A hedonic model on bred heifer prices: Auction, heifer, genetic, and reputation effects considered

by

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Abstract

In a highly variable and differentiated industry such as cattle production, producers constantly face management decisions regarding their operation. Two of the most critical questions a producer will ask are: who is the buyer of their cattle, and what qualities and characteristics should their product contain to attract multiple buyers?

The paper uses hedonic modeling to estimate marginal implicit values of characteristics of bred heifer sales to determine qualities and characteristics buyers demand. The sales data encompasses 10 years of transactions for Show-Me-Select bred heifer sales. Emphasis is on estimating implicit values of production and phenotypic factors, allowing for a deep analysis of estimated progeny differences, breed traits, and reputation effects. Sellers can self-select into production, genotypic, and phenotypic characteristics, so the premiums and/or discounts associated with artificial insemination and high-accuracy traits will be assessed. The value of this self-selection has been researched across sale barns and, to some extent, this group of sales; however, using newer data, this research project seeks to delve deeper into the value of these traits and characteristics and update past findings.

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Dedication

To H. & M. Bowen and G. & J. Wingert. 2 Timothy 2:15.

Chapter 1 - Introduction

When consumers reach for a cut of beef on the retail shelf, they express a willingness to pay for a particular cut. That specific cut contains different fat amounts, flavor profiles, size identities (volumetric and weight), and other qualitative and quantitative features the consumer prefers. If the butcher can observe enough of these transactions, he should be able to both serve the consumer and purchase the proper market inputs, forwarding the previous signal upstream. While it is recognized that one firm in an industry (in this case, a butcher) is often a price taker, not a price leader, if enough similar firms interact in the same way and offer the same signal, the industry upstream should react to that signal. However, every participant along the value chain has its own concerns, costs, and constraints that it must operate within to be able to supply the industry downstream, so the premium (or discount) must be different enough from the industry downstream for the upstream industry to be incentivized to adopt them, and not dilute the trait out.

This is particularly evidenced in the beef industry, mainly where there are many interacting derived demand curves. The primary demand curve, relating most to the consumer, is the local butcher and/or retail grocery store, followed closely by the packers. Below these two are the feedlots, the stocker/growers, the cow-calf producers, and finally the seedstock producers. Embedded within the interacting derived demand and supply curves are the increased transformation and transaction costs at every level, eventually passing all the costs (and necessary margins) onto the consumer. In this knowledge, it is in each participant's interest to increase their net margin between their demand curve and the supply curve of the next highest supply chain at every opportunity. The primary question that is posed every day, by all competitive individuals is "How do I increase my margin?" "How do we make a profit this week/month/quarter/year?" and especially in the livestock business, "How do I not lose my family's farm/ranch/legacy?". The sale of goods and services is crucial in these questions, and the interaction between buyers and sellers has long been studied by economists and sociologists alike. It can be imagined that it is a difficult question to consider, and it must be evaluated from many different angles. This paper begins with the evaluation of buyer behavior and the manner in which they interact with and perceive sellers, then moves into a data analysis and modeling approach that attempts to assign value to specific characteristics and traits reported by a bred heifer auction, including heifer information and derived consignor attributes.

Chapter 2 - Reputation and Bidder Behavior

When considering buyer decisions and their impact on the market, each seller's decisions and production styles are key components to study. Monopolistic competition theory posits that each firm will produce a similar type and kind of product while differentiating (or specializing) enough to compete in the market and extract economic rents. It is possible to observe this phenomenon in many world spaces; Universities offer unique academic units and degrees, technology companies differ among their processing systems and hardware components, and truck builders offer different body styles, engine and transmission combinations, and driver comfort levels.

In considering the case of universities, it would be too simple to attribute student enrollment and attendance to solely the academic units hosted by the institution. Thus, a subset of the measurable variables includes the degree of education a student can obtain at the university (Associate, Undergraduate, or Graduate degrees), distance from a student's family home, and cost of living at the institution. While these variables offer a beginning measure of the varying enrollment levels, what is omitted from the proposed theoretical model are the underlying advantages and disadvantages that are associated with each university. It would not be unreasonable for students to consider student life, the community's inclusivity of alternative beliefs and lifestyles, and the quality and personalities of the professors with whom they will interact. The mentioned variables could be considered individual characteristics or viewed as a whole; the University's social image and reputation.

A few challenges arise in developing the theorized reputation in the research setting. Is reputation established immediately, or does it require a period of observation and dispersion throughout the localized group of purchasers? Are the reputation variables a function of the measurable variables offered by the seller, or are they separate and unique? Do they offer an actual increase in quality, or are they due to an increased ability to command a premium or higher bidder activity in an auction? The literature has asked some of these questions; corporations with CEOs are largely the most studied, and reputation is often related to consumer loyalty, supporting the theory of the ability to command a higher premium.

Alloza et al. (2014) align their definition of reputation with the statement, "Corporate Reputation is a set of collective evaluations that is evoked in different audiences by the behaviour of a company and predisposes the audience towards support or resistance." This definition has many pieces that have value when they are broken apart. The first is the idea that reputation is a set of collective evaluations; this implies that there is a social component to reputation that uses debate, a common set of evaluation methods and norms, and a market unification around common "good" characteristics, perhaps while still disagreeing about minute differences. The second is the term "different audiences," which communicates that alternate types of buyers can be interested in different product attributes, creating differing opinions in the marketplace. Thirdly, it is necessary to capture the idea that behavioral attributes can influence a buyer's perception of a company; this suggests that consumers evaluate production practices, environmental concerns, treatment of employees, concern and support for the buyer, and general processes that influence the product. However, the final part of the definition produces the central consumer behavior theory that is relevant to this paper; the three aforementioned pieces combine to influence a buyer to a particular opinion, thought, or image of a company, which in turn causes them to buy in a manner that is relevant in the market. To sum this up, a consumer will inspect a product, the firm of origin, and the overall social perception of a) the product and b) the firm to lead them to a definitive value statement for each firm.

The authors rely heavily on Ajzen's Theory of Planned Behavior (2020) to create this definition. To continue improving the argument in support of reputation development and buyer behavior in the marketplace, the four basics of Ajzen's theory will be presented and expanded upon here. The four basics are the principle of compatibility, proximal determinants of behavior, determinants of intentions, and feedback effects.

In an auction setting, the principle of compatibility asks the question; is the buyer compatible with the item for sale? In reference to an Angus heifer that has been bred to a Gelbvieh bull, a registered purebred Hereford breeder would be less likely to be compatible with the lot as compared to a commercial Balancer cattle breeder that would incorporate their purchase into their ranch's production style with ease. The same theory could be used among two adjacent herds; if the seller's perceived production practices, such as bucket training, the use of an electric fence, or certain cow genetic family lines are compatible with the buyer's chosen practices, then bidding activity should increase with compatibility. However, this portion of the theory is not exclusive to the buyer's current production practices; on the contrary, it more accurately explains a bidder's future intentions. This principle could also include a timeframe component – the timing of the birth of the calf, the re-breeding of the heifer, and the capacity to wean the calf would also influence the bidder's decisions.

While producers are likely to buy from compatible herds, it does not necessarily explain all the variability in a buyer's bidding strategy. The proximal determinants of behavior suggest that buyers make decisions based on their control of fundamental factors (internal or external), such as time, money, or ability to overcome obstacles. Some examples of this might include a low set budget compared to financial freedom. When a buyer faces a limited budget, they are forced to rank the lots based on a reasonable assumption of 1) probability of winning, 2) the location of the lot in the order of the sale, and the utility of other lots that could be bought in place of the considered lot, in a sort of game theory scenario. For example, if the buyer's preferred lot is first in the ring and is able to be bought under budget, then the other lots need not be considered. However, suppose the favorite lot is last, and there is only a 50% chance it will be sold within the bidder's budget. In that case, they must decide if perhaps the earlier lots are of interest, and then subsequently assign a value to them (perhaps discounted, at an amount equivalent to the buyer's risk tolerance for the other lot). With this process, the buyer might experience a feeling of a loss of control over their bidding strategy, thus reducing their desire and intention to participate in the sale. Other factors could be external, such as unfamiliarity with the bidding process or a lack of (or feeling of lacking) complete information on the lot. The former arguably causes irregular and hesitant bidding, while the latter might create doubt in the buyer's mind about the actual value of the lot.

Unlike the other principles, the determinants of intentions are separated into three sections. The first is the buyer's attitude towards their intended behavior. Ajzen defines this as the subjective probability that performing an action or behavior will lead to a particular outcome or provide a specific experience. Thus, this is the probability assessed by the buyer that the heifer they are purchasing will fit their program, lead to a successful birth and re-breed, and be manageable to maintain in the herd. The second piece is the subjective norm, which includes injunctive and descriptive norms. The injunctive is the probability that important people (spouses, family, friends, peers, coworkers) will agree or disagree with the buyer's purchase. The more important a person is, and the stronger their opinion, the more likely it is that the buyer will be influenced. The descriptive norm is the probability of influential individuals conducting the same action or making the same purchase. Are industry leaders using semen from unique bulls?

Is the buyer's family using Angus, Hereford, or Simmental cattle? Do they want to be like their family? The final determinant of intention is the buyer's perceived control over their behavior or actions. Ajzen (2020) explains that perceived control is the buyer's calculation of the probability of control over all the previously mentioned factors, especially the market factors discussed under the proximal determinants of behavior in the previous paragraph. Buyers can control their knowledge about each lot to a certain extent. They can view the lot, search EPDs, read articles on the breed, and come to know different frame scores and conditioning levels, but they cannot discover information that is truly hidden. However, they can only control their budget to a certain extent – between savings and loans, they must strike a balance and not overextend themselves to be fiscally responsible. Additionally, buyers must be able to interact with the societal pressures they determine they will face, be it spouse, family, friends, or others. All these factors will encourage or suppress bidding by the buyer.

The previous paragraphs spend a bit of time discussing the buyers' anticipated results. It would be negligent to forget the manner in which they have set those expectations. The author claims that it comes from feedback from previous behaviors and interactions. Azjen posits, "Performance of a behavior results in information about the actual (as opposed to anticipated) outcomes, experiences, reactions by significant others, as well as about facilitating or impeding factors encountered…" (p. 316). He continues to discuss the idea that each interaction with an outcome changes and affects the behavioral, normative, and control beliefs that the buyer holds. For example, a heifer that exceeds expectations might lead to increased bidding of similar heifers from similar programs in the future, especially if the buyer's peers recognize their success and their spouse supports them in pursuing those heifers.

To transition into the next section, it would not be unreasonable to assume that bidder activity is a consequence of their previous market experiences. Ajzen developed the Theory of Planned Behavior, which has been used extensively to explain behavior and is wholly applicable in economics. An example of this is a paper by Pinto et al. (2023). In their work, they seek to provide a typical model, regressing price on breed, EPDs, and other characteristics. However, they also expand the regression to include reputational effects. The question remains though; were they successful in their work?

As described by Pinto et al. (2023), research has been conducted on feeder cattle prices and characteristics (Blank et al., 2016, Coatney et al., 1996, and Schroeder et al., 1988) as well as a few studies on bred cattle at auction (Boyer et al., 2021 and Mitchell et al., 2018). However, little research has been done on bred heifers and the qualitative and quantitative traits that seed stock and cow-calf producers might focus on when marketing heifers. The literature pool seems to grow as the industry begins to recognize the importance of 1) increasing net margins, 2) seeking to find the balance between female retention, longevity, and productivity in the herd, and 3) satisfying downstream stakeholders. The central question posed by Pinto et al. (2023) is whether investment in reputation is worthwhile and necessary. They reference Shapiro (1983), arguing that buyers recognize a high-quality and low-quality segment of the industry, which results from a snowballing effect over time. This is not incongruous with the argument that Alloza et al. (2014) present. Furthermore, they recognize the necessity for a producer to sell below the cost of production in order to establish their reputation in the market. Following a hedonic model approach, Pinto et al. (2023) test for reputation, associating each trait with a consignor identity and a tenure dummy. Their significant finding is that return producers gain a premium; however, they are unwilling to establish a firm stance on reputation, as they recognize that the sale in consideration orders lots according to producer tenure and reputation already. This makes it difficult to tell whether the reputation effects are accurate or perhaps result from other factors uncontrollable by the researchers. Their work is a sound basis for the model and discussion offered in this paper, as similar data is used.

Chapter 3 - Data Background

The University of Missouri Extension Services and their Show-Me-Select (SMS) Heifer program provided data to the authors, specifically sharing auction results for the years 2010-2023. Producers in Missouri have the option to register heifers for sale through the Show-Me-Select program, allowing for both private treaty and auction sales. The fixed costs associated with the SMS program are a $25 annual fee, with non-refundable variable costs of $22 per animal (based on 2023's terms). When heifers enter the program, they are subject to two farm visits by qualified extension agents and an identifying ear tag. As found in the appendix, this program requires producers to fit their heifers into specific qualifications to enter the auctions. Some of these range from minimum vaccination requirements and parasite and disease control practices (standardized production practices) to genetic requirements of both the heifers and the sire to which they are bred, if they are to enter into the auction at one of the identified regional sale barns (quality assurances). Furthermore, these heifers must be inspected to conform to a certain frame, weight, body condition, and disposition scores.

Several meetings with the extension staff revealed that approximately twelve sales were held each year, six regionally per spring and fall season. These sales conform to the common practice of spring and fall calving windows that are observed within the beef cattle industry. Before sale day, a joint effort between the producers, extension agent(s), and sale barn staff identifies all qualifying heifers. Information is gathered at that time, including details about the heifer and her parentage, genetic and physical information about the fetus, and production styles of the producer. The extension agents then use that information to compile a sale book, using one of two options. The first is a bulk data entry into a central database, generating a sale book with the pre-set information. The second option is to create a custom template, including the EPDs and information the agent feels is relevant to the buyers and is more typical of a bull sale catalog. This is indicative of a varying catalog between sales. After the catalog is created and a sale date is agreed upon, the information is posted on the Show-Me-Select website as well as distributed to interested parties. Cattle typically arrive at the sale facilities 24-48 hours in advance for viewing, depending on the facility. On sale day, lots of heifers, in random order and grouped by similar age, size, and calving window, enter the sale ring and are bid upon by the buyers. Following the completion of the sale, buyers are responsible for transporting the heifers home.

Chapter 4 - Data Description

For the years 2010-2023, there were 21,616 total heifers sold in 7,538 lots. The sire data were transmitted in two datasets – the first described 1,967 sire observations beginning in 2018 and ending in 2023 and was rather whole in its makeup; the second had data for the entirety of the heifer lots, 2010-2023, but contained only 2,356 sires. These two sheets were merged with each other and then merged with the heifer information to create the final dataset that the regression relies upon. The included variables are a broad collection; among them are price, size, genetic and reproductive information, as well as a unique identifier for each consignor.

A data cleaning process must occur to study the dataset more in-depth. A regression cannot be run on missing values, so any observation with a missing value was dropped from the dataset. Furthermore, to fix problems with outliers and avoid data errors with incorrectly entered data, a Median Absolute Deviation (MAD) process, as outlined by Leys et al. (2013) was conducted. Leys and their co-authors provide evidence and examples to support the hypothesis that this trimming method is more accurate than employing the Mean Absolute Deviation or other methods of dealing with outliers. They argued that the median only becomes absurd when more than 50 percent of the observations are contaminated. To calculate the median absolute deviations, the median was first taken from the intended variable. Secondly, the first median was subtracted from each value, and absolutes were taken so all numbers were positive. Next, the median of the new data string was taken and multiplied by 1.4826 (a value linked with the normality of data), and a median absolute deviation was found. To trim outliers, the MAD was then multiplied by the number of desired deviations to be used – 2 is described as poorly conservative, 2.5 is moderately conservative, and 3 is the most conservative recommendation from the researchers. For the purpose of the Show-Me-Select data, a value of 2.5 was used for the heifer weight as well as the birth weight (BW), weaning weight (WW), yearling weight (YW), maternal milk (MM), carcass weight (CW), ribeye (RE), and marbling (MRB) estimated progeny differences (EPDs).

4.1. The Dependent Variable: Lot Average Price

After removing outliers, the price variable becomes the primary interest, for if it should be used as a dependent variable, then it must vary reasonably. There are two methods in which the price variable was reported in the dataset: as a lot total and the average price per head. Thus, if a lot was sold for $4,000 dollars and there was one heifer in the lot, the average price was reported as $4,000 dollars. Furthermore, if the lot contained two heifers, the average price associated with both heifers was $2,000. For this analysis, the authors utilize the average price per heifer, as the lot size ranges from one to twelve heifers and averages below four head per lot. Additionally, the authors consider that the lots are claimed to be grouped uniformly, representing similar heifers with similar physical and genetic characteristics, reducing the chances of a buyer purchasing a lot for only one heifer. The statistics that describe the average price are as follows; a mean of $2058.67 dollars, a minimum of $1100 dollars, and a maximum of $3900 dollars. It is accurate to state that the distribution of prices exhibits a positive skew but is not out of bounds with the authors' expected price range given the data that the Show-Me-Select program self-reports on sales. The price distribution can be found in Figure 4.1. An additional aspect of the price variable is that each seller has the right to declare a minimum price floor – thus, if the seller sets the price floor at $4,000 dollars per animal, and a bid of $3,999 dollars per head or less is reached but not surpassed, the seller becomes the buyer and is responsible for pickup. With this in mind, that price is the price "paid" by the seller, when in actuality, they simply cover the commissions and fees associated with the heifer passing through the sale. The trend in flooring cattle can be analyzed more fully in Figure 4.2.

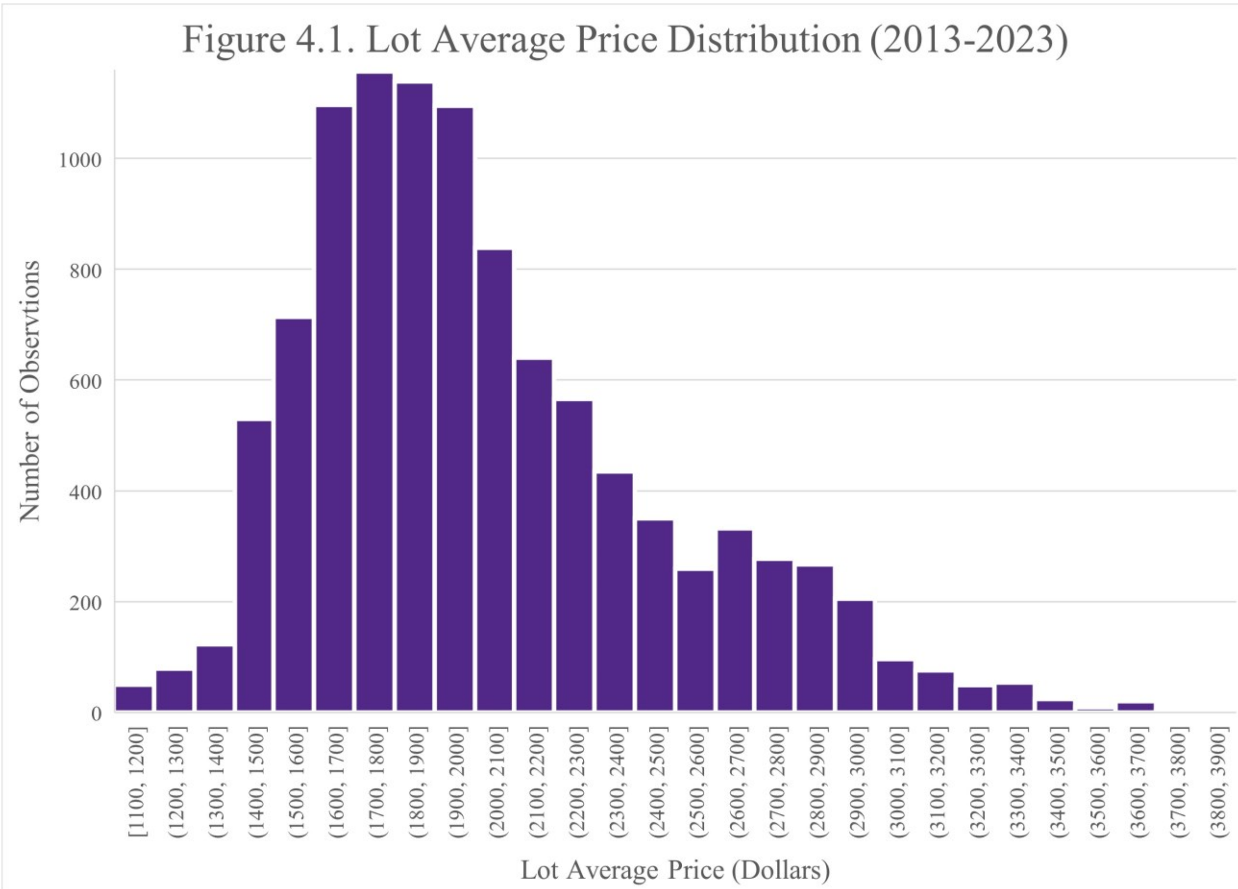


Figure 4.1. Dependent Variable (Lot Average Price) Distribution from 2013-2023

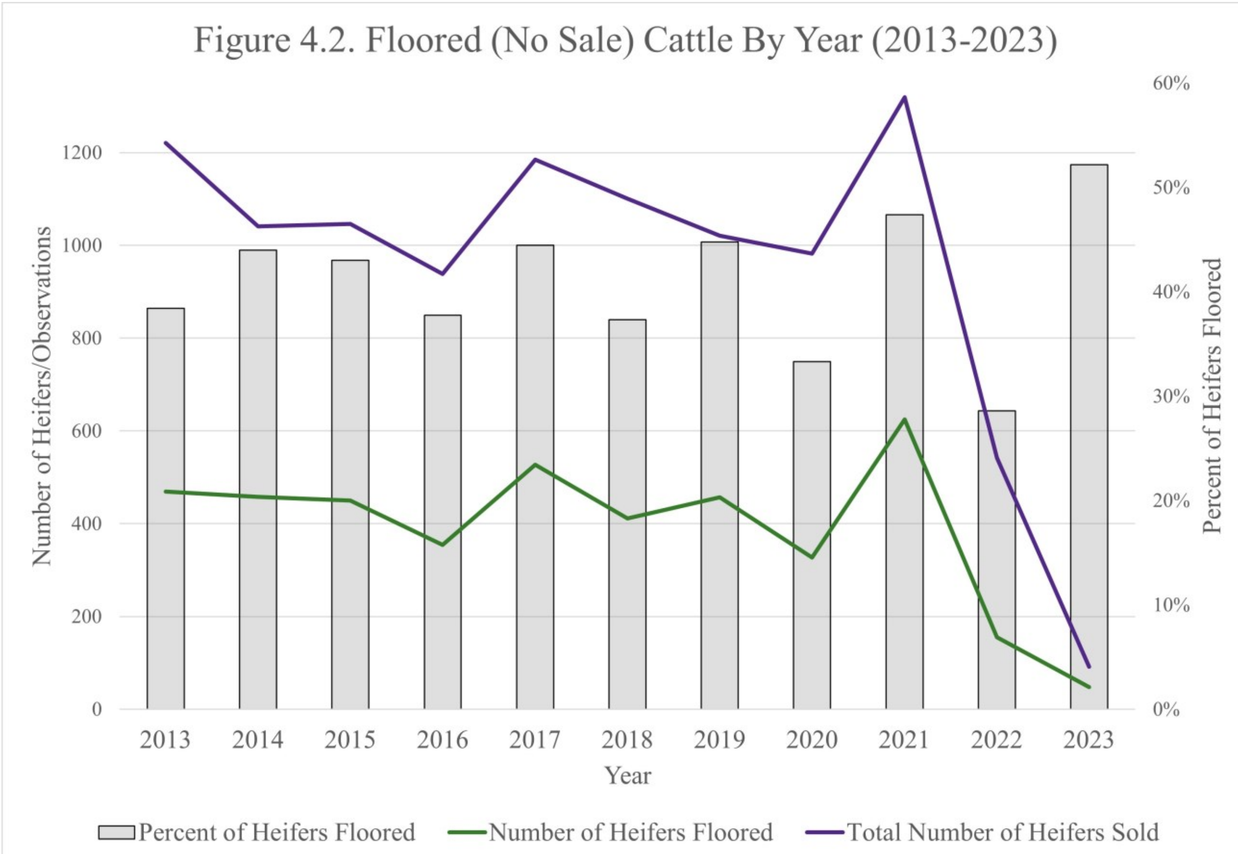


Figure 4.2. Yearly Trends in the Flooring of Heifers from 2013-2023

4.2. Auction and Lot Characteristics

4.2.1. Yearly and Seasonal Trends

Continuing after the data adjustments and drops, the overall dataset spanned from 2011-2023. The total observation count is 11,703 heifers. However, because the consignor tenure variable needs at least a year to determine the first-year producers and two years to assess second-year producers (described in more detail later), the beginning of the dataset is adjusted to begin in the year 2013. The first "long tenure" consignors can be determined this year, and the other two variables are accurate. These adjustments are reflected in the following table to report the number of observations and means in the dataset used in the creation of the model of this study. Additionally, a table of the remaining variables not reported in the text will be compiled in a table and reported in the appendix. Furthermore, a binary variable is reported to understand seasonal trends, and approximately 59% of the observed heifers are sold in the fall, as seen in the table.

Table 4.1. Yearly and Seasonal Trends of the SMS Sales by Individual Heifer Observation

Variable	N	Mean
2013	1221	0.116
2014	1041	0.099
2015	1046	0.100
2016	938	0.089
2017	1185	0.113
2018	1101	0.105
2019	1021	0.097
2020	982	0.094
2021	1319	0.126
2022	542	0.052
2023	92	0.009
Fall Sale	6223	0.593

N = 10,488

4.2.2. Sale Barn Effects

Nine unique sale locations, or sale barns, were identified and coded for. Table 4.2. shows that one sale barn held a special sale in which 11 heifers were sold using the SMS trademark. These heifers were marketed in two lots by two consignors – both lots contained the same type of heifer. Therefore, as will be discussed later, this location was dropped, and the consignors gathered all reputation effects from this sale that might have been associated with the location. Furthermore, as recognized earlier, these sales have been historically conducted in six defined regions of Missouri; however, sales have begun, ended, and moved in the program's extensive history, and each location's effect must be accounted for.

Table 4.2. Sale Barn Trends of the SMS Sales by Individual Heifer Observation for Years 2013-2023

Sale Barn	N	Mean
#2	1222	0.117
#3	1432	0.137
#4	268	0.026
#5	3043	0.290
#6	1816	0.173
#7	737	0.070
#8	11	0.001
#9	1651	0.157
#10	308	0.029

N = 10,488

4.2.3. Lot Order and Number of Heifers in the Lot

The next data to investigate is the lot order and number of heifers observed in each lot. For these variables, Parcell et al. (2006), who evaluated the Show-Me-Select program, as well as other research, like Pinto et al. (2022), can be looked to for expectations and guidance. Both mentioned papers expect a non-linear effect of both the lot order and the number of head in the lot. While some SMS sales have a smaller number of lots, some sales have experienced a larger showing, with greater than 100 lots; the maximum found in the dataset is 122 lots. Thus, a system was created to divide the lot order into three variables to represent each sale's beginning, middle, and end to avoid a collision between one sale’s end and another’s beginning or middle. Greater than three variables were considered for the different sections. However, some sales only reached 12-20 lots, thereby creating division challenges if more than three were used. As for the number of head in each lot, the range is from 1-12 heifers per lot, proving easier to capture in fixed effects of lot size. These will be broken up and described in the modeling section of this paper.

4.2.4. Calving Window and Number of Sires in the Lot

The number of sires used in the lot is also relevant – a greater number describes a lack of uniformity in the group of heifers. To summarize the data, an average of 1.13 sires were used across the entire dataset, with up to four sires in a lot at one time – this was well within the expectations of the authors, as sometimes heifers were artificially inseminated once, which was followed with a pasture exposure to a natural service bull(s). This practice extends the calving window (the time between the first expected day of calf birth and the last) of the lot; a factor that could also be seen as important to producers. Heifers and young breeding females, in general, pose a significant risk to the buyer as they are young and unproven – abortion and calving issues are associated with these females (Marshall et al., 2021). For the SMS data, a range of up to 96 days can be observed, however, the average span for a lot is only seven days.

4.3. Heifer Characteristics

4.3.1. Heifer Breed

The individual heifers can continue to be assessed. As recognized earlier, the breed itself is a component of breed registration, as it contains certain identities. While the buyers at the SMS sales could be anyone, they likely are producers themselves and have specific preferences regarding cattle. Breeds have unique traits, from growth and conformation to calving difficulties to rearing traits such as milk ability and maternal instinct. These things are of consideration for each producer. The University of Georgia published a review of work done by the U.S. Meat Animal Research Center that clearly outlines the advantages of each breed. Further, the researchers highlight the importance of selecting traits that are useful to the environment in which the cattle of interest will be raised, whether the calf is purebred or crossbred. They recognize that crossbred calves often outperform purebred calves in many situations, regardless of the environment. In general, crosses are made for hybrid vigor, thus to the correct buyer, they could be valuable, but to others, the loss of breed identity and characteristics might be detrimental. The dataset from the SMS sales contains breed variables – these are then translated into dummies. Table 4.3. outlines which breeds are present in which quantity. The variables are dummies, which are 1 if true and zero if not. The averages represent the proportion of the dataset represented by that breed or cross. Some examples of breeds and crosses present in the data are Angus and SimAngus; the first is a purebred animal, and the second is a cross between Simmental and Angus. These categories provide a relatively specific animal to the buyer. However, heifers can also be marketed as “based” in a breed but with unknown proportions of other breed(s). Thus, an “unknown cross” variable exists when a heifer is marketed as Angus (or other breeds) based, but no other breed is given. It is expected that unknown crosses will be less valuable than known crosses simply due to the ability of the producer to assign certain traits (and thus value) to the known breed. The final trait that each breed offers is coat color.

Table 4.3. Heifer Breed Identifications for Years 2013-2023

Breed	N	Mean
Angus	2224	0.212
Red Angus	397	0.038
Purebred Cattle	151	0.014
Angus X Simmental X Unknown	106	0.010
Angus X Gelbvieh	110	0.010
Angus X Hereford	1068	0.102
Angus X Simmental	596	0.057
Angus X Tarentaise	136	0.013
Angus X Unknown	4412	0.421
Small Angus Crosses	110	0.010
Red Angus X Unknown	312	0.030
Simmental X Unknown	414	0.039
Small Other Crosses	452	0.043

N = 10,488

4.3.2. Heifer Hide Color

The University of Georgia (2022) article discussing breed characteristics offers an interesting quip about cattle coat color, "How many times have you heard someone say, "I like 'em because they're black"? Coat color, whether it is red, black, white, yellow, gray or mixed, has little to do with performance, but it does affect how people perceive cattle" (p. 1). The literature supports this observation about the desirability of coat color, regardless of usefulness. There is great disparity among research throughout time regarding the value of black-hided cattle. Schroeder et al. (1988) reported a price premium for any cattle with a white face and not Angus based – these results were consistent with the market of the time. However, Blank, Saitone, and Sexton (2016) and Mitchell, Peel, and Brorsen (2018) found that black-hided cattle were more valuable, perhaps indicating a market shift. Regardless of the coat color that is valued at the time, the key is the recognition that buyers have a certain connotation associated with color, and it must be studied. Thus, like the breed variables, each color is given a dummy variable to become one when it is true of the heifer, and zero otherwise. Table 4.4. summarizes the breakdown of colors.

Table 4.4. Heifer Color Identifications for Years 2013-2023

Color	N	Mean
Black	7071	0.674
Red	851	0.081
Red with a White Face	236	0.023
Black with a Mott Face	589	0.056
Black with a White Face	1589	0.152
Other Colors	148	0.014

N = 10,488

4.3.3. Heifer Service Type

This leads to the next question: how many heifers were artificially inseminated? The data indicates that 60% of the observations were in an artificially inseminated lot, and a natural sire exclusively serviced 33% of the lots. The remaining percentage falls into the mixed category. Further, it should be recognized that the University of Missouri publications support this breakdown of the data – Thomas et al. (2016) discuss different methods of estrus synchronization and estimate a success rate of 50-80% among heifers, depending on the synchronization method.

4.3.4. Fetal Sex

The second to last portion of the lot characteristics includes a yes or no binary variable on whether the heifers in the group are exclusively carrying male or female fetuses, as well as a continuous variable that counts the calving window of the entire lot. This is a new area of literature for the Show-Me-Select data. This variable was not reported for much of the time frame that Parcell et al.'s papers (2003, 2006) cover and is not necessarily relevant to other sales.

However, the participating consignors can exercise the right to ultrasound the heifers and declare them as carrying a sexed fetus by a qualified veterinarian. Thus, in the aggregate, we discover that 14% of heifers carry a known male fetus, while 27% carry a known female fetus. Furthermore, for this research, the lots are aggregated. No lots are marketed with all the heifers carrying exclusively male fetuses, while nearly 9% of the lots are grouped together as exclusively female fetuses. About 60% of lots are sold as an unknown fetus.

4.4. Genetic and Performance Information

4.4.1. Tier-II and Registration Status

Two variables that will be assigned to each heifer based on the composition of their lot are the proportion of each lot that is registered with their respective breed association and the proportion of each lot that qualifies for the SMS Tier-II Status. The latter identification, as designated by the 2023 program requirements (found in the appendix) for the Show-Me-Select sale, are as follows: Minimum accuracies of 65% in Calving Ease Direct, 30% in Calving Ease Maternal, 75% in Weaning Weight, 20% in Carcass Weight, and 20% in Marbling of the heifer's sire. This is a single term, summary "variable," to guarantee to the buyer that the sire used is a sire of genetic superiority. Additionally, the registration eligibility of the heifer and her calf could signal to the buyer that the lot is of higher value. Significant work has been done to market Certified Angus Beef (C.A.B.) as a quality and differentiated beef brand. Thus, the advantage offered by the known EPDs of a registered female would be valuable to a buyer. Blank, Saitone, and Sexton (2016) found that C.A.B. candidates did indeed bring a premium in western U.S. calf and yearling prices, affirming similar work done by Parcell, Schroeder, and Hiner (1995) in the 1990s cow-calf market, that found registered females brought a premium, especially if they were of the Angus breed. This work, and others supports the idea that, in the beef case and in the livestock sector, the Angus breed is recognized as a popular breed, drawing many producers in each year.

4.4.2. Fetal Service Sire Breed

Beyond the individual heifer characteristics, a sire breakdown is given. This includes the breed of the sire, as well as the EPDs that each sire presents. The sire breed can be considered similar to the heifer breed variables. If he is registered, has EPDs reported, and is mated with a registered cow of the same breed, then the calf could be registered as well. Breed associations could be viewed as helpful in the production process and marketing of cattle and meat products, or they could be viewed as a hindrance. Additionally, as with the heifer breed discussion, each breed offers unique characteristics that the producer might consider. It is necessary to recognize that “Males account for approximately 90% of the gene pool, contributing more to the genetic makeup of a herd in one breeding season than a cow contributes in her lifetime” (Kutz, 2024, p. 2). As the author hints, each sire, and thus their breed, genetic, and phenotypic makeup, plays a critical role in the selection process of each producer, subsequently furthering the beef industry. From here, the discussion must move into the estimated progeny differences each sire presents to evaluate their genetic merit accurately.

4.4.3. Fetal Service Sire EPDs

Thompson et al. (2022) discuss bull-estimated progeny differences (EPDs) and describe the estimates as the animal’s genetic potential derived statistically from an animal and its relatives’ performance and historical data within a specific breed. They rely on a 1975 paper by Henderson that observes the selection occurring in the livestock segment, leading to bias when computing previous models of animal potential, and seeks to correct that by estimating a model that is less likely to yield biased results. Thompson et al. continue by arguing that EPDs reduce the “unknown” nature of mating decisions, thus increasing buyer confidence in their purchase. Thus, which EPDs should be included? The dataset provides the calving ease direct (CED), birthweight (BW), weaning weight (WW), yearling weight (YW), maternal milk (MM), ribeye (RE), marbling (MRB), fat thickness (FAT), and carcass weight (CW) EPDs and their associated accuracies. Both Thompson et al. and Boyer et al. (2019) (in association with a host of other literature) recognize that birthweight and calving ease direct EPDs are highly correlated, which is true of this dataset as well. Additionally, BW, WW, and YW are all growth indicators at different stages of an animal’s life. Thus, they often face the same issue of multicollinearity in models. Further, the four carcass considerations (CW, MRB, RE, and FAT) are all measures of yield grade. A larger carcass weight could indicate a larger ribeye (quantity of muscle) or an animal with more fat, though the first case is more likely. Lastly, it is perhaps redundant, yet necessary to be thorough, to mention that marbling is fat. Thus, six variables are included in the dataset.

Birthweight is chosen over calving ease, as adjustment factors (as will be discussed later) are available for birthweight but not calving ease. This requires that, logically, weaning weight is dropped as the separation of time between birth and the yearling calf is greater. These two variables only correlate at a value of 0.19, thus they are determined to be different enough for inclusion in the model. As for the carcass considerations, using the carcass weight variable limits the dataset by at least another 2,000-3,000 observations (this number is variable depending on the mix of other variables chosen). Therefore, it is dropped, and the ribeye EPD is retained. The final mix of variables to evaluate are the fat and marbling estimates, and they only correlate at a 0.09 value, thus they are both included. The resulting EPDs that are included in the dataset for consideration are the birthweight, yearling weight, maternal milk, marbling, fat, and ribeye EPDs. These variables are a representative mix for the buyers of the SMS sales – they include calving difficulty measures, growth factors and measures, as well as carcass determinations. Parcell et al. (2010) found that the buyers that participate in the SMS sales retain ownership through all levels of the beef supply chain, selling calves off the cow (36.72% of respondents), after backgrounding (53.11% of respondents), and until slaughter (9.04% of respondents).

The previous paragraph discusses two items that are necessary to recognize. The first is an acknowledgment of Thompson et al.'s interpretation of EPDs: EPDs are based on their respective breed. This is accurate, so any model conducted on EPDs must adjust for this, including the model in this paper. Kuehn and Thallman with the US Meat Animal Research Center have produced tables of factors for breed adjustment since 1993. Thus, all EPDs used in this paper are adjusted using their factors for each year. Commonly, they adjust to the Angus breed and provide factors for specific breeds. Some years are as few as six breeds, and others are as extensive as 18 or more. All years include the EPDs used by this paper's authors (BW, YW, MM, MRB, RE, FAT); however, they often include a weaning weight variable and a carcass weight adjustment. It should be noted that adjustment factors cannot be computed for all breeds every year based on data availability. Falling victim to this is often the carcass characteristics. Furthermore, they do not include an adjustment factor for calving ease, as it is often subject to each breed association's definition of calving ease.

4.4.4. Fetal Service Sire EPD Accuracies

Some factors do not need to be adjusted across breeds, though, and those are the EPD accuracies reported by the breed association. Driven by the number of registerable and reported progeny that an animal produces, these factors can be associated with higher confidence in the EPD given by the breed association. A higher confidence in the necessary traits would lead to a producer perhaps bidding more on the heifer or lot. However, due to the nature of the calculation, it is found that many accuracies between EPDs of the same animal are highly correlated (nearly 1). Nonetheless, the important takeaways are that the accuracies represent a wide variety of bulls; from little-used bulls with accuracies near zero to proven bulls with accuracies close to one. Surprisingly, these variables remain uncorrelated with the Tier-II status variable discussed earlier, which is often based on a moderate to highly accurate bull.

Table 4.5. Fetal Service Sire EPD Accuracies

EPD	Mean	Minimum	Maximum
Birth Weight Accuracy	0.731	0.05	0.99
Yearling Weight Accuracy	0.653	0.05	0.98
Maternal Milk Accuracy	0.493	0.05	0.97
Marbling Accuracy	0.486	0.05	0.86
Fat Accuracy	0.465	0.024	0.86
Ribeye Accuracy	0.470	0.05	0.86

N = 10,488

4.5. Consignor Information

4.5.1. Consignor Tenure

After considering all of the aforementioned lot, heifer, and sire variables, one piece remains. This paper begins with a discussion of reputation and buyer activity. Centered in the debate was the idea that consignors gather a particular value from buyers based on the amount of time and degree to which buyers are exposed to them. This idea is based on the economics of each decision, the control that each buyer has over their production practices, and the social pressures that each buyer might face. The created variables “First Year Producer,” “Second Year Producer,” and “Multiple Year Producer” are to determine the costs of entering the sale, the effects of sustained tenure, and to determine if producers gather a reputation as they remain in the sale. The determination of these variables is based on the Pinto et al. (2023) paper – they argue that, based on Shapiro's 1983 theory, a producer will have to enter the market and gain a reputation that should "snowball" over time. Only then will they receive premiums. These consignors are required to sell at the minimum that the market allows. Thus, the first-time consignors have a "1" in their first year and a zero for the second year and multiple-year categories. In their second year, they switch to having a "1" for the second-year variable in the corresponding year and zero for the other categories. In years three and forward, the multiple-year category equals "1".

4.5.2. Consignor Average Size

In addition to tenure, one must consider the amount of exposure, i.e., the number of animals, on which buyers can evaluate the producers. If a consignor sells one animal yearly, and it is their best animal, then a premium could be expected for that particular consignor, but the magnitude is unpredictable. A "shortage" of the same type of heifer might lead to increased competition in bidding. On the other hand, they might be relatively unfamiliar, especially in the large sales with more than 100 lots each sale, thereby reducing their available premium. Thus, a variable that tests for this type of producer would be valuable. In the same variable, it is possible to test the "big" producers as well. The questions that are applicable here are whether these producers are consistent, if a higher degree of exposure is valuable, and if there is value in knowing that more heifers of a (theoretical) similar type and kind are likely to be sold in the future. Further, if something were to occur with the purchased lot, they might have the knowledge, experience, and inventory to assist the buyer. Of course, this system only holds if producers sell a proportionate number of heifers as compared to their operation size; since the sale is based on females, and a high-quality sale of a similar kind is rare, the expectation is that it would hold to a certain degree. More doubt would be present if the sales were focused on bulls –

large producers tend to have specialized bull sales. This variable is created in the same way as the tenure variables – a three-year rolling average is created for each consignor after their third year participating in the sale. The variable reports the exact number of heifers sold in the first year for the first time a consignor sells and the average of two years for the second time a consignor sells. Through this method, the peaks and valleys associated with yearly supply are smoothed, and a "disbursement" type of peak, where a producer might sell all of their females as they exit the industry, is mellowed.

4.5.3. Individual Consignor Reputation

The third reputation test is a consignor dummy. After controlling yearly and seasonal trends, lot characteristics, and individual heifer and sire characteristics—all things a buyer might associate with each consignor—this is a test of reputation. With this, in a big model, the characteristics of each consignor would be related to this dummy. This includes cow genetic family lines, the use of "big name" sires, their involvement in their church, government, and community, their production methods, and perhaps even their perceived honesty. To break this down, some cow family lines are well-known in the cattle industry, but there is no way to test for this in the dataset. Therefore, the discussion must focus on production methods and community knowledge. If a producer feeds their cattle by hand (indicating an ability to handle them in a close environment, i.e. docility), runs them on pasture primarily (thereby creating a "true" assessment of growth-ability, despite the information that EPDs provide), and uses electric fences (indicating ease of management), then the consignor might receive a premium. Additionally, that premium might be added onto if they are a 4-H leader, coach a rec team, are owners of a small business, are involved with the livestock association, or are present in some other (positive, for this example) way in the community’s eye. The dummy associated with each consignor will capture these theorized value additions and others.

Chapter 5 - Model Creation

A hedonic model was created for this paper. The basis of the hedonic model lies in a 1976 paper by Ladd & Martin. The central theoretical and practical application is the assigning of money values to a particular input – the value of each input is determined by the multiplication of the quantity, or given level, of a particular characteristic by the implicit value of one unit of the characteristic. The common way this is evaluated in economic literature is to view each good as a bundle of characteristics, in which the buyer purchases the entire bundle but as a result of summing the individual characteristics presented by the bundle. In the case of a bred heifer, she might present an 800 lb. body weight, an AI calf, and be of the Angus breed. One continuous variable, weight, is multiplied by the value of one pound of weight. In other words, if the value of one pound of weight is one dollar, then the value of the heifer would be 800 pounds * $1/pound greater, or $800 dollars. On the other hand, the AI fetus and Angus breed are not continuous, i.e., they can only be measured in a yes or no quantity. In this case, dummy variables are established where each variable is given a one or zero value, typically one for true and zero for false. In this case, anytime the variable equals one, the variable's value is added (or subtracted for a negative value) to the overall price of the heifer. Still, anytime it is zero, nothing is added or subtracted. Furthermore, a group of related variables, such as multiple breeds, can be evaluated. For this, one dummy must be dropped, and any derived value is compared to the dropped dummy. In the case of the breeds, the Angus variable might be dropped, and the Hereford breed would be compared to it. A positive coefficient would indicate a premium as compared to the Angus breed, and a negative coefficient would indicate a discount. The last thing to be clear on regarding the hedonic model is the allowance of non-linear functional forms. As has been done with Parcell's research on SMS sales and other papers, such as Pinto et al. (2023) or Thompson et al. (2022), certain variables could be considered non-linearly.

The developed hedonic pricing model for bred heifer sales will estimate lot average prices as a function of yearly, seasonal, and location effects as well as lot, heifer, fetal, and service sire characteristics, coupled with EPDs and reputation effects. The model can be expressed as:

Price = *F(Year, Season, Location, [Lot, Heifer, Fetal, Service Sire] Characteristics, EPDs, Reputation Effects)*

The model is estimated using the Ordinary Least Squares method, quantifying the impact of the various independent variables on the dependent variables. This regression process minimizes the sum of squares residuals between observed and predicted prices. Through this approach, the contribution of each factor can be understood and offer insights into the determinants of market value. All variables used in the model were outlined in the data description section; however, their predicted values will be presented here.

Chapter 6 - Prediction of Variable Direction and Magnitude

6.1. Auction and Lot Characteristics

6.1.1. Yearly and Seasonal Trends

The yearly and seasonal trends will capture the cattle cycle. Asset fixity in livestock production (e.g., the inability to convert rocky pasture or a cattle trailer into crop ground or a planter quickly and without transaction costs) coupled with the biological constraints in cattle production (9 months of gestation, one or more years to capitalization on the initial investment) causes the cattle cycle. In short, producers can see prices increasing, but there is a delay until they can react, invest in, and gather that higher price, and by the time they do so, the whole industry has likely done so as well. Thus, it is expected that the yearly trend in prices will fluctuate as the cattle cycle does – perhaps even more so since the heifers offered at the sale are closer to the realized investment stage. The CME group and USDA ERS provide graphs and articles analyzing the cattle cycle for recent years; it is expected that the premiums for prices will decrease when there are peaks and increase when there are valleys in cattle inventories. Furthermore, the common cattle cycle encourages producers to calve in the springtime to reduce management costs, align the herd's feed intake needs with peak forage availability, and align the cattle markets with the U.S. consumer's demand schedule. With this knowledge in mind, the heifers marketed in the fall are anticipated to bring a premium, as they would calve in the spring.

6.1.2. Sale Barn Effects

The sale barn effect is anticipated in multiple ways. Since a portion of this paper focuses on reputation as an aspect, that will be the first interpretation discussed. With a good reputation, including sound sales practices, a talented auctioneer, easy load-in/out facilities, and a safe transaction system, a premium is expected. If one of these things (or other factors not listed) is weaker for a particular barn, the relative premium is expected to be less. Furthermore, the geographic aspect must be considered. Suppose the sale is located near a larger number of buyers. In that case, the ease of the transaction and the lower transportation costs for the buyer base at large, among other things, are expected to encourage bidders to be more liberal with their bidding at this sale barn. Additionally, this effect could speak to the types of buyers attracted to the sale. As Adam, Krämer, and Müller (2015) described, prices can be influenced by buyer competition, compounded by a high-pressure time constraint and the learned excitement of winning compared to the disappointment of losing. Therefore, sale barns are expected to bring varying premiums. Due to the nature of the hedonic models and dummy variables, sale barns will be compared with each other. Thus, for the consideration of the full model, the sale barn with the lowest returned value will be dropped so that values can be considered as premiums for the discussion since it cannot be said with certainty if each barn brings a premium or a discount.

6.1.3. Flooring (No Sale) of Cattle

Each producer likely decides to floor their cattle based on the sale barn they go through, among other factors, including market conditions. If the barn provides a price that they deem adequate, they will likely let their cattle sell, but if they do not, they will floor them (set a minimum price, with the intention of taking them back home if the price is not met). However, it is unclear what each producer deems as adequate. Thus, the effect of flooring heifers is unknown. As previously discussed, a minimum sale price might be declared if the income from the future sale of the animal is greater than the present-day opportunity cost. As theorized earlier, additional income might be garnered at a private auction due to increased scarcity, but the SMS sale provides little to no such incentive. One thought is that consignors in the SMS sales must set the floor low enough such that the heifer has a calculated chance of being sold but high enough that if the heifer does not sell, they can sell her later. This would indicate risk-taking behavior and yield a premium for the dummy variable in the developed model. The second belief could be that the floor will be set just above the producer's costs, or perhaps equal to or just above the heifer's value, yet low enough that almost any bid is accepted. Through this, the consignor makes a correct valuation of the heifer, resulting in a zero-sum or slight discount calculated by the model. The third alternative option not recognized earlier in the paragraph is that the floor price might be the producer's value of a similar type of heifer; with this in mind, the heifer would be retained in the original herd as a replacement female. It is impossible to accurately predict the behavior of the SMS producers without more information; therefore, the rest of the variables will be important.

6.1.4. Lot Order and Number of Heifers in the Lot

To begin the consideration of the lot level variables, the number of head that are in each lot is broken up and lot order is discussed. Parcell et al. (2006) and Pinto et al. (2023) found differing relationships when estimating the impact of lot size on the price variable. To discuss these, Pinto et al. recognize several studies that face an upward or downward-facing parabola depending on the regional preferences and market qualities; Parcell et al.'s study that interacts with the earlier SMS data indicates a linear relationship. Since a downward parabolic shape could cause the premium to decrease at a given lot size while in actuality, it might plateau (or the reverse could be true as well, given an upward shaping parabola), in this model, the number of head in each lot will be assigned a dummy variable. The dummy variables will be assigned in groups of two. Values greater than zero, but less than or equal to two will be grouped together. Furthermore, values greater than two and less than or equal to 4 are in another group. This pattern will continue until the final group is less than or equal to 8, then the pattern will change.

In the final group, there will be a “four” head group, as there are only 57 head that fit the specification of greater than ten. The base will be set at the first dummy – zero to two head in the lot, and premiums are expected for all other variables, although it is difficult to describe an anticipated shape. The lot order variables will operate in a wholly different manner, as they are broken into percentages of the total in the sale. A peak is expected in the middle of the sale, in accordance with Parcell et al.’s evaluation of the previous SMS sales. Furthermore, the beginning of the sale is expected to start slow, leading to a discount for the first variable, as compared to the final third of the data.

6.1.5. Calving Window and Number of Sires in the Lot

The calving window of the lots is anticipated to be important to buyers. In other words, the time between the first calf's birth and the second calf's birth within the lot is likely important. It indicates perhaps a lower chance of estrus detection or A.I. conception or an increase in management costs during this time. To this end, as the number of days increases, the value of the lot is expected to decrease. Parcell et al. (2006) specifies a dummy variable when this exceeds 30 days, and Pinto et al. (2023) find a decrease in the lot of 2-4% for every month that the time between the sale and calving accumulates. Additionally, lots are grouped into a calving span of 45 days or less, as outlined by the SMS guidelines. Furthermore, estrus in heifers occurs every 18-21 days. These varied results, guidelines, and biological norms lead the authors to specify a linear variable so as not to ignore the already discussed differing practices. The least discount is expected when there is a calving window of 0, and an accumulating discount is expected to decrease the lots' value as the span grows. The window, as discussed in the data section, is more likely to increase with the number of sires in the lot. The sires are modeled linearly by the authors of this paper. It is expected that with each bull increase, a discount will occur, a result confirmed by Parcell et al. (2006).

6.2. Heifer Characteristics

6.2.1. Heifer Weight

The heifer weight variable is important to the model, as a large portion of beef is marketed by the pound. In two cases, calves are weaned and sold at the sale barn by the pound and beef roasts are sold by the pound in the stores; thus, it would be logical to assume that every step in between has a weight component. It is predicted that the SMS auction price will increase as weight increases. Additionally, Marshall et al. (2021) spends some time discussing the value of getting a calf on the ground, including abortion risk associated with the age, weight, and frame size for buyers of bred females. It would be expected that the outcomes would be like those found by Marshall et al. (2021) and others with similar research (such as Schroeder, Mintert, Brazle, & Grunewald (1988) and Parcell, Schroeder, & Hiner (1995)) – a positive, increasing relationship. In this manner, buyers would signal to producers that within the limited specifications of the Show-Me-Select criteria, they prefer that the sellers provide every evidence and opportunity for the buyer to have a healthy calf on the ground in the future, and if the worst should happen, a reasonable salvage value is hoped for. While the exact slope cannot be clearly observed in Figure 6.1., it is clear that heifer weight and price are related and differentiated by other factors within this dataset. The price is expected to increase continually, with a plateau towards the maximum weight. Thus, the weight variable is broken into dummy variables; the first variable is from 800 pounds to less than or equal to 850 pounds, and the second is 851 pounds to less than or equal to 900 pounds. The rest of the variables increase by fifty-pound increments in a similar fashion.

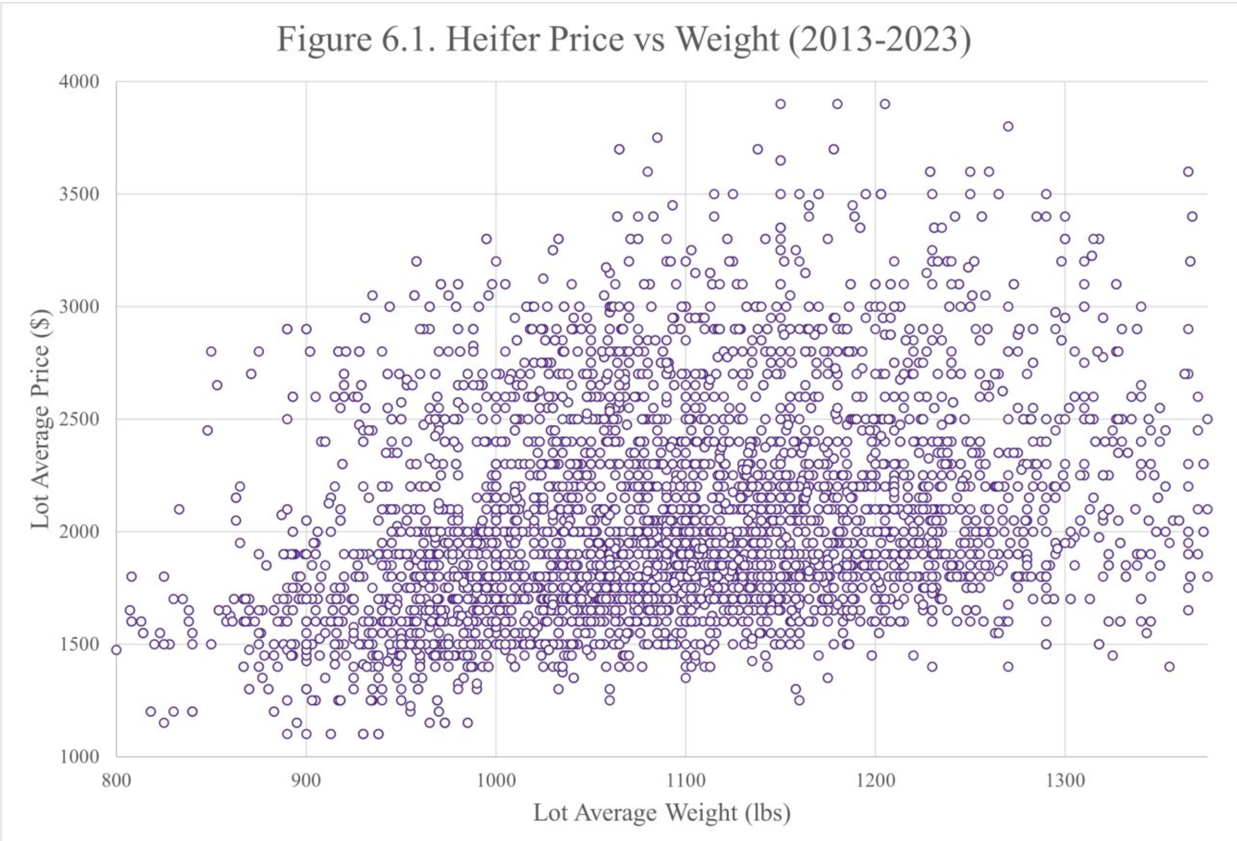


Figure 6.1. Heifer Price vs Weight for Years 2013-2023

6.2.2. Heifer Breed and Hide Color

The conversation will now move into multiple heifer variables, including breed and color. The largest breed given by the dataset is Angus, followed distantly by Hereford and Simmental. Furthermore, a large proportion of the data is an unknown cross on one side of the mating. Dummy variables are created for the eight-plus breeds, unknown categories, and crossbred cattle represented by the SMS producers, and the base is placed in Angus, as it seems that the breed is the most popular in Missouri. A premium could be anticipated for breeds that are useful for the Missouri climate and temperament, have strong association programs or support (Certified Angus Beef, to maintain this paper's example), or perhaps are rarer to find at sales, while a discount could be expected for those less desirable breeds. To continue with coat color, as discussed earlier, a binary variable is given to each color pattern possible, and the base is in black since that appears to be where the market preferences lie in terms of quantity. The same expectations as breed might be anticipated – a premium for those more desirable coats, and a discount for the less desirable, driven by common market preferences or biases.

6.2.3. Heifer Service Type

To begin evaluating the service type for each heifer, a binary dummy variable that is one when the lot is entirely serviced by artificial insemination is compared against a binary variable that is one when a natural sire entirely services the lot. Additionally, one more dummy is added for a lot mixed between natural and artificial service types. A premium is expected for artificially inseminated groups – the largest premium is expected for the lots that are wholly serviced by A.I. This was observed in Parcell et al.'s 2006 work with the SMS sales. However, the previous data indicated that a discount was given to the mixed lots. A cause of mixed lots could be the practice of artificially inseminating heifers and then turning them out with a cleanup bull, leading to a majority of females that are artificially inseminated, but some that are naturally sired as well, causing doubt about which sire is the true sire.

6.2.4. Fetal Sex

Not provided in Parcell et al.'s papers, on the other hand, is the fetal sex. This appears to be a unique area of the literature, so the following variables are created. A binary variable that is one when the lot is exclusively female fetuses and another variable when the lot is exclusively of an unspecified gender is compared against the lots that are exclusively male and of a mixed state. The lack of lots that are grouped entirely male in the dataset would indicate that they are less popular and might bring a discount. Contrary to this statement, the expectation would still remain that knowledge of fetal sex is more valuable than a lot, which is likely a mixed bag but is unknown. Thus, the exclusively female lots are expected to bring a premium, and the wholly unknown lots are anticipated to bring a discount as compared to the rest of the data, which contain mixed lots.

6.3. Genetic and Performance Information

6.3.1. Tier-II and Registration Status

The next variables of interest are the percentage of the lot that is registered and the percentage of the lot that is Tier-II qualifying. As discussed earlier, a registration status provides additional knowledge and security to the buyer of the given animals. This could include family lines or confidence in breed association support. Thus, as the percentage of the lot that is registered rises, a premium is expected. The maximum premium is expected at 100%. For this model, linearity will be assumed, as sufficient numbers do not exist for the creation of consistent dummy variables, as done with lot size. Furthermore, the Tier-II status measurement is expected to follow the same trend, as it provides "peace of mind" to the producer about the animal's safety and its ability to deliver a higher quality, live calf. The same process and assumptions outlined by the registration status will be followed for the Tier-II variable, making the maximum premium received by a consignor equal to 100%.

6.3.2. Fetal Service Sire Breed

Sire breeds can be considered similar to heifer breeds; however, they will admittedly be less intensive. Thus, a handful of sire breed variables are created. The largest concentration is by far in the Angus breed, with Red Angus having the only other large portion of data. Thus, a group variable is created for sites that are not Angus or Red Angus; a discount is expected for anything that is not black Angus, as many heifers are Angus-based, demonstrating popularity in Missouri, especially at this sale.

6.3.3. Fetal Service Sire EPDs

As for EPDs within the sale, all six are specified linearly. This methodology differs among the literature but seems the most appropriate for this study. Birth weight, as discussed earlier, can be an indicator of calving ease. Thus, a negative birthweight is expected to trigger a premium, while an increasing birthweight is expected to cause a discount. Yearling weight is a measure of actual growth and saleable carcass weight, therefore, it is likely that all increases to the yearling weight EPD would be desirable. On the other hand, the indicator of potential maternal ability and the milking value of the fetus is the maternal milk EPD. However, this is related to a higher energy demand, or with an increased feed cost – milk requires energy, and energy has to come from feed. Thus, it is uncertain what the impact of a change in the maternal milk EPD will be. Thompson et al. (2022) predict that their carcass characteristics will be insignificant – included among these are ribeye, marbling, and fat EPDs. They observed a positive coefficient for the ribeye EPD, and the prediction by the authors of this paper would be the same result. Furthermore, producers are occasionally rewarded for marbling scores; thus, a greater premium is expected with an increase in marbling. Lastly, excess fat is undesirable and measured in yield grade calculations, so a decrease in fat is anticipated to bring a premium to the consignors.

6.3.4. Fetal Service Sire EPD Accuracies

To attempt to add to the literature in the EPD space, the evaluation of the accuracies of these traits are also examined. The correlation among the variables necessitates the conglomeration of accuracies to describe the bull in question. Thus, three binary variables are created: a high, moderate, and low accuracy category for each bull is assigned. If a bull meets the standard of three or more traits exhibiting an accuracy of 0.9 or greater OR all traits are at a minimum 80% accurate, then the bull is determined to be highly accurate. Further, an accuracy group that meets the standard of 3 or more traits exhibiting no less than a 0.7 OR if all characteristics are at least 60% accurate, then the bull is determined to be moderately accurate. All other bulls are left in the low accuracy category. Therefore, it is expected that as compared to a low-accuracy bull, moderate accuracy would bring a slight premium, while a high-accuracy bull would bring a larger premium.

6.4. Consignor Information

The final categories to include in the model are the reputation variables. As described earlier, the consignor dummies are expected to capture the value of each consignor's reputation after controlling for the heifer and lot characteristics obtained from the dataset. Due to the nature of the dummy variables, each consignor's premium or discount will be based on the dropped dummy. Therefore, to simplify the interpretation, the consignor with the lowest premium will be dropped, so all relative premiums are positive. The second reputation variable was the average size of each consignor's yearly consignment to the sales. An increase in size is expected to result in increased market saturation/awareness by consumers and drive higher prices. However, there could be "too much" of a good thing, thereby indicating a drop-off point for reputation based on size. In other words, if the consignor provides almost all the animals at the sale, then it would still be accurate to assume a market adjustment for reputation, but the few other consignors in the sale might receive a higher premium, simply due to the lack of supply. Thus, this variable will be considered with a squared term. Finally, the tenure variable will consider the Shapiro effect. In this theory, first-year consignors will receive the lowest price, with an increasing effect for second-year consignors, and the highest premium for the multiple-year consignors. However, it could be argued that the multiple-year consignors have perhaps "settled" in their ways, leading to a decreased premium for them and a “novelty” price for new entrants. As such, the rolling average head and tenure variables are difficult to predict in magnitude and direction.

Chapter 7 - Model Fit

The specified model contained 333 variables, including 258 individual consignor dummies and 71 lot, heifer, and sire variables. The model has an adjusted R-squared of 0.76, and an RMSE of $220.64. Compared to the mean ($2058) and standard deviation ($451) of the dependent variable, the lot average price, this reduces the variability in the prediction of prices. Furthermore, the F-statistic was 101.39, with a p-value of less than 0.0001, indicating that the variables included are likely to be explanatory. The remaining 24% of the variation (as given by the R-squared term) is a comfortable margin. This shows that not all the variation was absorbed by the consignor dummies, which was a concern, and that there is still variation to be captured by future research.

Table 7.1. Full Model Fit Diagnostics

Number of Observations Read	10488
Number of Observations Used	10488

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F - Value	Pr > F
Model	333	1643642778	4935864	101.39	<.0001
Error	10154	494296535	48680		
Corrected Total	10487	2137939313			

Root MSE	220.6354
Dependent Mean	2058.67325
Coeff Var	10.71736

R-Square	0.7688
Adj R-Sq	0.7612

Four diagnostic tests were conducted to evaluate the model used in this paper: the multicollinearity variance inflation factors (VIF), the Breusch-Pagan heteroskedasticity test, the Durbin-Watson autocorrelation test, and the Ramsey RESET test for model specification. While these diagnostics indicate some areas that warrant attention, the overall confidence in the variables used to specify the model remains strong, and no adjustments will be made at this stage. First, 15 of the 75 non-consignor variables and 29 of the 258 consignor variables exhibited a VIF value greater than 10, particularly among the Sale Barn variables, the Weight Bin variables, and the Consignor Size variables. This suggests some multicollinearity but does not necessarily compromise the overall model integrity. The Breusch-Pagan test revealed an R-Square of 0.15 for the regression of variables on the squared residuals, accompanied by a significant F-value. This indicates that while there is some degree of heteroskedasticity, additional information may be needed to explain the error in the model fully. The low p-value on the chi-square distribution further suggests the presence of heteroskedasticity. The Durbin-Watson test for autocorrelation in errors indicated some positive autocorrelation in several cases. Finally, the Ramsey RESET test results showed the residuals have a slight positive skew and kurtosis less than 3, with p-values less than 0.01 for three different normality tests, suggesting minor deviations from normality. Overall, while these diagnostic tests highlight areas for potential improvement, they do not undermine the robustness of the model in its current form.

Chapter 8 - Model Results

8.1. Auction and Lot Characteristics

8.1.1. Yearly and Seasonal Trends

The analysis begins with evaluating the variables that the data description and the prediction sections began with. The yearly trends had extremes of a discount of $29 dollars and a premium of $1,036, resulting in a range of $1,069. The average price adjustment was $299 dollars, which perhaps indicates that 2019 was a valley for cattle prices, indicating the tightening of margins beforehand, with expansion afterward. To examine this, the CME Group and the USDA can be referenced. As mentioned earlier, the helpful graphs and data provided by these organizations can help disentangle the results gained from the model. The cattle inventory chart indicates that cattle became relatively more available from 2014 until 2019 and became increasingly scarce from 2019 to 2023. Given a 9-month gestation period, the price and quantity interaction in the market would indicate that 2018 or 2019 might be the lowest prices, which is consistent with the prices found by the model. Furthermore, the Prices Received for Cattle by Month graph follows a similar trend – decreasing prices until mid-to-late 2019, then a moderately continuous price increase for the subsequent years. Thus, while the $1,069 dollar range might seem large, it seems consistent with numbers reported for the entire country's cattle market. A quick correlation analysis of the percentage change between the yearly estimates and the data provided by the USDA in their creation of the Prices Received for Cattle by Month graph yields a correlation of 0.79 for the corresponding years. To round this discussion out, the fall sale variable, which was one when true, only adds $7 dollars to each heifer and carries a p-value of 0.24. Thus, there is a reduced chance that the variable is statistically significant, but it is essential to leave in the model, as it has already been discussed that fall buyers likely face differing considerations due to the time of year.

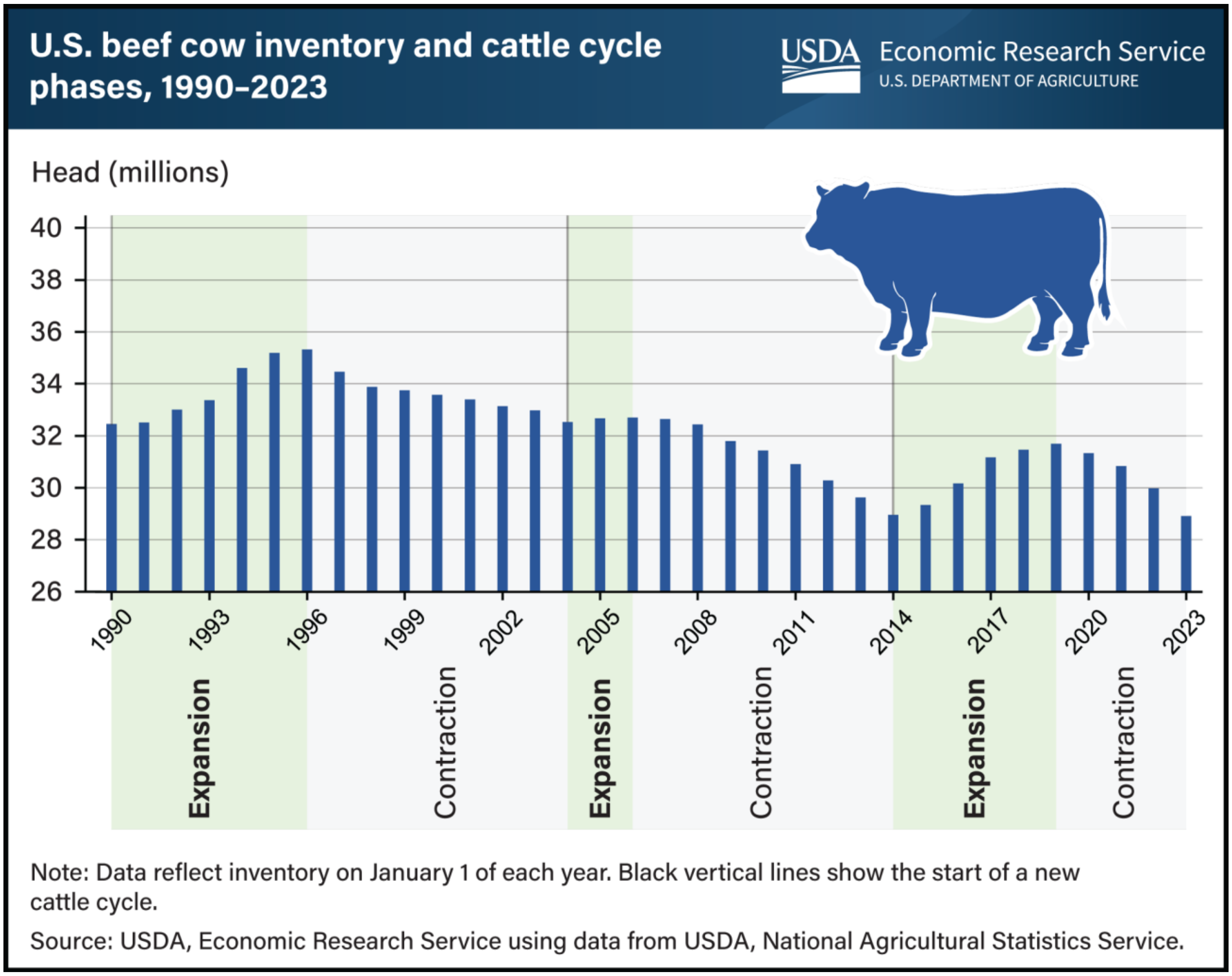
Table 8.1. Parameter Estimates for the Yearly and Seasonal Trends

Variable	Parameter Estimate
2013	164.416 ****
2014	1036.735 ****
2015	745.960 ****
2016	192.153 ****
2017	82.079 ****
2018	-29.373 ****
2019	BASE
2020	165.103 ****
2021	130.228 ****
2022	191.167 ****
2023	312.582 ****
Fall Sale	7.849

N = 10488

**** $p < 0.01$, *** $p < 0.05$,
** $p < 0.1$, * $p < 0.2$

Figure 8.1. U.S. Beef Cow Inventory and Cattle Cycle Phases (1990-2023) (USDA, ERS)



8.1.2. Sale Barn Effects

The location effects were also declared to be of interest. Since the location variable with the lowest return was dropped, all the other variables are compared to it. The highest relative location premium was nearly $300 dollars, and the average location premium was $217 dollars. As hypothesized, all sale barns have differing premiums associated with them. This aligns with Parcell et al. (2006), in which the authors assigned regional dummy variables to capture each region's value. They found $10 and $82 associated with each region as compared to their base; in other words, the two tested sale barns brought premiums.

8.1.3. Flooring (No Sale) of Cattle

The value of the floored animal was approximately $64 dollars less than other heifers. While conforming to one of the described possible avenues, it is a bit surprising. It indicates a proper evaluation of the heifers, all else held constant; not a severe overvaluation on behalf of the producers. It could indicate an undervaluation on the buyer's part. The $64 dollars, while the next incremental bid would likely outspend it, represents an incentive for the buyer to purchase the heifer. To the consignor, this amount could be the cost of transporting the heifer back home and maintaining her until a private treaty sale could be made. This difference follows the results of Taylor et al. (2006) – while this study is less rigorous than that found in Taylor et al.'s, it is not readily apparent what causes the differences in buyer and consignor opinions. A possible explanation is that sellers cannot transmit complete information to the buyers about pedigree or performance, thus leading to undervaluation by buyers. As recognized earlier, buyer confidence is an essential driver in bidding activity. Therefore, this inefficiency would plausibly cause buyers not to meet the buy-back price.

8.1.4. Lot Order and Number of Heifers in the Lot

The most general lot characteristics yielded some interesting results; the lot order and the number of head in each lot. Lot order did yield an apparent parabolic shape, as expected from previous literature; however, the first 1/3 of the data did not bring a premium or discount as compared to the last third. While somewhat surprising, it perhaps indicates that the bidders at the auctions do not have as much of an aversion to the beginning of the sales. This could indicate that sale organizers represent the sellers well or that buyers already have a set budget and stick to that budget well. The other explanation for these results could be that the random order of the lots sufficiently equalizes the higher and lower quality heifers, keeping buyers engaged. The seemingly most likely explanation is that the lots are uniform for the entirety of the sale, which maintains buyer social competitiveness. This is especially true after controlling for the number of head in each lot. Parcell et al. (2006) in their analysis of the SMS data, argued that Missouri producers would likely need to replace, on average, seven head in their herd each year. With this knowledge, they argued that larger lots would receive a premium so buyers would not need to purchase multiple lots. The given results cease increasing per head after the 4-6 head category; because each dollar amount is a per heifer price, the amount can be multiplied by the number of head in the lot – thus, the premium per lot is technically still increasing, but only because of the increase in the number of heifers in the lot. Figure 8.2. shows the estimated premiums based on the lot order, while Figure 8.3. shows the trend in premiums.

Figure 8.2. Individual Heifer Premiums Associated with the Order in which the Lots Appear

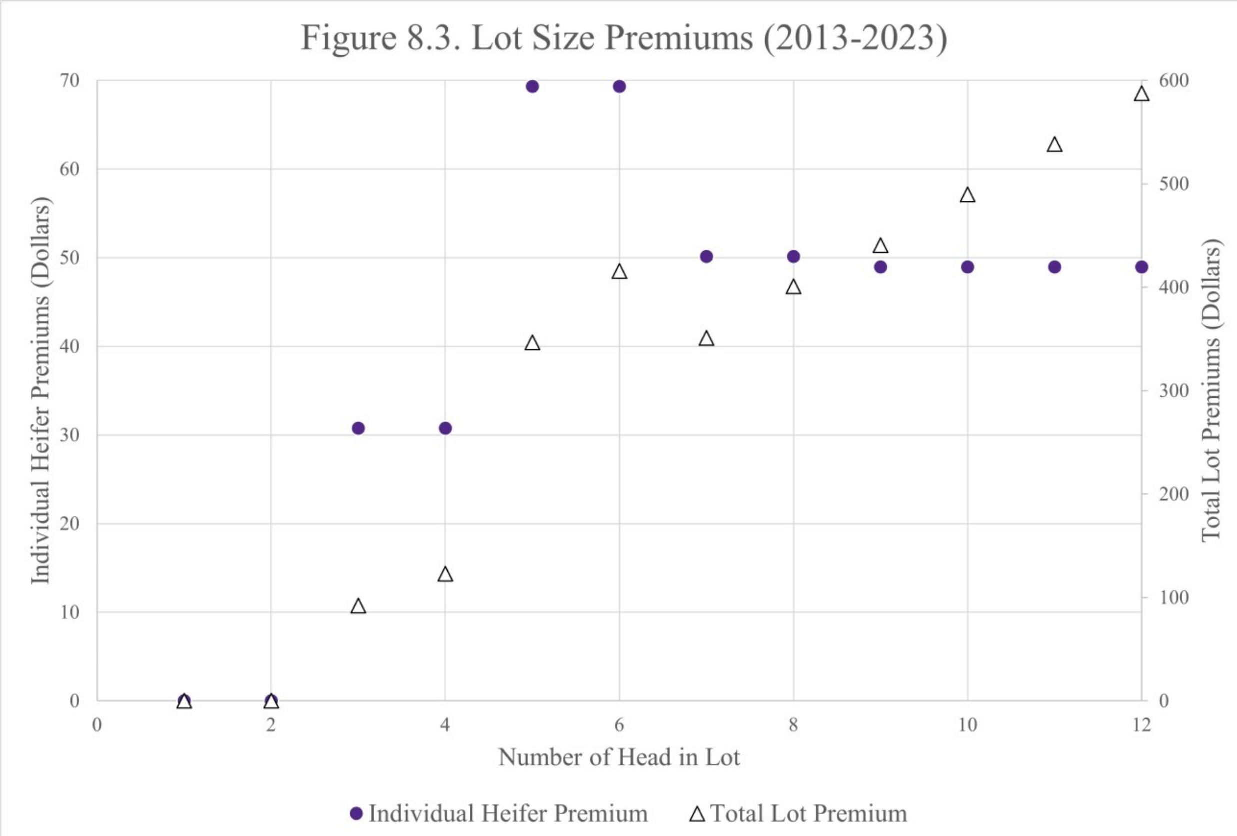


Figure 8.3. Lot Size Premiums for each Individual Heifer and the Full Lot

8.1.5. Calving Window and Number of Sires in the Lot

Other factors that are represented by a discount in the model are the linear specification of the number of sires and the calving window. While concentrated around one, the number of sires can reach up to four in the dataset. Thus, for each sire, a discount of $17.12 dollars is realized. This represents a lack of uniformity in the lot, which appears to be displeasing to the buyers. It could be related to a deviation from the buyer's preferred sire group, family line, or other factors not measured by the model or mentioned here. Additionally, the model explains that for each incremental day that the calving window increases, a $0.39 cent discount occurs. While seemingly not a large amount, on average, the seven-day window indicates a $2.73 increment, which jumps to $8.21 when a 21-day estrous cycle is calculated and $16.42 when two are observed in a lot. This is slightly less than the $24 dollar discount reported by Parcell et al. (2006) in their model for calving windows that exceeded 30 days. However, either way that it is calculated, the days between calves increase the costs of management and care; thus, a discount each day is reasonable. It likely varies for each producer as to the specific cost of each additional day, but pen uniformity and cost aspects are, without doubt, altered with each day that the window increases.

8.2. Heifer Characteristics

8.2.1. Heifer Weight

Modeling weight yielded results that followed the hypothesized form. Weight increased steadily until the 1251-1300 pound category was reached when a plateau was discovered, which later led to the market seeing a minor decrease for the heifers heavier than 1350 pounds, as compared to the 800-pound animals. This indicates that buyers do not consider the weight of a heifer a "bad" or downside; in fact, they find it beneficial until the plateau. At that point, they expect some challenges with calving or even a lesser salvage value for the heifer, should they need to sell her. Both Marshall et al. (2021) and Boyer et al. (2021) spend time evaluating the salvage value of females, and the essence of the argument is that they would likely be sold for processing. Thus, weight is not necessarily an invaluable category for the buyer or seller to consider. Additionally, the larger the animals, the fewer days the bidder has to spend feeding and adding growth to her within his own operation.

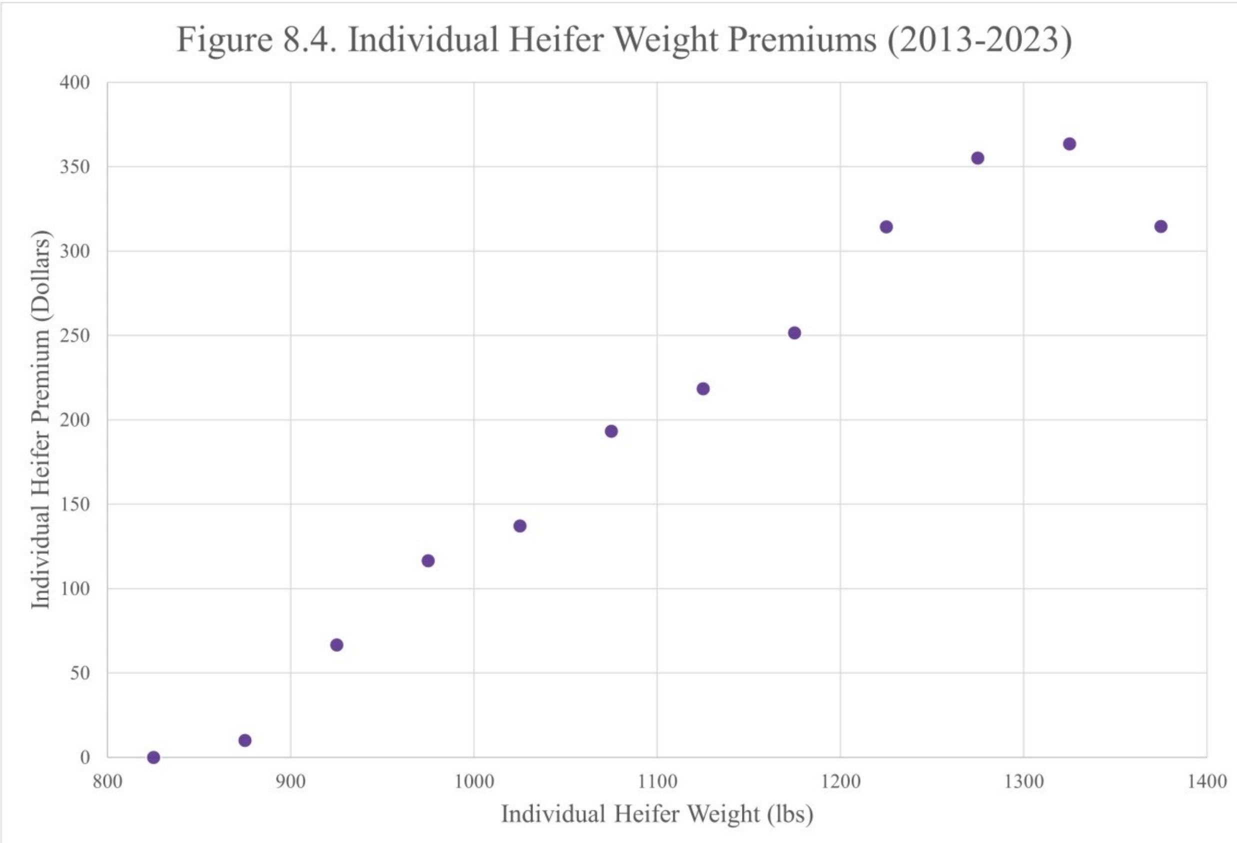


Figure 8.4. Individual Heifer Premiums vs Heifer Weight

8.2.2. Heifer Breed and Hide Color

Heifer breeds and colors were theorized to be valuable based on the climate and producer preferences in the localized area of production, driving premiums and discounts for certain categories. Varying levels of dollar amounts and varying degrees of explainability were found in the model. Heifer color is an interesting facet of these auctions. Each producer has a different preference, from solid colors and rarer colors to even colors that represent some character; the model explains that producers have preferences regarding what their heifers look like from the road. The red heifers lack a bit of statistical significance, with a p-value nearing 0.16 and 0.09, in the categories of solid red and red with a white face, respectively. Their premiums are $25 and $33 dollars, respectively. The black hides that were given premiums are the Black Mott Faced and the Black Whited Faced Heifers. These heifers are often crossbred heifers and indicate heterogeneity in their genetic makeup, which is desirable. They returned significant results for their consignors of $68 and $91 dollars each. The difference in the coloration is minute, but it does make an economic difference to the buyers. Allison (2009) was specifically written for producers and explicitly designed to inform producers how to create different hair styles and types by crossing specific hair colors and pigments of skin, knowing that producers have particular preferences regarding cattle color. The buyers at the SMS sales do discount the other heifers that do not fit these categories – this discount amounts to $88 dollars per head and carries a p-value less than 0.01. From here, the discussion of results can move into the breeds of the individual heifers and the sires of the fetuses.

As discussed earlier, breed offers a producer identity but is much more specific than the color consideration. Thus, the results are varying in their impact. Angus and Gelbvieh cross heifers, called Balancers, drew a $113 discount as compared to Angus. This is mildly surprising, considering that some of the largest Gelbvieh producers are in nearby states, according to the American Gelbvieh Association – perhaps these breeders prefer purebred Gelbvieh heifers. Angus and Hereford crosses also drew a discount of $41. The model calculated a $13 discount for the Angus and Simmental crosses (this cross did have a 0.46 p-value, so some doubt as to its difference from zero exists), and when a third, unknown cross is entered into the mix of Angus and Simmental, a deeper $38 dollar discount is expected, which is increasingly significant. However, Angus and Tarentaise crosses returned a premium of $50, and since Tarentaise cattle descend from the French Alps and are less common in the United States, this is a bit surprising. The last two categories of Angus crossbreds are the Angus that have an unknown or undeclared cross, which did not attract a premium or discount, and the “Catch All” category for other Angus crosses, which drew a $90 dollar discount. The other “Catch All” for crosses was for any that did not contain any Angus portion – these drew a $27 dollar discount, with a p-value of 0.149. The Simmental crosses, with an unknown portion of their pedigree, brought an $88 dollar premium as compared to the purebred Angus. This was the opposite of the Red Angus Cattle crossed with an unknown counterpart; these heifers brought a $42 dollar discount. On the other hand, their purebred Red Angus counterparts brought a premium of $68 dollars. The final purebred groups that were too small to remain as their own dummies, resulting in a group variable, brought a discount of $87 dollars. The increased p-values found for some variables could be explained by many things, including variability in bidder activity over the years (changing preferences, perhaps).

Table 8.2. Heifer Breed and Color Premiums

Variable	Parameter Estimate
Angus	BASE
Red Angus	68.984 ***
Small Purebred	-87.090 ****
Angus X Simmental X Unknown	-38.108
Angus X Gelbvieh	-113.441 ****
Angus X Hereford	-41.660 ****
Angus X Simmental	-13.182
Angus X Tarentaise	50.947 **
Angus X Unknown	3.116
Smaller Angus Crossbreds	-90.764 ****
Red Angus X Unknown	-42.197 **
Simmental X Unknown	88.409 ****
Smaller Misc. Crosses	-27.527 *
Black	BASE
Red	25.099 *
Red with White Face	33.556 **
Black with Mott Face	68.240 ****
Black with White Face	91.132 ****
Other Colors	-88.692 ****

N = 10488

**** $p < 0.01$, *** $p < 0.05$, ** $p < 0.1$, * $p < 0.2$

8.2.3. Heifer Service Type

The lots that are sired by artificial insemination are valued higher, as expected. A premium of $84 dollars is estimated for those lots, as compared to the lots sired by a natural sire. As Parcell et al. (2006) pointed out, buyers believed that an artificially inseminated heifer indicated a higher value for the calf and, thus, the lot. This could be true for many reasons – family lines, dam and sire potential, confirmation of the producer's existing production practices, and much more. However, Parcell et al.'s work demonstrates a $15 dollar discount for lots that are mixed between AI and natural service, $42 dollars lower than the predicted outcome of this later data. The $27 dollar premium arrives at a lower rate than the previously discussed premium for lots that are fully AI-sired. However, it still attracts a premium, perhaps as an incentive to those few heifers within the lot that are AI-sired. As discovered by the service types and will be supported by the fetal sex section, the buyers of the SMS sale are interested in high-quality calves, and that extends into markers of that quality as well.

8.2.4. Fetal Sex

The discussion of the results then moves into the fetal characteristics, especially the fetal sex, as that is a new piece of research, as well as the service type of each lot. The model predicts a $38 dollar premium for lots with heifers carrying exclusively female calves. On the other hand, a $22 dollar discount is expected for lots of unknown gender, which is a bit of a surprise. The lot marketing the unknown or undeclared gender is expected to be evaluated like the base – a mixed bag of both male and female fetuses. In this case, the producer cannot count on a certain type of fetus to fit into a particular production style – i.e., a producer seeking males to feed out and sell as direct-to-consumer beef or another producer looking to make a start in the seed stock business and needing high quality registered females to enter. In both cases, having knowledge of the gender would be valuable to the buyer. As discussed earlier, the higher prevalence of female grouped lots indicates that the organizers perceive a value for those lots, and the model agrees, all else held constant.

8.3. Genetic and Performance Information

8.3.1. Tier-II and Registration Status

Registration status and Tier II qualification signify to buyers that the calf that they are purchasing is of higher quality, perhaps even if that quality is of a social nature. Thus, the discussion earlier predicted a premium for both the higher the percentage of the lot that was registered and the higher the percentage of the lot that qualified for Tier II status. In accordance with this, at 100%, the Tier II status yielded a nearly $63 dollar premium per head, and the registration status was close behind with a $54 dollar premium per head at 100%. Pinto et al. (2023) found a premium associated with registered bred heifers, but due to the location of the sale and climate considerations, it was not significant. This signal to producers in the SMS market indicates a desired type of heifer by the buyers and tells them to continue to invest in certain production practices. Often, the interested buyer might be a member of the respective breed association, which would cause them to have a "limited" market for the cattle that conform to the breed, another reason that prices might be driven up. Other reasons might include the ability to market the subsequent beef through a breed program, such as Certified Angus Beef or Certified Hereford Beef.

8.3.2. Fetal Service Sire Breed and EPDs

Facing a high p-value conundrum, the sire breeds did not bring about exciting results – the p-values were greater than 0.6, and the parameter estimates were centered around zero. Thus, it can be said that in the SMS sale, other sire characteristics are more important to the buyers than the sire breed. However, the sire traits of interest in the model are the EPD and their impact on prices. Contrary to the hypotheses made earlier in this paper, the Birthweight EPD resulted in a positive parameter estimate. From this result, it can be speculated that, while birthweight might be partially used to estimate calving difficulty, it is also used to estimate the growth of a calf. The parameter was estimated at nearly $14, and when extrapolated to the extremes of the dataset, the maximal premiums and discounts were negative $40 and positive $38. The yearling weight variable estimates $1.43 per pound of weight, with a minimum of $69 and a maximum of $209. Consignors found a $52 discount at the harshest and a $16 discount at the lightest impact that maternal milk made on their prices. However, surprisingly, while buyers often get premiums at the packer for marbling, marbling received a $16 discount for each whole unit change, which translates into a range of a $2 premium for the sires with the lowest marbling EPDs, and a $24 discount for the sires with the highest marbling EPDs. This did agree with the fat variable, which did return the highest parameter estimate of negative $257. Still, the fat variable only ranges from -0.102 to 0.091, which means that the price impact is only $26 to negative $23, respectively. Finally, the ribeye variable followed expectations and returned a positive coefficient, yielding a negative $4 discount at the dataset minimum and a $56 premium at the maximum.

8.3.3. Fetal Service Sire EPD Accuracies

Related to the EPDs, the setup of the model describes the creation of three dummy variables that group the accuracies of the bulls. There was the high accuracy group, moderate accuracy group, and low accuracy group. It was thought that the high accuracy group might bring the highest premium, with the other two falling in line second and third, respectively. The model shows different things, though – the high accuracy group is not statistically different from the low accuracy group, despite having the ability to provide more reassurance to the buyer. Even more surprising is that the moderate accuracy group discounts the consignors by $45. Smith et al. (2023) did a choice experiment where producers could elect bulls of varying nature, some of which had GE-EPDs (Genomic Enhanced EPDs), simply meaning the bulls presented had higher accuracy EPDs, backed by genetic DNA tissue testing. Their study resulted in the participants not placing a value on bulls with the higher accuracy, indicating to the researchers that while producers find accuracy important, they did not find it valuable enough to assign a dollar value. This appears to be the category this study's model also falls into.

Table 8.3. Heifer Fetal Service Sire EPD and Accuracy Parameter Estimates

Variable	Parameter Estimate
Birth Weight (BW)	13.894 ****
Yearling Weight (YW)	1.435 ****
Maternal Milk (MM)	-1.281 ***
Marbling (MRB)	-16.452 *
Fat (FAT)	-257.413 ***
Ribeye (RE)	36.722 ****
HI_ACC	-0.036
MOD_ACC	-45.571 ****
LOW_ACC	BASE

N = 10488

**** $p < 0.01$, *** $p < 0.05$, ** $p < 0.1$, * $p < 0.2$

8.4. Consignor Information

8.4.1. Consignor Tenure

The final characteristics offered when creating the model were the reputation effects. These consisted of the consignor dummies, tenure dummies, and consignor's average rolling size. The tenure dummies were as interesting as the accuracy variables. The first-year producers did not gain a premium, which was expected, but they also did not experience a discount, as Shapiro

(1983) theorized and developed. This was determined by using the first-year consignors as the base and seeking a statistically different coefficient from the second and multi-year producers. The multi-year producers did not show any statistical difference. The result makes one wonder if long-term producers settle into their production practices after recouping their entry costs and become less innovative than their second-year counterparts. These counterparts recoup a $57 premium from the sale, which is an improvement over their first year, but does not seem to be enough to continue that momentum into years three and beyond. This could be because the cost of that sudden and rapid gain is too costly to sustain over the long term, thus, they drop out of the sale. This is especially true when considering that this variable is meant to capture the effect of the duration of a buyer's exposure to a seller. This exposure might be increased through investments in advertising, networking, and industry events, just some examples of activities that sellers might engage in for the short term (second year). Yet, in the long run, they might prove costly. To test this, a model might be created over a shorter time span so that these investors might have a higher chance of remaining in the model, creating a better probability that a premium is observed for the second-year and multiple-year producers. Still, two categories remain unfinished in the paper.

8.4.2. Consignor Average Size

The next category of interest is the average size of each consignor. These variables (the rolling average and its squared term) return interesting results. Both are statistically significant, indicating a parabolic relationship facing upward with a vertex at its minimum. However, the parabola indicates a discount for the whole of the dataset, regardless of the size of the producer – more severe for some than others. The maximal discount is at 65 head, discounting those producers $88. Thus, as the parabola gets closer to one, the discount decreases, indicating that the smaller producers perhaps provide the market with 1) a desirable, differentiated product and 2) a shortage of the product. The monopolistic theory would support this idea, as well as the larger producers reducing their discounts. Likely, these larger producers would benefit from greater market exposure, as theorized with the tenure variable. However, this exposure comes from the buyers' ability to evaluate more animals in a shorter period of time, observing consistency across contemporary groups rather than across a herd's generations. Theorized earlier was a concern that the market might become saturated with a particular consignor's animals, making the current estimated parabolic shape unrealistic at some point. However, since all parameter estimates are discounts, that makes that concern less necessary to evaluate until consignors begin increasing in size, or the parabolic shape changes.

8.4.3. Individual Consignor Premiums

Finally, after considering all possible measurable considerations, including variables that describe the world situation, the sale that the consignors participate in, the lot that each heifer contributes to, the individual heifer, and the sire that the buyer could potentially be interested in, the last variables to be considered in the full model are the individual consignor effects. The surprising aspect about these effects are that they provide up to $1,353 to the most "reputable" consignor, per head. The average consignor garners $569, with three observations each of the most frequent premiums near the $351, $504, $642, $666, and $785 marks. If rounding to the tens place, other localized statistical modes occur around the $450 and $640 marks, with eight observations each. However, it is possible to see that premiums steadily increase through the consignors. These observations are all consistent with the earlier predictions and, as the next figure will show, collect themselves from a variety of consignors. As a summary, of all 259 consignors, the average consignor only has 40 heifers in the entirety of the dataset. However, there are much larger and smaller producers than that. Overall, it is important to note that each consignor brings a certain varying value to these sales, which is determined by the buyer and influenced by the seller's actions, not measurable within the sale.

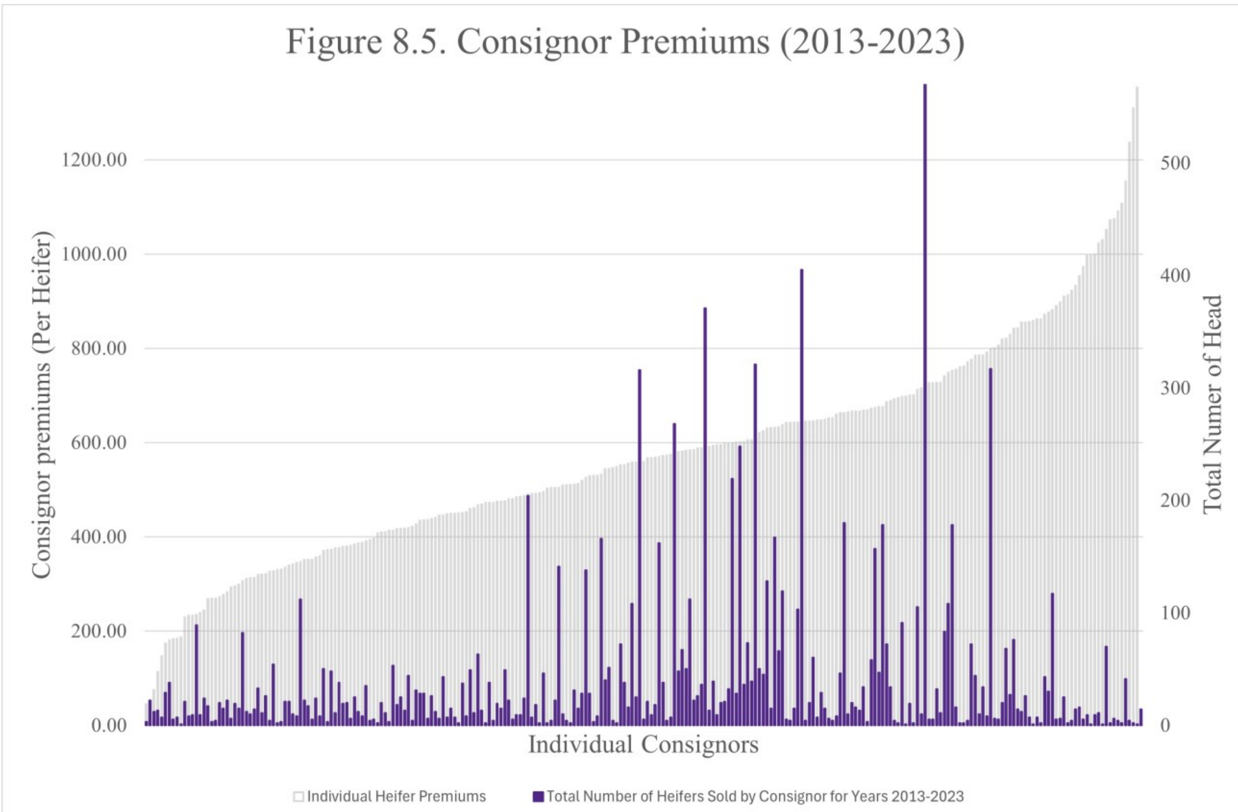


Figure 8.5. Individual Consignor Premiums and their Total Heifer Sales in the SMS Program

Chapter 9 - Implications

The results of this study are directly and indirectly applicable by producers of the SMS sale and the broader cattle sector. Upheld in the results were the norms that breed and color were important, especially as they related to regional production practices. Producers in Missouri are largely cow-calf producers with Angus interests; thus, the Angus and Red Angus breeds and black-hided cattle are valuable, especially when buyers can secure two generations of females with one purchase through a lot that has been ultra sounded and declared as carrying female fetuses. However, those preferences could vary with climate and production differences. Furthermore, high-quality calves contained value, including calves that were AI sired and demonstrated growth traits, as they relate to frame size, while reducing maintenance costs through the reduction of maternal milk EPD. However, the most significant thing to recognize for the buyers was the reputation effects. While most might pick up on cues within the market, it is crucial to go beyond what is generally recognized and encourage producers to engage in several aspects of their production strategy. The fostering of a high-value sale that encourages competition among bidders while reducing the cost of the transaction, both physical and emotional, and dispersing the correct information to the bidders without overwhelming them unnecessarily will create a positive reputation for the particular sale. Furthermore, increasing their relative "good" in the market by specializing in the right things (building their reputation based on monopolistic competition norms), participating in the community in a way seen as valuable, and providing overall associative value to the buyer is recommended. Finally, in accordance with Shapiro (1983), Pinto et al. (2023), and Ajzen, the continuance of these things year after year will only continue to bring a premium to the consignor and the sale in question, thereby increasing the farm or ranch's bottom line.

Chapter 10 - Conclusion

To conclude, this paper has modeled price as a dependent variable on considerations of heifer, season, breed, EPD, and reputation considerations and effects. Reputation is not an aspect that is commonly measurable in data, due to a lack of collection, or the broadness of the market. However, anonymous consignor effects could be added to the model thanks to the Missouri Show-Me-Select Bred Heifer sale. The model confirmed some aspects of previous research and added a sense of support to Shapiro and Ajzen's theories on behavior. The significance of this research can be communicated to producers in Missouri and translated to producers in other areas so that margins might be ever-increasing, increasing confidence and innovation in the market.

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Appendix A - Full Model Results

Appendix Table A.1. Full Model Results: Auction and Lot Characteristics

Year and Season

Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
2013		1221			0.116	164.416	0.0001
2014		1041			0.099	1036.735	0.0001
2015		1046			0.100	745.960	0.0001
2016		938			0.089	192.153	0.0001
2017		1185			0.113	82.079	0.0001
2018		1101			0.105	-29.373	0.006
2019	BASE	1021			0.097	BASE	
2020		982			0.094	165.103	0.0001
2021		1319			0.126	130.228	0.0001
2022		542			0.052	191.167	0.0001
2023		92			0.009	312.582	0.0001
Fall Sale	(1=True)	6223			0.593	7.849	0.2376

Location

Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Sale Barn #2		1222			0.117	215.472	0.0001
Sale Barn #3		1432			0.137	164.829	0.0001
Sale Barn #4		268			0.026	298.657	0.0001
Sale Barn #5		3043			0.290	260.044	0.0001
Sale Barn #6		1816			0.173	172.141	0.0001
Sale Barn #7	BASE	737			0.070	BASE	
Sale Barn #8	DROPPED	11			0.001	DROP	
Sale Barn #9		1651			0.157	137.884	0.0001
Sale Barn #10		308			0.029	273.520	0.0001

Lot Characteristics

Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Floored?	(1=True)	4281			0.408	-64.959	0.0001
Lot - First 1/3		3541			0.338	-0.439	0.9451
Lot - Second 1/3		3790			0.361	23.746	0.0001
Lot - Third 1/3		3157			0.301	BASE	
Number of Sires			1	4	1.135	-17.120	0.0505
Calving Window	(# Days)		0	96	7.314	-0.391	0.1146

Head

Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Head	Dummies Used		1	12	3.842		
HBin1	<=2	2685			0.256	BASE	
HBin3	3-4	4609			0.439	30.752	0.0001
HBin5	5-6	2338			0.223	69.296	0.0001
HBin7	7-8	469			0.045	50.125	0.0009
HBin9	9-12	387			0.037	48.955	0.0136

Appendix Table A.2. Full Model Results: Heifer Characteristics

Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Weight							
Lot_Avg_Weight	Dummies Used		800	1375	1087.860		
WBin1	<=850 lbs	52			0.005	BASE	
WBin2	851-900	258			0.025	10.100	0.7774
WBin3	901-950	644			0.061	66.628	0.0503
WBin4	951-1000	1445			0.138	116.556	0.0005
WBin5	1001-1050	1677			0.160	137.077	0.0001
WBin6	1051-1100	1831			0.175	193.320	0.0001
WBin7	1101-1150	1771			0.169	218.358	0.0001
WBin8	1151-1200	1205			0.115	251.486	0.0001
WBin9	1201-1251	878			0.084	314.407	0.0001
WBin10	1251-1300	423			0.040	355.243	0.0001
WBin11	1301-1350	244			0.023	363.652	0.0001
WBin12	1351+	60			0.006	314.729	0.0001

Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Heifer Breed and Color							
Angus Percent	1 if Pedigree has Angus	8762			0.835		
Unknown Percent	1 if Pedigree has Unknown	5644			0.538		
Red Angus Percent	1 if Pedigree has Red Angus	796			0.076		
Charolais Percent	1 if Pedigree has Charolais	116			0.011		
Gelbvieh Percent	1 if Pedigree has Gelbvieh	281			0.027		
Hereford Percent	1 if Pedigree has Hereford	1259			0.120		
Simmental Percent	1 if Pedigree has Simmental	1204			0.115		
Tarentaise percent	1 if Pedigree has Tarentaise	174			0.017		
Limousin Percent	1 if Pedigree has Limousin	6			0.001		
Black Polled Hereford Percent	1 if Pedigree has Black Polled Hereford	4			0.000		
Beefmaster Percent	1 if Pedigree has Beefmaster	19			0.002		
Saler Percent	1 if Pedigree has Saler	43			0.004		
Angus	Purebred/BASE	2224			0.212	BASE	
Red Angus	Purebred	397			0.038	68.984	0.0276
Small Purebred	Purebred	151			0.014	-87.090	0.0008
Angus X Simmental X Unknown	Crossbreds	106			0.010	-38.108	0.2025
Angus X Gelbvieh	Crossbreds/Balancers	110			0.010	-113.441	0.0001
Angus X Hereford	Crossbreds	1068			0.102	-41.660	0.004
Angus X Simmental	Crossbreds/SimAngus	596			0.057	-13.182	0.4604
Angus X Tarentaise	Crossbreds	136			0.013	50.947	0.0642
Angus X Unknown	Crossbreds	4412			0.421	3.116	0.7437
Smaller Angus Crossbreds	Crossbreds	110			0.010	-90.764	0.0009
Red Angus X Unknown	Crossbreds	312			0.030	-42.197	0.0696
Simmental X Unknown	Crossbreds	414			0.039	88.409	0.002
Smaller Misc. Crosses	Crossbreds	452			0.043	-27.527	0.1488
Black	Color Categories	7071			0.674	BASE	
Red	Color Categories	851			0.081	25.099	0.1624
Red with White Face	Color Categories	236			0.023	33.556	0.0903
Black with Mott Face	Color Categories	589			0.056	68.240	0.0001
Black with White Face	Color Categories	1589			0.152	91.132	0.0001
Other Colors	Color Categories	148			0.014	-88.692	0.0001

Fetal Characteristics							
Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
LM	1 if Lot Contains Any Male Fetuses	1537			0.147		
LF	1 if Lot Contains Any Female Fetuses	2849			0.272		
LU	1 if Lot Contains Any Unknown Fetuses	7337			0.700		
EXLF	1 if Lot Solely Contains Females	967			0.092	38.663	0.0001
EXLU	1 if Lot Solely Contains Unknowns	6100			0.582	-21.953	0.0125
Artificial Insemination	1 if Lot was Exclusively AI	6282			0.599	84.063	0.0001
Natural Service	1 if Lot was Exclusively NS	3578			0.341	BASE	
Mixed Service Type	1 if Lot was Exclusively Mixed	628			0.060	27.431	0.0562

Appendix Table A.3. Full Model Results: Genetic and Performance Information

Registration and Tier-II							
Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
% Tier II	% of Lot that qualifies for Tier-II	1093	0	1	0.104	63.470	0.0001
% Registered	% of Lot that is Registered	654	0	1	0.062	54.833	0.0002
Sire Breeds							
Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Angus Sire	BASE	9706			0.925	BASE	
Red Angus Sire		781			0.074	-8.201	0.6849
Other Sire Breed		132			0.013	-12.920	0.6668
EPDs and Accuracies							
Variable	Description	N	Min	Max	Mean	Parameter Estimate	P-Value
Birth Weight (BW)			-2.9	2.8	-0.146	13.894	0.0001
Birth Weight Accuracy			0.05	0.99	0.731		
Yearling Weight (YW)			48.1	146	101.740	1.435	0.0001
Yearling Weight Accuracy			0.05	0.98	0.653		
Maternal Milk (MM)			13	41	27.822	-1.281	0.0152
Maternal Milk Accuracy			0.05	0.97	0.493		
Marbling (MRB)			-0.13	1.44	0.672	-16.452	0.1078
Marbling Accuracy			0.05	0.86	0.486		
Fat (FAT)			-0.102	0.091	0.003	-257.413	0.0128
Fat Accuracy			0.024	0.86	0.465		
Ribeye (RE)			-0.12	1.54	0.638	36.722	0.0024
Ribeye Accuracy			0.05	0.86	0.470		
HI_ACC		777			0.074	-0.036	0.9978
MOD_ACC		2725			0.260	-45.571	0.0001
LOW_ACC	BASE	6986			0.666	BASE	

Appendix Table A.4. Full Model Results: Consignor Information

Reputation Effects							
Variable	**Description**	**N**	**Min**	**Max**	**Mean**	**Parameter Estimate**	**P-Value**
First Year Consignor	BASE	1882			0.179	BASE	
Second Year Consignor		1297			0.124	57.238	0.0001
Multiple Year Consignor		7309			0.697	-4.082	0.7495
Rolling Average Head			1	120	38.478	-2.738	0.0001
Rolling Average Head Squared			1	14400	2288.220	0.021	0.0002

Appendix B - 2023 SMS Requirements

Missouri Show-Me-Select® Replacement Heifers, Inc.

Program Objectives

- Improved heifer development through a Total Quality Management strategy
- Increased marketing opportunities for and added value for Missouri-raised heifers
- Creation of reliable sources of quality replacement heifers based on management, reproduction and genetics

2023 Requirements for Show-Me-Select Program & Sales

PROGRAM ELIGIBILITY REQUIREMENTS

Enrollment: To enroll heifers in the Show-Me-Select Replacement Heifer Program, contact the regional extension livestock coordinator that serves your region. Enrollment deadlines are February 1st for the spring breeding season and September 1st for the fall breeding season.

Ownership**:** Heifers enrolled in the program must be owned by Missouri residents. Heifers that are purchased rather than home-raised must be owned a minimum of 60 days prior to breeding. The name and address of the original breeder and the approximate birth dates of the heifers must still be reported for purchased heifers.

Minimum vaccination requirements: Follow label directions for all products used. A comprehensive herd health vaccination program starting at weaning age or before should be administered under the advice and guidance of a veterinarian in the context of a valid veterinary-client-patient relationship. The following vaccination program is required at a minimum:

Calfhood vaccination against Brucellosis (Bangs) is OPTIONAL. Official calfhood vaccination (OCV) tag number will be recorded as a secondary, official ID. Heifers not receiving an official ID at OCV, must receive an official 840 ID. Official 840 ID tags are available from accredited veterinarians through the State Veterinarian's office.

Weaning

Vaccination against IBR, BVD, PI 3, BRSV, leptospirosis (5-way), vibriosis (optional) and 8-way clostridia. Heifers must be 5 months of age or older at time of vaccinations and receive booster vaccination according to label directions.

Prebreeding

Between 30 and 60 days prior to breeding, booster vaccinations must be given against IBR, BVD, leptospirosis (5-way) and vibriosis (optional). Modified live vaccines for IBR and BVD are recommended. If killed viral vaccine products are used, two boosters are strongly recommended.

Pregnancy check

A booster vaccination against leptospirosis (5-way) and clostridia (8-way) is required at pregnancy examination.

Prebreeding evaluation: A prebreeding reproductive evaluation is required for all heifers and must be performed 30 to 60 days prior to breeding. Individual animal identification, pelvic measurement and reproductive tract score is required at this time. Heifers must have a minimum pelvic area of 150 cm^2. Heifers with a pelvic area smaller than 150 cm^2 may be re-measured at the initial pregnancy exam, performed within 90 days from the start of the breeding season. At that time, heifers that are re-measured must have a minimum pelvic area of 180 cm^2 to qualify.

Breeding: Producers using artificial insemination must report breeding dates as well as method of estrus synchronization (if applicable). Natural service bull exposure dates are also reported. To ensure accuracy when distinguishing between AI versus natural service pregnancies, heifers that are bred artificially may not be exposed for natural service for a minimum of:

- 14 days following a non-synchronized, spontaneous estrus.
- 14 days after the administration of PG at the beginning of a synchronized period, when AI is performed on the basis of observed heat.
- 14 days after fixed-time AI when heifers are inseminated by appointment, following administration of an estrus synchronization protocol.

Pregnancy examination: An initial pregnancy examination must be performed within 90 days from the start of the breeding season. Individual animal identification, pregnancy status and fetal age (in days) are required. Reporting of fetal sex is optional. Any heifer that fails to become pregnant, or loses a pregnancy following the original breeding season, is no longer eligible for the program.

GENETIC REQUIREMENTS

Sire requirements: Eligible sires must have known ID, be registered by their respective national breed registry, and have complete EPD information. Sires will be evaluated for qualification in the program based on the EPD provided by their respective breed registry and not on EPD produced by progeny registration in any other breed or hybrid registry. **All sires used in conjunction with artificial insemination must have a minimum accuracy value listed in Table 1 on a BIF scale of zero to one for CED EPD's.** Sires must meet calving ease EPD requirements listed in Table 2. All Natural Service sires must have GE-EPDs.

Table 1. Active Sire Percentile Rank and Accuracy Requirements

Breed Group	Percentile/EPD Requirement	A.I. Accuracy Requirement
Angus	CED ≥ 7.0	0.60
International Genetic Solutions	CED ≥ 14.0	0.60
Hereford	Upper 25%	0.50
American	Upper 20%	0.60
British	Upper 25%	0.60
Continental	Upper 15%	0.60
Hybrid	Upper 15%	0.60

- **All sires must be approved by a Regional Extension Livestock Specialist prior to the planned breeding season.**
- Bulls or semen purchased on or after February 1 of the current year must meet the requirements in Tables 1 and 2. Bulls or semen purchased before February 1 must meet the previous year's requirements.
- Two sire classifications will be recognized in SMS Heifer Sales:
  - Artificial insemination sires
  - Natural service sires

Table 2. Service sire EPD requirements for calving ease.
** Check online or with a regional extension livestock specialist for current requirements. Significant changes may occur as genetic evaluations are updated.*
For a complete list see the SMS website: https://extension2.missouri.edu/programs/show-me-select-replacement-heifer-program

Service Sire Breed	Minimum Calving Ease EPD
Angus	7.0
Charolais	10.9
Gelbvieh & Balancer	14.0
Limousin & LimFlex	14.0
Hereford	6.5
Red Angus	14.0
Simmental & SimAngus	14.0

Tier Two Classification: Heifers will be eligible to qualify for Tier Two in the Show-Me-Select Replacement Heifer Program based on the following minimum accuracies of the heifer's sire at the time of sale for the respective traits listed below.

Trait	Accuracy
Calving ease (direct)	.65
Calving ease (maternal)	.30
Weaning weight	.75
Carcass weight	.20
Marbling	.20

Show-Me-Plus Classification: Heifers tested with a heifer genomic prediction panel approved by University of Missouri Extension will be given the designation of a Show-Me-Plus Heifer. These include breed association GE-EPD, GeneMax Advantage, Igenity Gelbvieh, Red Navigator, Igenity Beef, and Method Choice tests. Heifer DNA samples must be submitted and paid for two months prior to sale date. Genomic panel results must be sent to Regional Coordinator and State Beef Geneticist prior to tagging.

SALE ELIGIBILITY REQUIREMENTS

Parasite control: All heifers must be treated for internal and external parasites within 30 days of sale. Products for internal parasite control must have a label claim for immature stages of the parasite life cycle.

Surgery: Horns and scurs (over 2 inches in length) must be removed and heifers must be completely healed by sale day.

Implants & MGA: It is recommended that heifers not be implanted. If heifers are implanted, it is required that only FDA approved products for replacement heifers be used and administered according to label guidelines. Use of MGA to synchronize estrus is permitted (e.g. for a period of 14 days), but longer term feeding of MGA is prohibited.

Blemishes: Heifers with active cases of Pinkeye or scars resulting from Pinkeye are not eligible for sale. In addition, heifers with rat-tails, bob-tails, frozen ears or other physical blemishes or deformities will not be eligible for sale. The regional sale committees reserve the right to refuse any heifer that does not meet the criteria for blemishes or any heifer deemed to have an undesirable disposition on sale day.

BVD-PI*:* Heifers offered for sale must be tested and guaranteed negative for BVD-PI.

Inspection of heifers: Heifers will be evaluated prior to sale by a certified USDA grader for frame, muscle, foot and leg conformation, body condition, blemishes and disposition. All heifers must be a frame score of medium or large and a muscle score of No. 1 or No. 2. Heifers should have a hoof claw shape score of 3 to 7 and a hoof set angle of 3 to 7. Leg conformation that results in uncoordinated, slow movement or a stiff, restricted range of motion is not acceptable. Heifers that are severely post-legged, splay-footed, sickle-hocked, knock-kneed, or bucked-kneed will not be eligible for consignment in a sanctioned Show-Me-Select sale. Bred heifers on the day of sale must weigh a minimum of 800 pounds and receive a body condition score within a range of 5 through 8 using a 9 point scale. For more information, refer to MU Extension publication *g2093: Screening Criteria for Show-Me-Select Replacement Heifers.*

Pregnancy: A confirmatory pregnancy examination must be performed within 30 days prior to sale. The consignor guarantees bred heifers to be safe in calf at the time of sale. If a heifer is proven by veterinary exam within 30 days after sale not to have been pregnant, the consignor will replace the heifer or make a financial settlement with the buyer. Spring calving heifers must be bred to calve prior to May 1 and fall calving heifers must be bred to calve prior to December 1. Heifers in individual sale lots are grouped to calve within approximately 45 days of each other based on expected calving dates.

CERTIFICATION

An official Show-Me-Select program ear tag is required for sale of heifers as Show-Me-Select heifers. Only heifers that are officially enrolled in the Show-Me-Select Replacement Heifer Program and meet all requirements listed above are eligible receive a certified Show-Me-Select Replacement Heifer ear tag. Misrepresentation, false advertisement or use of the Missouri Show-Me-Select Replacement Heifer trademark, for heifers that do not meet the aforementioned requirements is subject to penalty.

FEE STRUCTURE

An annual membership fee of $25 will be assessed from each producer. An enrollment fee of $2 per heifer will be assessed at prebreeding on heifers entered into the program. All forms for prebreeding must be submitted prior to pregnancy exam. A certification tag fee of $20 per heifer will be assessed at the time Show-Me-Select qualified heifers receive their official tag. An official Show-Me-Select ear tag is required for heifers to sell through a sanctioned sale or private treaty but is optional for heifers retained on-farm.

Show-Me-Select Replacement Heifers, Inc. a non-profit organization in cooperation with
University of Missouri Extension - College of Agriculture, Food and Natural Resources - Division of Animal Sciences - Division of Applied Social Sciences
MU College of Veterinary Medicine - Missouri Cattlemen's Association - Missouri Department of Agriculture