and organized, simple analyses was applied to quantify the performance of calves produced from the Center. Multiple approaches were utilized to gauge success. Analyses of the data included changes in birth weights, weaning weights, death loss, dam longevity, offspring values, and carcass grade over the long term. Sale values were then compared to US average values specific to offspring marketing channels, controlling for variability in cattle prices since 2002.

Although research was initially focused on profitability on a per head basis for the Center, the aggregate nature of cost measures made per cow profitability infeasible given the current data available. The historical data only contained farm totals for annual labor, feed, nutrition, reproductive, and marketing costs per each given year. Quantifying cost

results on a per cow basis would require several assumptions using national averages of per cow feed and mineral consumption. With the analyses comparing performance of cattle from the Center against the national average, cost inputs would lack variability due to assumed US averages, which would limit quality of the results. Additionally, the research structure of the Center raises issues related to cost assessment, such as labor, which may not be representative of a commercial operation. Because of these obstacles, this analysis focuses on comparing values collected at the Center that are representative of a commercial operation on a per head basis.

Chapter 5.2 Description of Thompson Farm Inventory

Mirroring conventional herd management practices of commercial cattle producers, the Thompson Research Center retains replacement heifers and moves steer calves to feedlots in western Kansas. Open cows and low-performing calves are sold through local auction markets. Some heifers are sold every year through the SMS program or they qualify heifers to be candidates for the SMS program and then sell these high-quality bred females at premium prices. Throughout this research, Center offspring were organized into three groups: steers sent to the feedlot; SMS heifers, bred SMS qualifying heifers that were sold locally, or heifers retained within the herd; and calves sold shortly post weaning at local livestock auction markets.

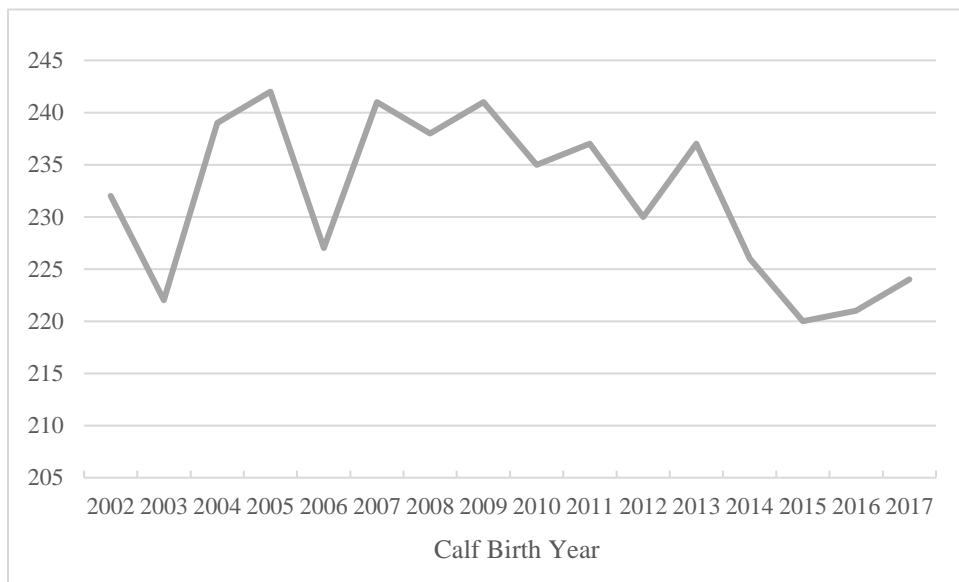
To monitor carcass performance and capture maximum value, the Center retains ownership of steers through finishing and slaughter. From 2008 to 2016, the Center sent steers to the Irsik and Doll feedyard in western Kansas feedyard. In 2017, the farm moved steers to Tiffany Cattle Company at Herrington, KS. Retention of ownership

allows the Center to not only capture added value through carcass premiums received but gather information on steer performance in the feedyard and resulting carcass merit.

Chapter 5.3 Descriptive Statistics

Figure 5 displays the approximate number of cows in the Center’s cow herd. Total Center inventory includes cows in which offspring were to be fed out at feedlots, retained as replacement heifers, sold through SMS heifer sales, bred and sold premium-valued heifers that could have qualified for the SMS heifer program, and offspring sold locally shortly post weaning. In Figure 5, along with all further graphs, the independent variable is representative of the year in which calves were born. Additionally, cows whose offspring died on farm and open cows sent to the University of Missouri for use in AI training are represented.

Figure 5 Number of Cows in Thompson Farm Herd Annually



It is important to note that cows that tested open and sold locally are not included in Figure 5. The Center follows the national trend (Figure 1 in introduction) of commercial

cow calf producers decreasing herd numbers during the years 2013 and 2014. Although the farm is operated as a research center owned by the University of Missouri, farm management makes decisions based on cattle and feed market conditions similar to other commercial cattle operations in the area. Therefore, economic performance evaluation of cattle produced from the Center is extremely valuable to producers throughout the industry.

Figure 6 is representative of the previously described offspring on an annual basis. Steers sent to the feedlot, heifer calves retained in the herd, and premium SMS-qualifying heifers which were bred and sold, in addition to weaned calves sold locally represent the majority of offspring produced at the Center. Therefore, analysis applied to these data focuses on the three categories of offspring. Replacement heifers retained in the herd, heifers sold through SMS sales, and bred heifers that were sold that could have qualified for SMS are grouped together throughout the analysis.

Figure 6 Percentage of Thompson HErd Offspring Categorized by Fate

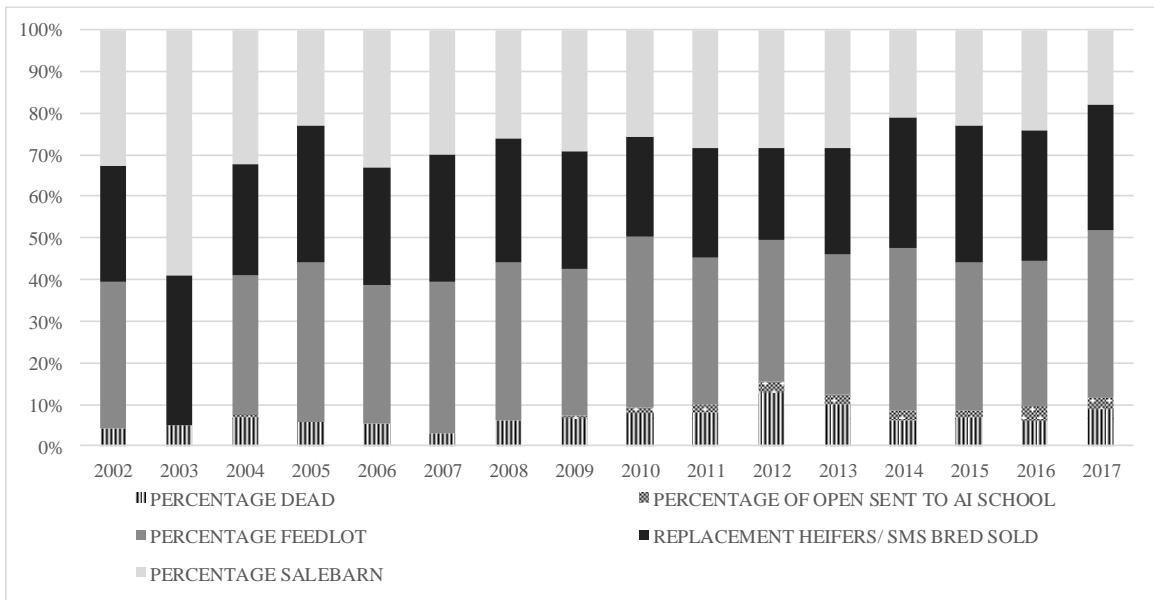
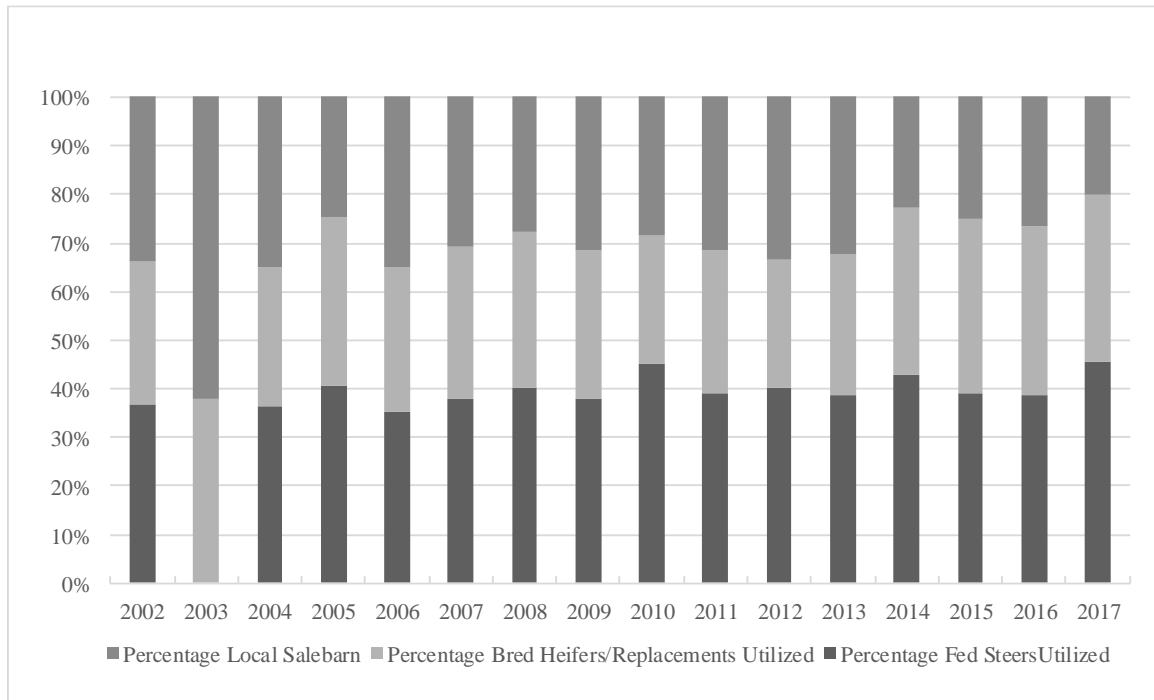


Figure 7 represents the percentage of offspring that were either sent to the feedlot, retained as replacement heifers, sold through SMS sales, bred and sold premium-valued heifers that could have qualified for the SMS program, and offspring sold locally shortly post weaning. Dead calves are excluded from Figure 7. Apart from 2003, the data is fairly consistent in terms of the proportion of calves that were sent to the various sale outlets.

Figure 7 Percentage of Thompson Farm Offspring in Top 3 Fates



One point of consideration to note is that calves sold locally are unlikely to capture as high of a value compared to offspring where ownership was retained further into the production cycle. Weaned calves that were sold were treated similar to calves sold through the local livestock auction markets and were evaluated primarily by weight and age. Although more risk is associated with retaining ownership, returns on reproductive investment such as superior dams or premium carcasses are realized further in the overall production cycle.

Chapter 5.3 Part A Birthweight and Weaning Weights

Figure 8 displays annual average birthweights and weaning weights of all calves produced at the Center from 2002 to 2017. Average weaning weights steadily increased over the 15-year period likely resulting from more calves being born earlier in calving season. Earlier calving at the Center is a result of estrous synchronization and FTAI protocols that decrease the calving window and concentrate the entire calving distribution. Overall, birthweights tend to trend downward over time, a likely result of high-accuracy sires with calving-ease traits used to breed the Center heifers. Breeding heifers to high accuracy calving ease sires reduces the risk of dystocia and associated loss of the calf or dam.

Figure 8 Thompson Farm Birthweights and Weaning Weights



Figures 9 and 10 illustrates birthweights and weaning weights of calves separated by gender. Female calves produced at the Center experienced greater declines in birth weight compared to males. Weaning remained consistent for both genders. As mentioned previously, high-accuracy calving ease sires were used to breed heifers in order to reduce the risk of calving difficulty during the first calving period. Although further analysis is needed, the greater decline in female birth weight compared to males could be representative of female calves more responsive to “calving-ease” genetics.

Figure 9 Thompson Farm Birthweights and Weaning Weights - Females

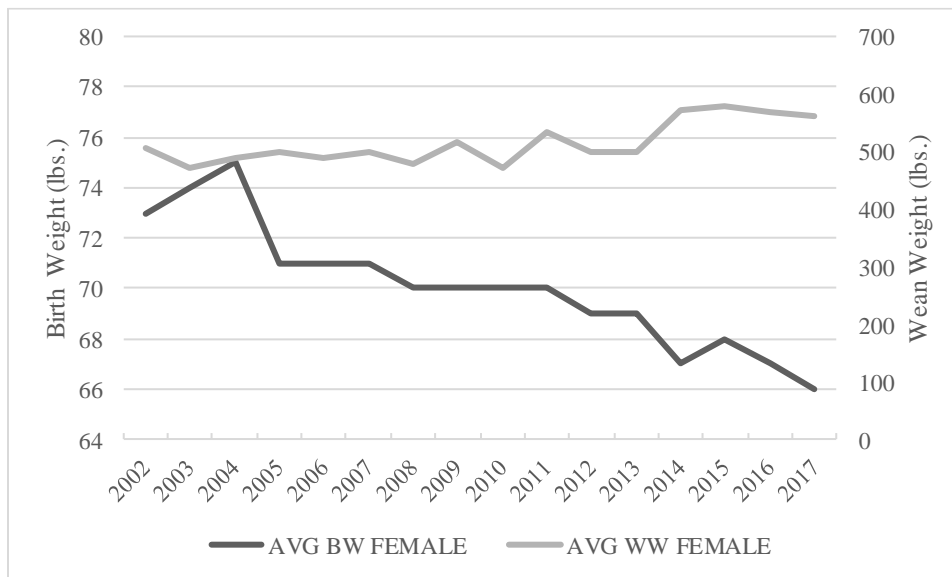
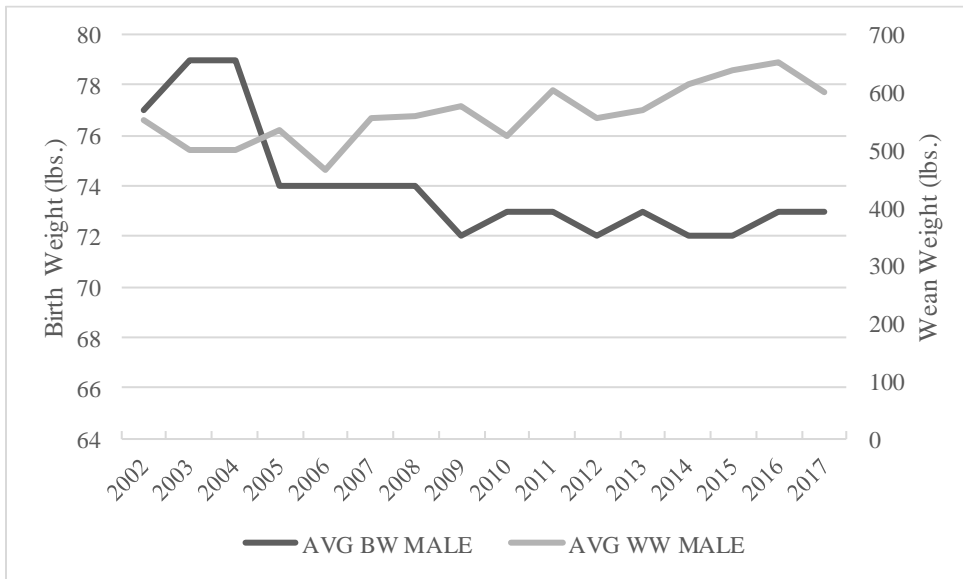


Figure 10 Thompson Farm Birthweights and Weaning Weights- Males



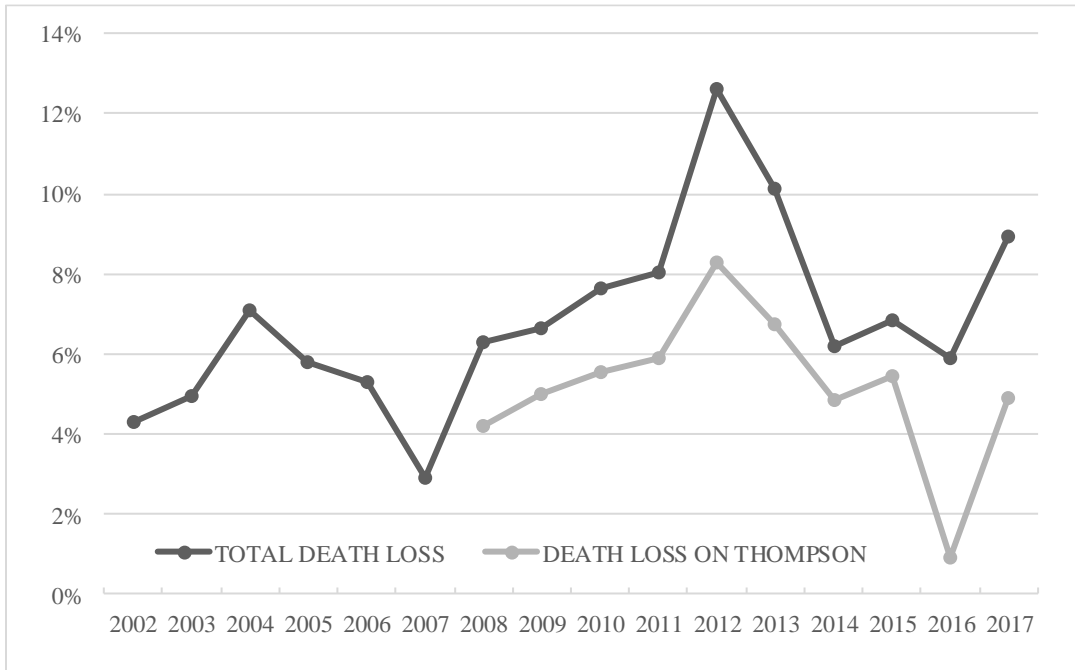
Chapter 5.3 Part B Death Loss

Figure 11 displays the death loss percentage of calves relative to total number of calves born for the respective year at the Center. Total death loss includes deaths of calves at the Center and steers being fed in a feedlots. The difference between the two lines pertain to deaths of steers that occurred at the feedlot; 2016 is a good example of the potential risks associated with retaining ownership through the feedlot. While death losses at the Center were less than one percent, total death loss including losses at the feed yard totalled almost six percent. Weather related issues were cited as the likely cause of a high percentage of death loss at the Center in 2012.

Death losses have a large impact on the bottom line of a cow-calf operation; if calves die before they can be sold, the producer incurred all costs associated with producing that calf without collecting any return. As of May 2010, 2.9 percent of US beef cows have

calves born dead and an additional 3.5 percent of calves born in the US die before weaning, summing to an average total death loss in the US of 6.4 percent.⁴⁰ Apart from 2012 and 2013, death losses at the Center before weaning were well below the national average reported in 2010.

Figure 11 Death Loss Rate of Thompson Herd



Chapter 5.4 Analysis Methodology

Once the data from 1999 to 2018 was organized, it was possible to evaluate various measures of calf performance. Apart from descriptive results, further analyses required a value to be determined for each calf. Throughout the analysis, sale-price values for cattle produced from the Center were compared to similar national average sale prices for each

⁴⁰ Ibid. USDA, APHIS (2011).

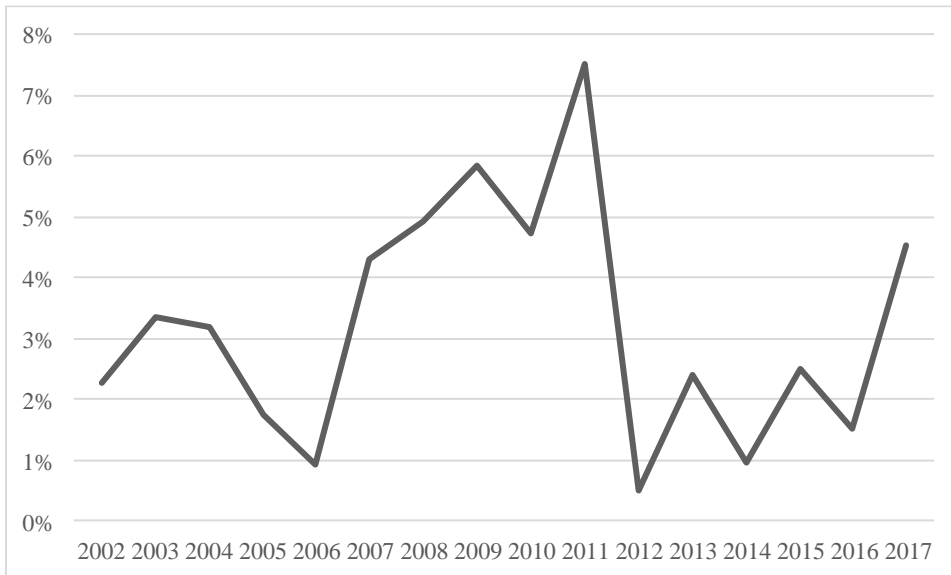
year. Utilizing ratios of sale prices for cattle produced from the Center to US national average sale prices provides a consistent way to examine results.

The project focuses on calves from 2002 forward because of missing data prior 2002.

Within that time period however, the database is missing information on only a small number of sale prices. To conduct analysis, it was necessary to have a value for every animal produced at the Center, which required a limited number of assumptions to be applied in the dataset. It is imperative to highlight the fact that the majority of data used within the analysis was sourced from records maintained at the Center. As Figure 12

illustrates, the number of assumptions is marginal relative to total offspring observed in a given year.

Figure 12 Percentage of Sale Price Assumptions Compared to Offspring Counts



Sale prices that were missing from local auction markets represented the majority of missing values. Table 7 details the assumptions that were applied to create values for

missing data. For example, one likely reason for lacking prices was a result of a calf sold as a cow-calf pair. For the majority of auction market data, the lower 30 percentile or average was applied to sale prices of weaned calves sold at local livestock auction markets for a given year. A lower 30 percentile or average was applied based on the variability within the auction market sale prices in that year. For example, if 2016 sale price data for calves sold from the Center at local auction markets showed a large range in price, the lower 30 percentile of those sale prices was calculated. It was assumed these calves were on the lower end of quality, age, or weight and therefore sold on the lower end of the price range. If sale prices for a given year lacked variability, a simple average was assumed. Additionally, several missing prices from local auction markets for steers were assumed as 999 dollars if local auction market steer prices were in the range of 999 dollars for that given year.

Additionally, a small amount of fed steer value assumptions was applied based upon the average values of fed steers that received the same quality grades in that given year.

Unfortunately, individual sale values for 2015-born fed steers bought by Tyson was missing from the data. Therefore, the aggregate sale amount Tyson paid was divided on a per head basis and that quotient was applied to the analysis. Although it is not necessarily a preferred choice to assume sale prices for cattle that were sold in the case of missing data, assumptions are representative of only a small proportion of the total data and were essential in conducting the analysis.

Table 7 Assumption Calculation Methodology

<p><u>ASSUMPTIONS MADE WHEN PRICES WERE MISSING</u></p> <p>AUCTION MARKET HEIFERS: LOWER 30 PERCENTILE OF OPEN HEIFERS</p> <p>AUCTION MARKET STEERS: \$999 OR AVG OF NON FED STEERS</p> <p>AUCTION MARKET FREEMARTIN: LOWER 30 PERCENTILE OF AUCTION MARKET STEERS</p> <p>TF FED FREEMARTIN: LOWER 30 PERCENTILE OF FEELOT STEER VALUES</p> <p>MISSING TYSON FEEDLOT STEERS: ASSUMED SALE PRICE/HEAD FROM TYSON AGGREGATE SALE DATA</p> <p>MISSING FEEDLOT STEERS: ASSUMED AVG FED STEER PRICE W SAME QUALITY GRADE</p> <p>AUCTION MARKET BULL CALVES: AVG BULL CALF AUCTION MARKET PRICE</p>

Chapter 5.5 Measuring the Value of Thompson Farm Offspring

Once the Thompson Farm database was complete and select sale price assumptions were applied, sale prices for steers sent to feedlots, heifers retained or SMS bred heifers, and calves that were sold locally shortly post weaning were valued against national or regional average sale prices. These ratios were used to evaluate sales performance for animals produced from the Center against the national/regional averages and to determine changes in the performance of cattle produced from the Center over time. Analysis was applied to each of the three offspring categories as well as a weighted average for the farm as a whole.

Chapter 5.5 Part A Thompson Farm Feedlot Steers

To evaluate fed steer sale prices for the Center relative to similar US national average sale prices, individual prices for fed steers from the Center from 2008 through 2017 were compared to USDA AMS national weighted average monthly prices reported by the Livestock Marketing Information Center (LMIC). National fed steer average prices were pulled for the month of May in the year following a steer’s birth to proxy the sale price during the same period that steers from the Center were slaughtered. Using data from this time period created a comparable time frame to compare fed-steer prices from the Center.

Figure 13 Value of Difference of Thompson Farm Fed Steer and May t+1 AMS Steer Values 2008-2017

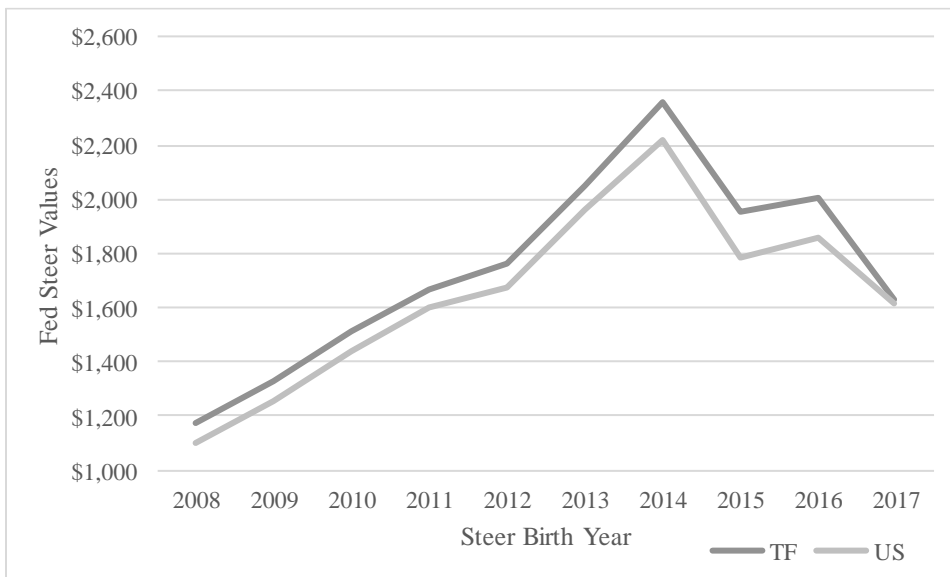


Figure 13 illustrates annual average values for fed steers from the Center and AMS May t+1 average live steer values from 2008 to 2017. Although the analysis focuses on added revenue instead of profitability, Figure 13 displays several years of added value the Center received on average consistently above compared US averages for fed steers. For example, in 2015 the Center to US fed steer difference in added value was \$173 on a per

animal basis. An extra \$173 per animal would allow a commercial cow-calf producer to make a considerable investment in genetic improvement on their operation.

There are also factors other than adoption of reproductive and genetic technologies at play that affect fed steer performance of steers from the Center, including feedlot performance of Irsik and Doll and Tiffany Cattle Company compared to others.

Additionally, it is important to note the analysis is based on aggregate data during time periods where only two feedlots were utilized and should not be viewed as representative of national average feedlot performance. For example, it is unknown how the two feedlots performed against US average feedlot performance. However, the analysis assumes strong genetic performance by fed steers from the Center that played a large factor in the added value seen in Figure 13.

Figure 14 Thompson/US Values Ratio Averaged Annually for Fed Steers 2008-2016

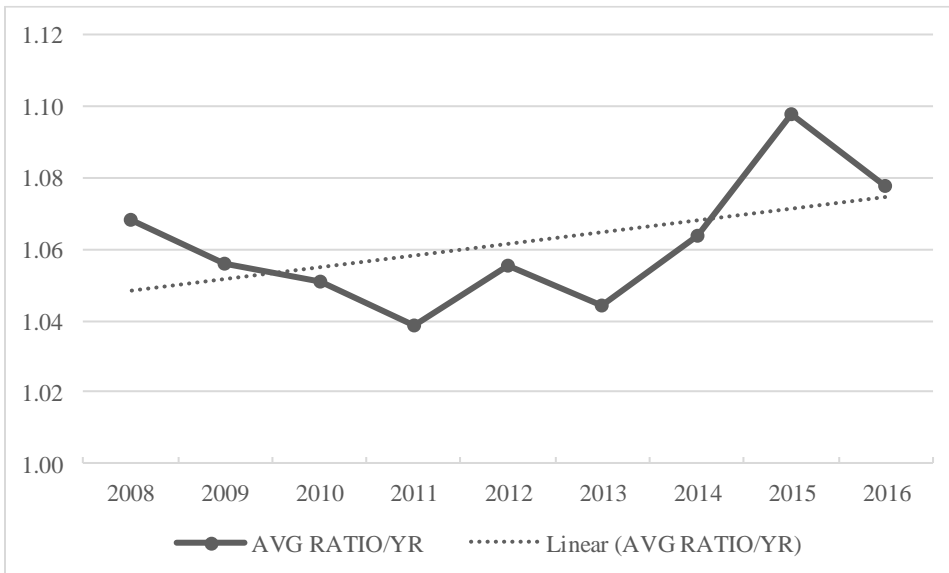


Figure 14 details the ratio of annual average prices for steers produced from the Center relative to the national fed steer weighted average prices for May $t+1$. The years shown in the graph represent birth years for steers that were fed. Data reflects years 2008 to 2016 due to missing sale values for fed steers from the Center in 2005 and 2007. As shown in Figure 14, over the 2008 to 2016 time period, the Center over US ratio was consistently well above one. The annual averages of ratios comparing fed steer values for the Center to national fed steer values trend upward over the period as well. Strong performance for cattle from the Center over this time span supports investment by the industry in reproductive and genetic technologies that deliver improved carcass quality grades and increased premiums.

When a trend was inserted to compare performance of fed steers from the Center to national averages for fed steer prices over time, results showed a 0.33 percent increase in the ratio value annually from 2008 to 2016. Equation 1 represents the regression output of the ratio as a function of trend which explains 24 percent of the variation in data. The P-value, which is used to determine the statistical significance, fails to reject at the null at 0.17. However, when including trend to describe the Center to US ratio, the focus is to analyze the impact of time on changes in the ratio, not to reject the null hypothesis. This positive trend shows that the value for cattle produced from the Center is increasing at a faster rate than the US average over time, correlating the investment that better genetics builds on itself over time.

Equation 1 Regression Equation as Function of Time 2008-2016

Annual Average (Thompson Farm steers values/US May steer values) = 1.0451 + 0.0033 (TIME)

Time P-value: 0.177

R Square: 0.24

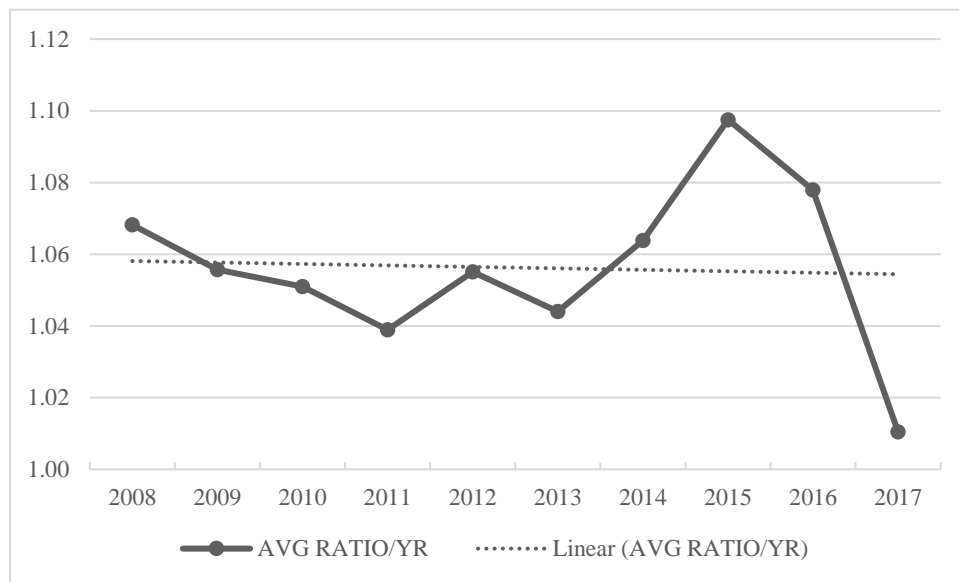
In 2017 the Thompson Research Center moved steers from the Irsik and Doll Feed Yard to Tiffany Cattle Company to feed 2017-born steers. Unfortunately, 2018 Thompson Research Center feedlot values, representative of 2017-born steers, fell compared to past performance as shown in Figure 14. Lower values for 2017-born steers may have resulted from a change in marketing strategies. Tiffany Cattle Company sold the entire pen of steers as a single group compared to the way in which Irsik and Doll marketed the steers based on the order in which the steers finished prior to harvest. The data for 2017-born steers that were born later in the calving season indicated that those steers were marketed at lighter weights than higher-valued steers in the same calf crop resulting in a lower sale price received.

As Figure 15 illustrates, the comparison for Center to US average fed steer values for 2017-born steers pulls the trendline down when compared to the 2008 to 2016-time sequence. However, the average ratio for 2017 is still greater than one. This shows that the average for 2017-born steers from the Center still out-performed the 2017-born US fed steer average values despite the transition to the new feed yard.

The difference in performance fed steer values from the Center when compared to US average fed steer values highlights the importance in applying proper genetics and marketing strategies. Although use of FTAI generally results in more uniform calf crops, a small proportion of the entire calf crop will be represented by calves born later in the

calving season. Quality grade and carcass weight are both determinants in assigning value to a carcass. To capture value, strategic marketing must be practiced to benefit from investments in genetics.

Figure 15 Thompson/US Values Ratio Averaged Annually for Fed Steers 2008-2017



Equation 2 Regression Equation as Function of Time 2008-2017

$$\text{Annual Average (Thompson Farm steers values/US May steer values)} = 1.059 + -0.0004 (\text{TIME})$$

Time P-value: 0.88

R Square: 0.0028

When fed steers prices from the Center were compared to national averages over the 2008 to 2017 time period and fit as a function of trend, the results changed because of lower prices for 2017-born steers from the Center compared to the US average. The results display a 0.04 percent annual decline as results from 2017 skewed the trendline downward. Equation 2 reflects the regression output as a function of trend that is

representative of 0.28 percent of the variation in the data. The P-value, which is used to determine the statistical significance, fails to reject the null at 0.88. Even if this analysis is not looking for statistically significant differences, this high P-value marks a lack of difference in trendline across time.

In years 2008 through 2016 steers from the Center performed well compared to US fed steer values while the average for 2017 was only slightly above the national average. The risk of reducing performance when feedlots are changed are risks commercial cow-calf producers face when determining whether to retain ownership through the finishing phase. However, the Center still received added value for steers in 2017, the difference in premiums compared to others was not as great.

Additionally, a Two-Sample T Test was applied to the Center annual average fed steer price values and the USDA AMS May national average fed steer price for steers born in years 2008 through 2017. The T Test compares the differences of means across time. Results from the test reported a 0.55 two-tailed P-value. As discussed previously, a 0.55 P-value does not display a statistically significant difference which was expected as the Center annual average fed steer values should be similar to the national average.

Figure 16 Thompson/US Fed Steer Values Individually by Year

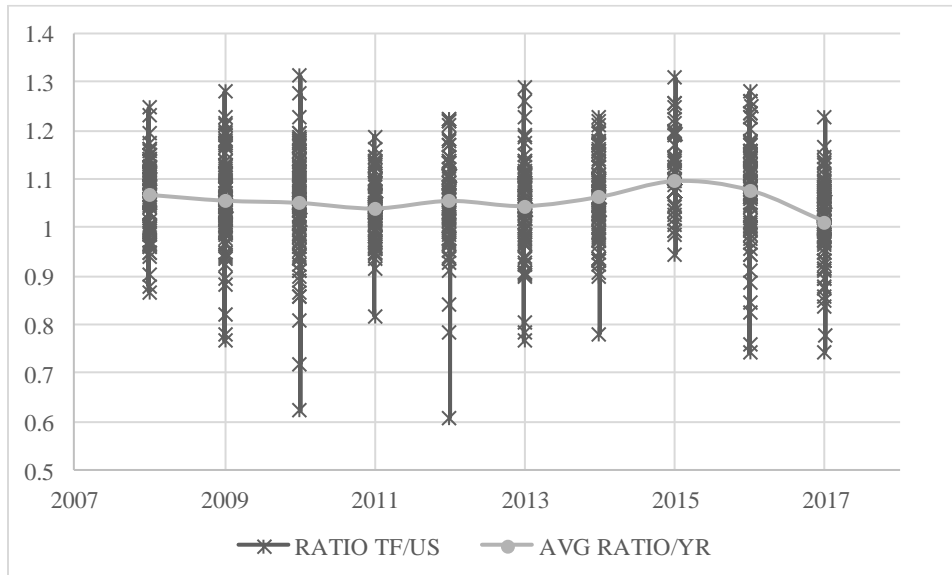


Table 8 Percentage of Observations that Performed Above the Average Thompson/US Fed Steer Values by Year

2008	53.3%
2009	47.1%
2010	55.2%
2011	51.8%
2012	53.8%
2013	52.5%
2014	50.0%
2015	29.5%
2016	54.5%
2017	52.2%

Figure 16 is a scatterplot for all individual fed steer prices from the Center compared with the national May t+1 fed steer prices. Due to missing sale prices for steers from the Center in 2005 and 2007, Figure 16 displays values from 2008 through 2017. As seen in Figure 16, the majority of fed steer prices for steers from the Center consistently performed greater than the national average for steers born in 2008 to 2017.

The scatterplot shows variability of the Thompson Farm individual data compared to the national average prices. Within Figure 16 a few outliers are pulling average results lower, especially for steers born in 2010 and 2012. Variability in the data reminds us that the Center operates similar to a commercial cow-calf operation. Values for lower performing steer may have resulted from exogenous factors such as weather, injury, or sickness.

Table 8 displays the percentage of Center/US fed steer observations and again illustrates that the cattle outperformed the annual average ratio. Apart from 2015, approximately half of the observations within the scatterplot consistently performed above and below the average. The 2015 Tyson fed steer data only provided an aggregate lot value instead of a per steer value, so the analysis divided the aggregate lot value by the number of fed steers sold to Tyson in that given year. The Center/US fed steer ratio at 1.0768 for the 42 Tyson observations was slightly below the annual average ratio of 1.0975 which pulled down the percentage of observations above the annual average as displayed in Table 8.

Chapter 5.5 Part B Replacements/Bred Heifers

The analysis also evaluated the performance of premium heifers; heifers retained within the Thompson herd, heifers sold through SMS sales, or heifers that qualified for the SMS program that were bred and sold at a premium. To conduct the analysis, retained heifers had to be assigned a proper value to ensure that the analysis encompassed the entire Center and was representative of a commercial operation. Average annual sale values from SMS qualifying heifers, whether they were sold through SMS sales or sold locally, were used to value replacement heifers retained at the Center. This assumption was based on the fact that replacement heifers retained by the Center were likely top performers

among their contemporaries and should be valued at the same level as heifers that were sold.

Once all heifers were assigned a value, they were compared to the USDA AMS

Oklahoma City bred heifer average using October through December values for the next

year. These comparison data were chosen to represent local bred heifer prices during or

for the same time period that heifers from the Center were sold in a given year. For

example, a heifer calf born in early February of 2012 would not likely have been sold as a

bred heifer until the fall of 2013.

Figure 17 Difference of OK Bred Heifer Values and Premium Heifers Annual Average Sale Values for 2003-2017

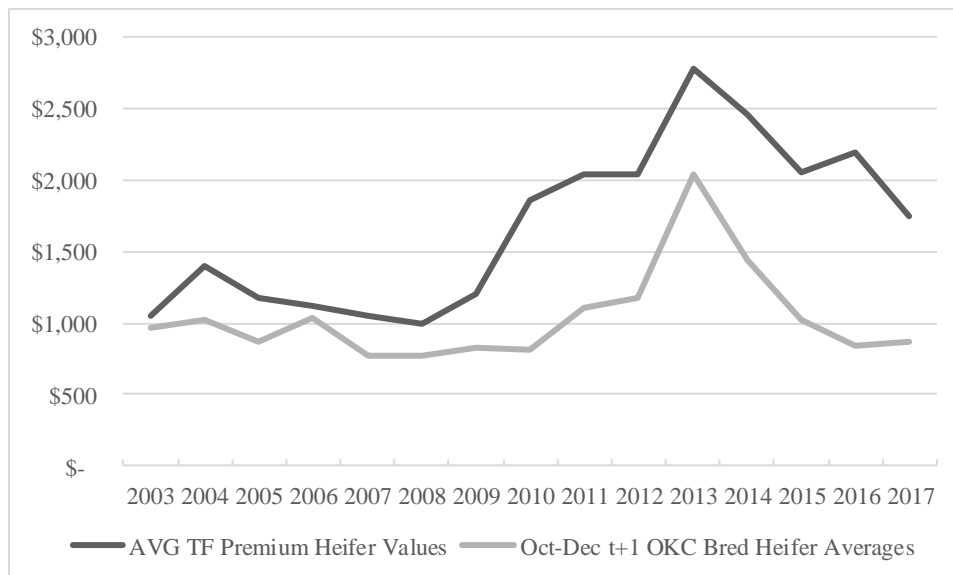


Figure 17 summarizes annual average values for bred heifer/SMS heifer/replacement values for the Center and Oklahoma City bred heifer t+1 October through December averages from 2003 to 2017. Although the analysis focuses on added revenue instead of profitability, Figure 17 displays several years of significant increases in added value the

Center received on average compared to Oklahoma City bred heifer t+1 October through December averages. At the maximum point of difference in 2016, annual price averages for premium heifers from the Center were \$1,352 per heifer more than Oklahoma City bred heifer values. This added value provides a significant opportunity for investments in genetic improvement moving forward.

Figure 18 Thompson/OK City Value Ratio Averaged Annually for Premium Heifers 2003-2017

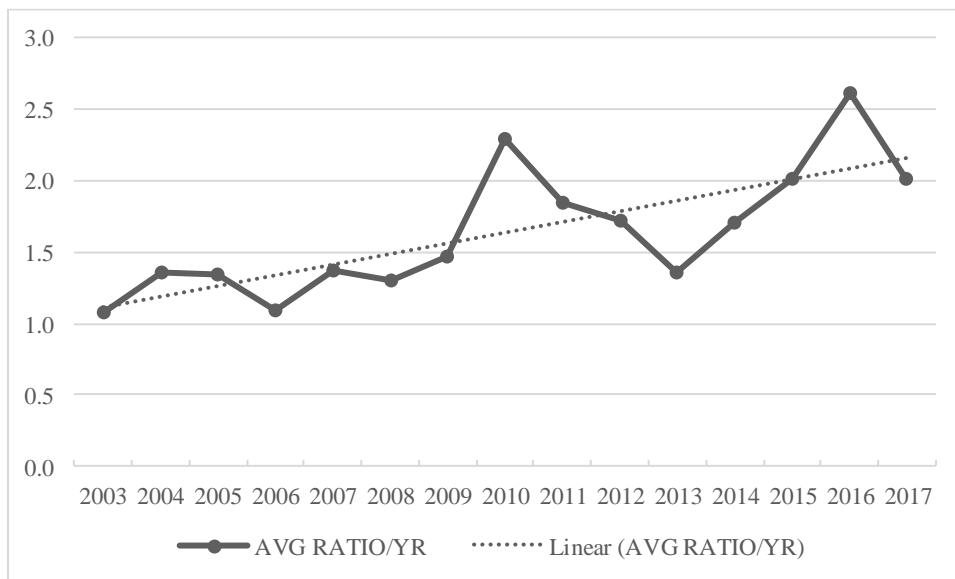


Figure 18 illustrates the change over time as annual average bred heifer/SMS heifer/replacement values for the Center were compared to Oklahoma City bred heifer averages for October through December. Compared to the Oklahoma City averages, bred heifers from the Center performed exceptionally well. Values for heifers from the Center compared well over Oklahoma City averages for the entire time sequence from 2003 through 2017.

When the ratio was fit as a function of trend, bred heifer/SMS heifer/replacement values for heifer from the Center showed a 7.5 percent increase per year from 2003 through

2017 compared to Oklahoma City bred heifer values. The R Squared for the trend equaled 0.57 showing the change over time accounts for 57 percent of the variability within the data. A small P-value of 0.001 shows statistical significance of the trend parameter in the premium heifer value for the Center compared to Oklahoma City bred heifer prices. Bred heifer/SMS heifer/replacements from the Center performed exceptionally well and gained in value over time when compared to Oklahoma City averages.

Equation 3 Regression Equation as Function of Time 2003-2017

Annual Average (Thompson Farm premium heifer values/ OK City bred heifer values) = 1.038 + 0.075 (TIME)

Time P-value: 0.001

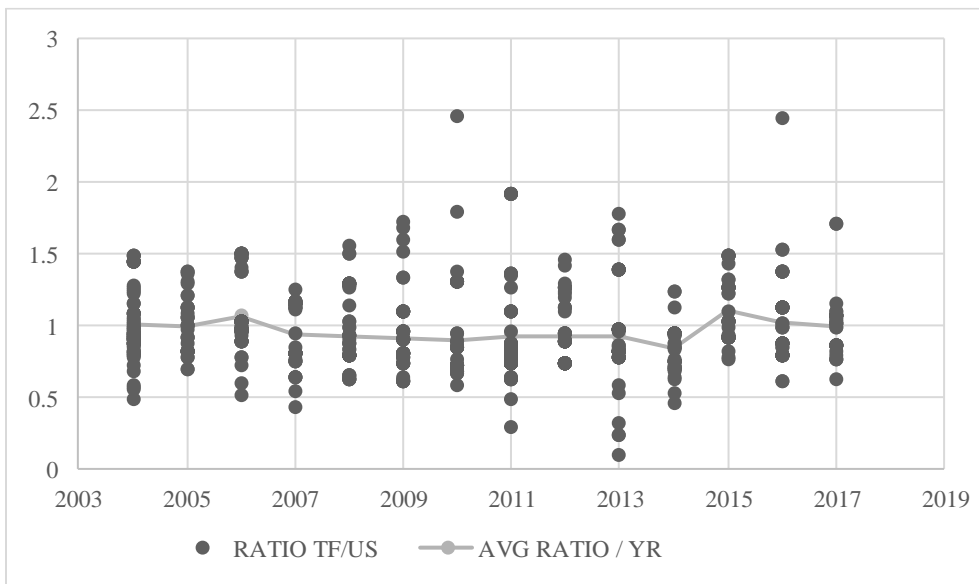
R Square: 0.567

Previous chapters highlighted the importance of investing in replacements when striving for herd improvement and highlight the potential added value resulting from superior quality AI-bred heifers. These data support these claims as values for heifers from the Center outperform regional markets for this category. SMS-participating heifers captured significant premiums compared to regional market sales. High quality replacements create the opportunity for significant gains in equity within a herd long term, underscoring the return on investment that results from the adoption and use of reproductive and genetic technologies and based on the performance of heifers developed and bred at the Thompson Research Center.

Chapter 5.5 Part C Residual Auction Market Calves

Calves that were sold from the Center through local livestock auction markets shortly after weaning were compared to USDA Economic Research Service (ERS) sale price averages for 500-550 pounds steers that were sold in November of the same year. Calves at the Center are usually born in the late winter or very early spring; therefore, November would be a plausible sale time period for weaned calves. Weaned calf sale values for the Center were then compared to November ERS 500-550 pounds steer values.

Figure 19 Thompson/US Values Ratio Averaged Annually for Weaned Calves 2004-2017



As the scatterplot in Figure 19 illustrates, values for calves that were sold from the Center through local auction markets represent significant variability, making accurate comparisons difficult. Reasons for the variability within these local livestock auction markets may have resulted for a variety of reasons and perhaps due to calves being sold

as cow-calf pairs, calves sold at various weights or ages, etc. The average ratio of weaned calves from the Center compared to national average weaned steer values centered around one. Therefore, residual calves from the Center performed similarly to US average weaned steer values.

It is important to note that calves from the Center that were sold through local livestock auction markets were likely the lowest performing calves in the herd for that given year and may not accurately represent auction market performance had all calves from the Center been sold through those markets. Local livestock auction markets fail to capture the full added value of reproductive and genetic investments when averaged over the long term. This combination lowers the sales performance of calves marketed through local livestock auction markets compared to sales results from fed steers and premium heifers. Local auction markets are an essential sales outlet for commercial cow-calf operations. However, premiums for retaining ownership through harvest, retaining heifers, or marketing heifers through branded sales such as SMS should be the focus to capture added value that results from use of reproductive and genetic technologies.

Chapter 5.6 Weighted Average Value Comparison for Thompson Farm

Data were analyzed in aggregate to measure performance of cattle produced from the Center compared to US or regional averages. The fed steer, premium heifer, and sales of calves through local livestock auction markets were compared with their previously allotted US or regional average prices. A weighted average was then calculated based on the percentage of share each category represents for a calf crop in a given year from the Center (Figure 7). For example, in 2004 approximately 37 percent of offspring from the Center were finished steers. For the calculated weighted average in 2004, the 37 percent

was applied to the Center fed steer / AMS fed steer value ratio. It is important to note that values for steers that were fed in 2005 and 2007 are not represented.

Figure 20 Weighted Average Values Thompson Farm and US 2004-2017

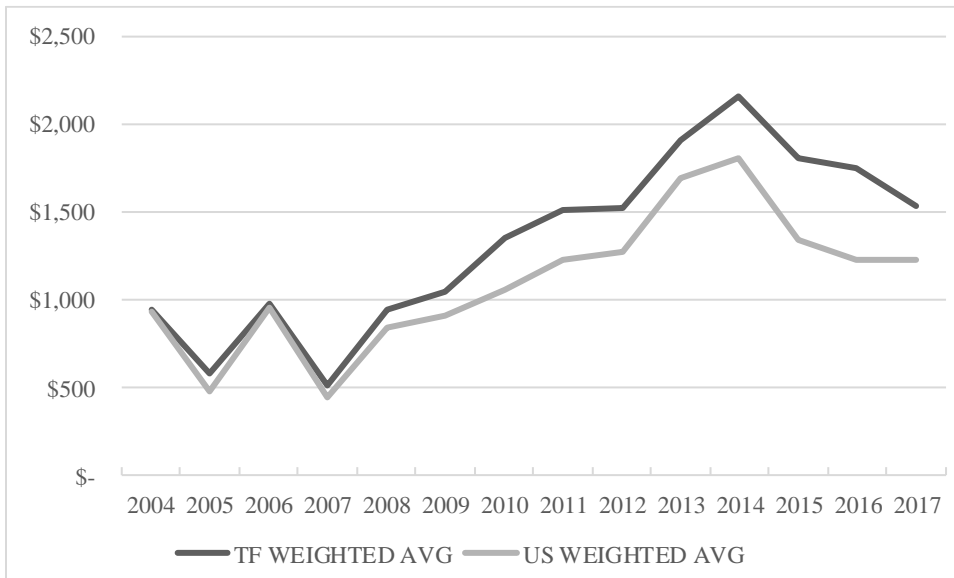


Figure 20 illustrates the difference in weighted average values from the Center compared to US averages that were weighted based on the percentage makeup of auction market calves, fed steers, and premium heifers in a given year. Although this analysis does not measure profitability, the difference between weighted average values from the Center over time compared to US weighted averages shows considerable added value. When the difference was the largest in 2016, the Center captured an additional annual average of \$529 on a per animal basis. With \$529 additional value captured per animal per year, a great deal of reinvestment in reproductive and genetic technology can be implemented within the herd.

Figure 21 Thompson/US Values Ratio for Offspring 2004-2017

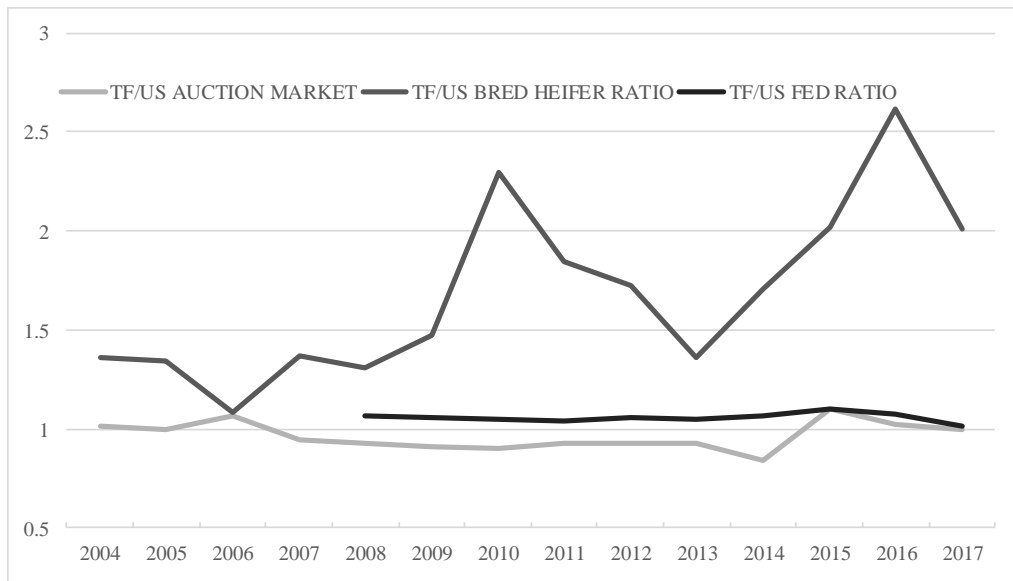


Figure 21 illustrates the Center/US ratios for the top three sales avenues for calves from the Center, including local auction markets, premium heifers, and fed steers. As shown in Figure 21, the premium heifer category represents the high performer. Fed steers perform on average slightly above US fed steer averages. Auction market results are either slightly above, below, or follow national averages.

Figure 22 Thompson/US Values Ratio Weighted Averages for Offspring 2004-2017

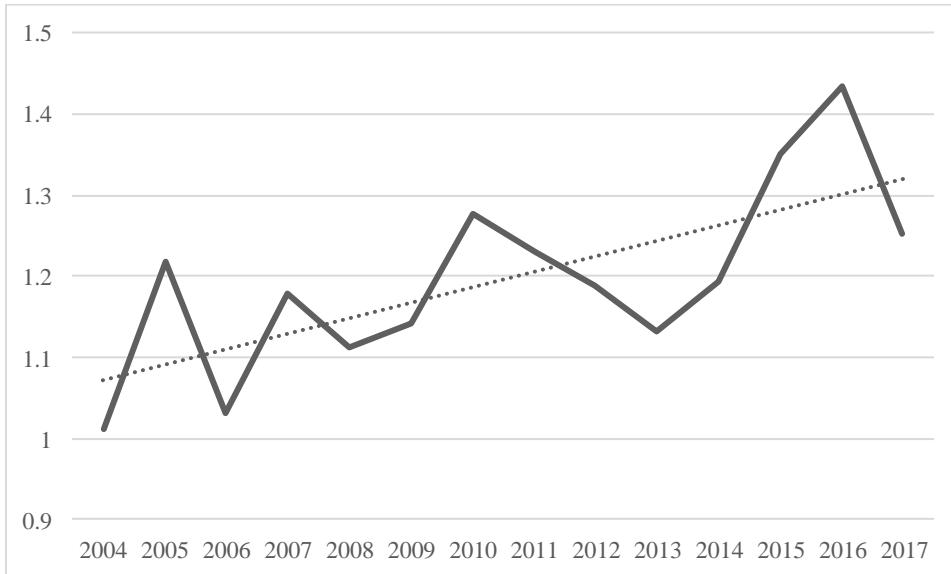


Figure 22 illustrates the lines of Figure 21 when the weighted averages were applied. As shown in Figure 22, values for the Center compared to US/regional averages demonstrated that cattle from the Center continually outperformed US averages. Impressively, throughout the entire time period from 2004 through 2017 values for the Center performed better compared to US average values. Premium heifer comparative ratios represented 31.5 percent of the data applied to the weighted average across years. This represented the greatest percentage of gain among the categories and at an average share of 31.5 percent of Center offspring which had a positively impact on the weighted average ratio.

Equation 4 Regression Equation as Function of Time 2004-2017

Weighted Annual Average (Thompson Farm Offspring Values/ National or Regional Averages) = 1.053+ 0.019 (TIME)

Time P-value: 0.005

R Square: 0.495

One a per calf basis, when trend was applied as a function of the regression output (Equation 4), results showed a 1.9 percent per year improvement in offspring value from the Center compared to US/regional average values across time. An R Square of 0.495 denotes that 49.5 percent of the variability within the data was explained by the change over time. Regression output with weighted average ratios as a function of trend reported a P-value of 0.005 showing a statistically significant increase in value over time.

These aggregate results from the Center allow for a long-term evaluation of investments in reproductive and genetic technologies. The Center realized its greatest gains from differences in performance from superior heifers produced at the Center compared to average bred heifer values. Investments in reproductive and genetic technologies were focused around SMS and replacement heifers. From 2008 to 2016, the Center also realized greater returns in finished steer values compared to national fed steer prices. Results from sales of cattle through local livestock auction markets show the importance of retaining ownership or selling animals through alternative marketing channels when calves are of superior quality based on genetic merit. These alternative marketing strategies provide the opportunity to capture added value and improve return on investment.

Chapter 5.7 Top Utilized Sire Evaluation

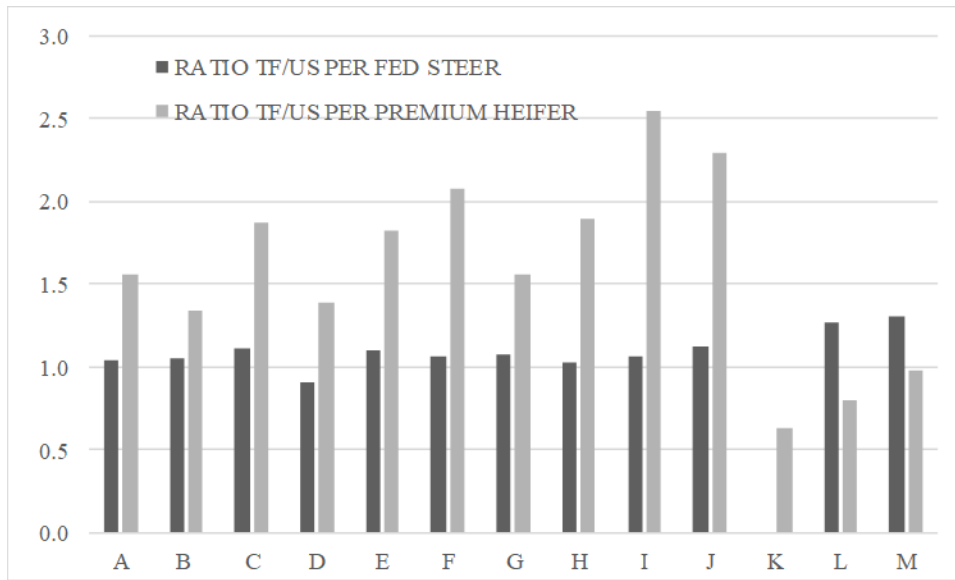
Over the duration of research conducted at the Thompson Research Center, semen from sires utilized for AI has been carefully selected with the intent of continually improving performance of offspring produced from the herd. Figure 23 illustrates results for progeny from the 13 most heavily used sires at the Center and represents aggregate summaries for fed steers and premium heifers. Table 9 lists the sires by name, the number

of fed steers and premium heifer offspring that were produced, and whether the sire was utilized through artificial insemination or natural service.

Performance of progeny from these bulls was evaluated using the average difference in value for progeny from the Center compared to US/regional values on a per calf basis. It is important to consider sample size when comparing sire performance between premium heifer and fed steer offspring. For example, as Table 9 notes, Sire F's premium heifer performance compared to the national average appears to be much higher than his fed steer offspring compared to the national fed steer average values. However, sample sizes of 36 and 18 for fed steers and premium heifers, respectively, may affect these results. The time period over which the sire was used can also affect value of progeny relative to other sires. Use and distribution of these data must be considered carefully for the aforementioned reasons.

Sire H (Bar 12-2) shown in Figure 23, is a natural service sire whose progeny compared favorably with many of the AI sires that were used. Additionally, steer progeny from Sire D (7AN178) shown in Figure 23 underperformed compared to other sires. However, these results may not be representative of overall progeny performance from Sire D as premium heifer values from this sire were above Oklahoma City bred heifer values. Overall, progeny from the most heavily utilized sires at the Center nearly always outperformed contemporary comparisons.

Figure 23 Top Utilized Sires of Fed Steers and Premium Heifers



Source: USDA, AMS

Table 9 Top Utilized Sires of Fed Steers and Premium Heifers

	TOP UTILIZED SIRES FOR PREMIUM HEIFERS/FED STEERS	ARTIFICIAL/NATURAL SERVICE	# TF FED STEERS SIRE	# TF PREMIUM HEIFERS SIRE	RATIO TF/US PER FED STEER	RATIO TF/US PER PREMIUM HEIFER
A	7AN222 (GAR PREDESTINED)	AI	220	208	1.03	1.56
B	BEXTOR (C R A BEXTOR 872 5205 608)	AI	55	28	1.05	1.33
C	NET WORTH (NET WORTH)	AI	46	45	1.11	1.88
D	7AN178 (BAR EXT TRAVERLER 205)	AI	42	42	0.90	1.39
E	TC TOTAL (TC TOTAL 410)	AI	37	34	1.10	1.82
F	NPV (SINCLAIR NET PRESENT VALUE)	AI	36	18	1.06	2.07
G	SURE SHOT (MOGCK SURE SHOT)	AI	31	27	1.07	1.55
H	B A R 12-2 (B A R OBJECTIVE 9055-0T26)	NS	29	13	1.03	1.90
I	PROSPERITY (SAV PROSPERITY 9131)	AI	26	13	1.06	2.54
J	HOOVER DAM (HOOVER DAM)	AI	26	23	1.13	2.29
K	5TR8 (RITO 5TR8 OF RITA 3X12 RRT)	AI	0	41	0.62	N/A
L	PINNACLE (GAR PINNACLE)	AI	14	36	1.26	0.80
M	Sleepy Boy (JWK SLEEPY BOY 8134)	AI	12	30	1.30	0.98

Chapter 5.8 Additional Research Opportunities

The database from the Thompson Research Center creates opportunities for future research and analysis. Potential research opportunities lay within the cost side of the ledger. Although complete per head costs are difficult if not impossible to measure given current data collection practices at the Center, investigation of costs associated with reproductive technologies including FTAI and related costs tied to genetic technologies could be expanded. Further analysis using alternative sources of data is also a possibility. Additionally, comparison against performance of individual AI sires and AI-sired dams across time could be evaluated.

Research possibilities are extended beyond economic analyses to evaluation of animal performance and production over time based on more detailed genetic analyses. The Thompson Farm database contains information regarding birthweights, weaning weights, sale prices, medication administered, palpation records, lineages, carcass data, sale dates and weights, etc. Vast research capabilities for various research interests lie within the Thompson Farm database.

Chapter 6: Conclusion

Adoption of reproductive technologies for beef producers, such as enhancing genetics by applying estrous synchronization and FTAI protocols, has been slow due to a lack of familiarity and perceived risk of lower profitability. Producers cite increased cost with unknown reward as well as increased labor costs and time as reasons for failure to implement these technologies in their operations.

Previous studies reported in the literature analyzed portions of the beef cattle production cycle including added value of finished steers or determinants to be considered in heifer retention. Additionally, research has previously evaluated impacts of grid pricing and measured consumer demand elasticities for premium quality beef. Various research projects have aimed to measure the value of artificial insemination compared to natural service, but these studies were usually limited to short-term results with small sample sizes. This study provides a holistic, long-term evaluation for all offspring, including fed steers, premium heifers, or calves sold through local livestock auction markets and how those progenies performed against national or regional average values for a given year.

Results indicated that the value of Thompson Farm fed steers consistently exceeded industry averages and increased their advantage over time by 0.33 percent annually from 2008 through 2016. Premium heifers, the focus of the farm's added value capture, performed consistently and impressively above Oklahoma City bred heifer May averages. As quality of the cattle from the Center improved over time, both fed steers and premium heifers realized continual improvement.

These results in addition reinforce the importance of marketing to capture added value that results from technology adoption. Differences in fed steer values were observed between aggregate sales of steers versus staging harvest based on perceived finish. Added value capture for SMS qualifying heifers resulted from branded marketing through the program that allowed genetic superiority to be recognized. Calves sold shortly post weaning at local livestock auction markets did not capture added value in relation to other sectors and performed along national averages.

The Thompson Research Center operates similarly to a commercial cow-calf operation and affords the opportunity to consider values of offspring in the long term. Therefore, findings from this analysis will be instrumental in supporting the case for technology adoption. As demand for high-quality beef continues to grow, consumers of beef, domestic and abroad, are willing to pay a premium for superior quality. For the US beef industry to supply that demand, it is vital that producers, regardless of size, recognize these market signals. Heifers retained within US beef herds provide opportunities to expand quality beef markets through enhanced genetic merit. The results from this study should be used to encourage producers to invest in reproductive and genetic technologies that will support and sustain their operations over the long term.

Bibliography

- Brown, D. Scott. "Marketing Opportunities for AI Bred Heifers and AI Sired Progeny" *USDA Added Value Beef Study* (2014): 148.
- Brown, D. Scott and David J. Patterson "Development of High-Quality Marketing Program for Missouri Cow-Calf Operators" *USDA Value-Added Beef Study* (2014):2.
- Certified Angus Beef, "Partners Propel Sales to New Heights," *Certified Angus Beef Brand Update 2018* volume 22 (November 2018): 6.
- Eversole, Dan E., Milyssa F. Browne, John B. Hall, and Richard E. Dietz. "Body Condition Scoring Beef Cows," *Virginia Cooperative Extension* (2009).
- Fausti, Scott W., Matthew A. Diersin, Bashir A. Qasmi, and Jing Li. "Value-Based Marketing: Discussion of Issues and Trends in Slaughter Cattle Markets" *Journal of Agribusiness* no. 28 (Fall 2010): 89-110.
- Fraiser-Pope, Kelsey, Ted C. Schroeder, Michael R. Langemeier, and Kevin L. Herbel, "Cow- Calf -Producers Risk Preference Impacts on Retained Ownership Strategies" *Journal of Agricultural and Applied Economics* no. 43 (November 2011):497-513.
- Hughes, Harlan. "Raised Replacement Heifers: Some Economic Considerations" *Management Considerations in Beef Heifer Development and Puberty* (November, 2013): 643-52.
- Lambert, D.K. "Calf Retention and Production Decisions Over Time." *Western Journal of Agricultural Economics*, no. (1989)14: 9.
- Lardner, Bart, Daal Damiran, and Kathy Larson. "Comparison of Fixed-time Artificial Insemination vs. Natural Service in Beef Cows: Reproductive Efficiency and System Cost" (2015).
- Mao, Yanwei, David .L Hopkins, Yimin. Zhang, Xin Luo. "Consumption Patterns and Consumer Attitudes to Beef and Sheep Meat in China." *American Journal of Food and Nutrition Research* no. 4(2016): 30-39.
- McDonald, Allen and Ted C. Scroeder. "Fed Cattle Profit Determinants Under Grid Pricing" *Journal of Agricultural and Applied Economics* no. 35 (April 2003).
- National Cattlemen's Beef Association. "National Meat Case Study." (November, 2007) Accessed February 2019. Available at: www.beefitswhatsfordinner.com/sales-data/retail-insights.
- Parcell, Joe. L., Jason R.V. Franken, Maria Cox, David J. Patterson, and Richard F. Randle. "Buyers' Perceptions of Importance and Willingness-To-Pay for Certain Attributes of Source and Production Verified Bred Heifers" *Agricultural Economics* no. 41 (2010): 463-470.
- Patterson, David J., Personal Interview to Emma Downing, April 2019.
- Patterson, David J., D. Scott Brown, W. Justin Sexten, Jared E. Decker, and Scott E. Poock. "Management Strategies for Adding Value to Replacement Beef Heifers: A Working Model" *Management Considerations in Beef Heifer Development and Puberty* (November 2013): 653- 666.
- Patterson, David J. and D. Scott Brown. "Rebuilding the US Beef Herd: Rethinking the Way Industry Develops" *Management Considerations in Beef Heifer Development and Puberty* (November 2013): 470-476.

- Perry, G.A. et al., “Management Factors Influencing Fertility in Synchronized and Natural Breeding Programs,” *South Dakota State University* (2008).
- Pierce, John. “The Federal Grading System for Animal Products.” *Fat Content and Composition of Animal Products: Proceedings of a Symposium*, Washington, D.C. December 1974.
- Rorie, R.W., T.R. Bilby, and T.D. Lester. “Application of Electronic Estrus Detection Technologies to Reproductive Management of Cattle.” *Theriogenology*, no. 57 (2002): 137-148.
- Steiner, Jillian and D. Scott Brown. “Should Beef Quality Grade be a Priority?” *USDA Value-Added Beef Study* (2014): 155.
- White, Brad, JD Anderson, Robert L. Larson, K.C. Olson, and Daniel U. Thomson. “The Cow-Calf Operation Retained Ownership Decision” *Professional Animal Scientist* no. 23 (2007): 18-28.
- USDA AMS, National Summary of Meats Graded Livestock Marketing Information Center Report (LMIC). Accessed April 2019.
- ERS Livestock and Meat International Trade Data. Accessed February 2019.
- Foreign Agricultural Service Global Agricultural Information Network (GAIN) *CPTPP Changes to Japanese Beef Market*. December 2018. Available at www.fas.usda.gov/
- Market News, Livestock Marketing Information Center Report (LMIC). Accessed April 2019.
- National Animal Health Monitoring System. *Reference of Beef Cow-calf Management Practices in the US*. Fort Collins Colorado: Animal and Plant Health Inspection Service (APHIS), February 2009.
- National Animal Health Monitoring System. *Small-Scale US Cow-Calf Operations*. Fort Collins Colorado: Animal and Plant Health Inspection Service (APHIS), April 2011.

* Citations presented in the Chicago Manual of Style format