PRICE DETERMINANTS OF BRED COWS SOLD IN OKLAHOMA AUCTIONS

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Abstract:

Bred cows are inputs into beef production. Often producers are directly marketing cows as beef replacement animals. Alternatively, some producers are capitalizing on alternative marketing opportunities and are selling cull cows as bred cows. These two distinct marketing strategies create two unique subclasses of bred cows sold in Oklahoma auctions, which results in quality and value variation. Product differentiation and price variability is frequently modeled using the hedonic approach. Hedonic models have previously been applied to various classes of cattle including cull cows and cow-calf pairs. However, no previous research has determined the value of bred cow characteristics. There is a need for research that explicitly estimates the value of bred cow characteristics in a hedonic framework. The objective of this research is to determine the market value of various bred cow traits, including age, weight, months bred, cow quality, and hide color. In addition to physical characteristics, this research accounts for market factors and price seasonality. Results presented in this research will benefit both bred cow buyers and sellers. Sellers will be more informed on which traits buyers find desirable. Furthermore, bred cow buyers will be able to use these results to further refine their current cow procurement practices.

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CHAPTER I

INTRODUCTION

Bred cows are inputs into beef production. They are a unique asset by reason of the future production output (i.e. the unborn calf) they are bundled with at the time of sale. Often producers are directly marketing bred cows as beef replacement animals. Alternatively, many producers are capitalizing on alternative marketing opportunities and are selling their older cull cows as bred cows. Research has determined that cull cow retention and marketing as bred has the potential to be an economically viable opportunity for cow-calf producers (Amadou, 2012). Past research has also identified several other replacement cow marketing and procurement strategies (Trapp, 1986; Lawrence, 2001). However, in auctions across the state of Oklahoma, quality variation in the bred cows sold is noticeable. This difference in quality is due, in part, to the two distinct subclasses of bred cows sold in Oklahoma Auctions.

Bred cow price differentials are a consequence of many factors, including a cow's characteristics. In addition to a cow's characteristics, previous research has found that market factors play a significant role in determining prices (Schroeder et al., 1988). Market factors would include sale location, time of sale, and expectations about both input and output prices. The variability in bred cow prices, a result of both characteristics and market factors, suggests that producers are considering production decisions and are purchasing bred cows based on the perceived value of specific traits. While there are numerous studies on cow marketing strategies, all disregard the problem of differences in bred cow attributes and the resulting variability in prices. No previous research has considered the contribution bred cow traits have on their total value. A standard methodology to quantify product differentiation and price variability is the hedonic approach.

Numerous previous studies have implemented the hedonic approach to examine the relationship between the characteristics of agricultural goods and their corresponding prices. Specifically, a considerable amount of research effort has been devoted towards identifying factors impacting feeder cattle price differentials (e.g., Buccola, 1980; Marsh, 1985; Faminow and Gum, 1986; Baily, Peterson, and Brorsen, 1991; Schroeder et al., 1988; Coatney et al., 1996; Avent, Ward, and Lalman, 2004; Williams et al., 2012; Zimmerman et al., 2012). Initial studies focused on physical characteristics. As feeder cattle marketing research was refined further, researchers began to focus on marketing factors and value-added programs. Results from these academic studies provide producers with valuable information on the linkage between feeder cattle characteristics and their accompanying premiums and discounts.

In addition to feeder cattle hedonic analyses, research has also focused in the area of breeding stock and cull cows. Specifically, research has focused on the determinants of value for beef bulls, cull cows, and cow-calf pairs. Mintert et al. (1990) determined the impact of a number of cow characteristics. Later, Parcell, Schroeder, Hiner (1995) estimated determinants for Kansas cow-calf pairs. One problem remains unsolved in the livestock marketing research as it relates to livestock price determinants, which is the factors impacting bred cow prices. Bred cows are the only class of cattle that has not been examined in a hedonic framework.

This study addresses the question of how do physical characteristics, temporal, and market factors influence the price of bred cows sold in auctions across the state of Oklahoma. Research on bred cow price determinants will provide sellers with information on which traits buyers find desirable along with the value of those attributes. Furthermore, buyers will be able to make more efficient production decisions, regarding replacement cow procurement.

1.1 Herd Management and the Cow Cycle

Cowherd management requires the consideration of many different factors, as it relates to culling and replacing animals. Assessing the value of individual bred cows is a subsequent decision that must follow the evaluation of different herd management strategies. Producers must be cognizant of various production and market factors, which may set the precedence for the replacement and culling decision.

Trapp (1986) summarizes the traditional framework of asset replacement theory, which states that the cull decision should be made simultaneously with an addition. Every time a producer sells a cow the traditional theory assumes that this decision is matched with a replacement. Trapp (1986) argues that this approach implicitly assumes constant firm size. The decision to cull and replace cows is further complicated due to the cyclical nature of prices. The traditional cow cycle is similar to most business cycles. There is a period of expansion followed by a period of liquidation. This study argues that asset replacement theory should be revised to account for varying herd size and prices. This paper addresses the question of which scenarios would require varying herd sizes and what criteria should be used. Trapp (1986) constructs an investment criterion for replacement cows that allows herd size and prices to vary. Trapp (1986) applies a net present value criterion to his analysis of optimal culling and replacement rates.

Trapp (1986) determines optimal culling rates, replacement rates, and herd size patterns. The decision to cull and replace stands alone. The only linkage between decisions is the impact on per unit production cost and herd size (Trapp, 1986). The strategy developed in this study anticipates a cyclical peak and builds a young cowherd accordingly. The rate at which the herd is culled and replaced is larger during the up phase relative to the down phase of the price cycle. This higher rate is a result of the producers anticipation of a peak. During the down phase of the cycle, the producer culls the remaining older cows and adds fewer new animals to the herd. Trapp (1986) demonstrates that a more adjustable strategy is optimal when considering cycle prices and non-constant firm size.

Lawrence (2001) develops four herd replacement retention strategies that use the knowledge of the cattle cycle. Two of the strategies used, steady size and cash flow, are among the most common strategies used by producers. The dollar cost averaging strategy (DCA) requires producers to retain the same dollar amount of heifers each year. While the number of heifers changes, the dollar value is constant. The fourth strategy used is the rolling average value. The rolling average value strategy (RAV) requires producers to retain the ten-year average value of heifers each fall. Lawrence (2001) uses a 30-year period to determine the effectiveness of the four heifer retention strategies. During the 30-year period, the steady size and cash flow approach are outperformed by the DCA and RAV strategies. Lawrence (2001) uses the change in net worth for economic comparison of the four strategies. Both the DCA and RAV have substantial increases in accumulated cash and herd net worth. The results determine that higher average annual revenue and higher returns over economic and capital costs are achieved using the DCA and RAV strategy (Lawrence, 2001). Results presented in this study offer four alternative investment strategies that allows producers to improve upon their herd management decisions.

In addition to the various investment strategies made available to producers through the findings of past research, studies have also examined the profitability of various cull cow retention and feeding strategies. Amadou et al. (2014) looked at the influence of body condition score (BCS) on returns from the delayed marketing of cull cows. Specifically, two delayed marketing and feeding programs are examined; the two feeding programs studied are a native pasture and a dry lot feeding program. Cull cow prices are subject to seasonal variation. Most often cull cows are sold at a seasonal low point. By retaining cull cows and selling at a later date producers may be able to receive a higher price due to the seasonal nature of cow prices. Furthermore, the feeding programs examined may allow producers to further improve upon returns which result from enhanced quality of the cows marketed. In their analysis, Amadou et al. (2014) determine that heavy cull cows should be sold immediately. Cows with a lower BCS benefit most from the two proposed feeding programs. The greatest net returns are achieved from the native pasture retention system. Results presented by Amadou et al. (2014) provide producers with a method for improving the value of their cull cows. Later, Amadou (2012) proposed that the value of cull cows can be improved further by marketing culls as bred cows.

Research has identified optimal strategies for cyclical prices. Moreover, research has also investigated the numerous culling and replacement strategies available to producers. This past research promotes the need for research with an objective of determining the value of brood stock traits, specifically bred cow characteristics. If producers can be provided with information on the value of individual bred cows, production decisions that involve optimal culling and replacement strategies could be refined further.

1.2 Background

As cattle prices rise, producers begin searching for ways to increase revenue; this creates a need for breeding stock as producers begin herd expansion. The choice between buying and raising replacement cows is a tough decision to make for many cow-calf producers. Adding to that decision is the choice between heifers and cows. The decision is made with many tradeoffs. Often the market encourages a quick response, which makes the purchase of bred cows a viable option. Fewer resources have to be allocated towards buying bred cows as compared to heifer development and sourcing sire genetics.

For producers who are still unable to expand their herds, bred cows can be an alternative marketing strategy for their cows. By marketing cows as bred, instead of open, producers have the potential to gain additional revenue. Those in possession of quality heifers and cows can consider selling them as bred. Producers looking to increase the salvage value of their cull cows can consider retention and delayed marketing as bred. In the state of Oklahoma, the average bred cow is valued 8% per head higher than the average cull cow (Peel and Doye, 2008).

To make more definite production decisions and capitalize on various cow marketing opportunities, producers need to be informed about the value placed on individual traits. How much do bred cow characteristics impact the price of bred cows? This research will determine the value of bred cow traits. This study uses fifteen years of USDA AMS reports for seven Oklahoma auctions to assess the market value of various bred cow characteristics.

1.3 Objectives

The primary objective of this research is to determine factors that influence bred cow price variability. Specific objectives are to:

1. determine the implicit value of bred cow traits, including but not limited to age, weight, months bred, quality, and hide color,
2. determine how marketing factors impact bred cow prices, and
3. provide producers with information that will help improve replacement cow procurement and marketing strategies.

CHAPTER II

REVIEW OF LITERATURE

Hedonic models have become a standard methodology for determining the value of product characteristics. The development and application of hedonic models is well documented in the academic literature. The objective of this chapter is to review relevant work that uses hedonic pricing models to examine the value of livestock characteristics.

This review will begin by examining historical studies that developed the hedonic approach and the associated economic theory. The review will go into further detail by reviewing the application of hedonic models in livestock related studies, specifically feeder cattle, cow-calf pairs, cows, and bulls. This chapter will conclude by drawing conclusions from past studies and their implications for the development of a bred cow hedonic pricing model.

2.1 Historical Studies

Fredrick Waugh is credited with being one of the earliest analyses on the valuation of characteristics influencing agricultural product prices (Taylor, 2003). In Waugh's (1928) analysis, the relationship between vegetable prices and their associated characteristics are examined and findings with significant implications were discussed. Price variation among similar products was not a novel idea at the time; however, few studies had introduced this approach in an agricultural economics setting. Later studies have used Waugh's (1928) early work for comparison (Ladd and Martin, 1976; Ladd and Suvannunt, 1976). Most reviews of hedonic literature credit Court (1939) and Haas (1922) with being some of the earliest studies in the area of hedonic prices

(Chin and Chau, 2003). Among the studies that followed, Lancaster (1966) and Rosen (1974) are widely cited as being significant contributors to the topic of hedonic prices. In the livestock literature, most studies have employed an approach similar to the framework originally developed by Ladd and Martin (1976).

In 1966, Lancaster's seminal paper titled "A New approach to consumer theory" looked at the impact product characteristics have on consumer utility. The traditional approach states that utility is derived from the goods being consumed. Lancaster (1966) argues that utility is derived not from the goods being consumed; instead, utility is derived from the characteristics that the good possesses. In Lancaster's (1966) theoretical model it is assumed that goods are consumed individually or as a group, which is the input for the consumption activity, and the resulting output is the bundle of utility bearing characteristics. Furthermore, consumer preference indirectly ranks goods through the direct ranking of their characteristics. For example, a meal possesses both nutritional and aesthetic characteristics. Lancaster (1966) argues that different meals will possesses different proportions of nutritional and aesthetic properties. Lancaster (1966) summarizes his approach with three main points:

1. the characteristics a good possesses, rather than the good itself, offer utility to the consumer of the good,
2. a good possesses many characteristics, which are shared by multiple goods, and
3. a combination of goods possess a set of characteristics that do not pertain to each good separately (Lancaster, 1966).

Previous studies had considered an approach similar to Lancaster's (1966) proposed approach, but as he points out, these past studies only implemented them as an ad hoc solution to a specific problem. He argues that his hedonic utility will replace the traditional approach all together, due its ability to more accurately reflect consumer purchasing behavior. The key innovation of this approach is the insight that goods possess a bundle of characteristics in fixed proportions; these characteristics, not the goods themselves, are what consumers hold preference on (Lancaster, 1966). Lancaster (1966) states that his approach is capable of illustrating many of the common-sense behaviors exhibited by the consumer, which have been in most cases ignored and left out of the traditional approach.

Lancaster's (1966) new approach received some criticism in the years that followed. Researchers argued that his results could be invalidated by relaxing the assumptions of his model. Ladd and Zober (1977) refine Lancaster's (1966) model by excluding some of his most criticized assumptions. In doing so, Ladd and Zober (1977) hope that useful conclusions could still be drawn from a more relaxed version of Lancaster's (1966) original model. The three most widely criticized assumptions of Lancaster's (1966) model are: every characteristic has nonnegative marginal utility, utility is independent of the distribution of characteristics among products, and linear consumption technology (Ladd and Zober, 1977). Ladd and Zober (1977) conclude that the application of their revised Lancaster (1966) model yields important implications that relate consumer purchasing behavior to the quality of the products being purchased. First, the total price of product and be deconstructed into amounts paid for each characteristic. Second, consumer preference is dependent upon the quantity of the desirable characteristics (Ladd and Zober, 1977).

The hedonic hypothesis states that a good is valued for its utility-bearing characteristics (Rosen, 1974). Rosen (1974) adds to that hedonic hypothesis by proposing that the price of a good is the summation of the goods hedonic prices. Hedonic prices are defined as the implicit value of the characteristics of a good. The set of implicit prices is estimated by regressing the product price on its characteristics. The set of estimated implicit prices is what guides consumption and production behavior. Before Rosen (1974), no previous research had examined the implications of the hedonic hypothesis in a market equilibrium setting. Rosen (1974) inserts a market between producers and consumers. Consumers have preferences for product characteristics. Producers provided consumers with desirable products by providing them with a good that is a collection of desired characteristics. As summarized in Chin and Chau (2003), Rosen's (1974) paper has two distinct sections. In the first section, hedonic prices are estimated, and the reservation price for an additional unit of a characteristic is derived. The second section of Rosen's (1974) paper presents an empirical method for deriving market structure from the set of estimated hedonic prices. Consumption occurs at the intersection of the inverse demand curves and the marginal cost curve of all buyers (Rosen, 1974).

Ladd and Suvannunt (1976) develop a theoretical model of consumer goods characteristics. From this model two themes are discussed:

1. the price of a product is equal to the sum of the marginal value of the products characteristics, and
2. consumer demand functions are affected by the characteristics of the goods (Ladd and Suvannunt, 1976).

In their theoretical model, the amount of utility consumer experiences from consumption of goods is dependent upon the amount of product characteristics consumed through their purchase of goods. From this arises the consumer's utility function, where utility is a function of the quantity of the goods purchased and the quantities of each characteristic provided by one unit of each good. The consumer's selection of goods yields the total product characteristic combination that maximizes utility (Ladd and Suvannunt, 1976). Ladd and Suvannunt (1976) differentiate utility with respect to the total amount of a specific characteristic provided, which yields the marginal utility of that characteristic. Through utility maximization and differentiation, Ladd and Suvannunt (1976) form a model supporting theme 1. Their approach excludes Lancaster's (1966) linear consumption technology and nonnegative marginal utility assumptions. Ladd and Suvannunt (1976) state that the assumption of utility depending upon the total quantity of the characteristics does apply; furthermore, the two themes previously described can still be derived through the modification of the Consumer Goods Characteristic Model (CGCM).

Ladd and Suvannunt (1976) test theme one by regressing price on the nutritional composition of thirty-one food items. Through regression Ladd and Suvannunt (1976) are able to find results consistent with theme one. Regression coefficients represent implicit prices for each nutritional component. Negative coefficients represent a reduction in the price of a product due to the quantity of the undesirable characteristics tied to the good. Results from a Lancaster model, the CGCM, and the less restrictive CGCM model support claims from theme one. Their results support theme two, which can be used in the decisions necessary to provide consumers with a more desirable product. The CGCM model will allow for a better valuation of product quality. Ladd and Suvannunt (1976) note some of the practical applications of the model developed. The model can be used as a tool for grading schemes of consumer goods.

Ladd and Suvannunt (1976) were the first to develop a model of consumer goods characteristics from which two themes are developed and tested. Ladd and Martin (1976) develop a similar model relating to production input characteristics (ICM), which draws from the two themes similar to those presented in Ladd and Suvannunt (1976). The first theme is a production inputs price is equal to the sum of the implicit characteristic prices. The second theme is demand for an input is influenced by the characteristics of the input. Using a modified form of neoclassical firm theory, the two themes are tested and statistical results are compared with those from previous research. Using a firm's profit function, Ladd and Martin (1976) differentiate profit with respect to the quantity of an input used in production. Ladd and Martin (1976) then solve for the price paid for an input used in production, which yields an equation that supports their first theme.

Ladd and Martin (1976) state that the contribution of a production input is derived from the useful characteristics that it possesses. Likewise, total production depends upon the total input characteristics used in production (Ladd and Martin, 1976). To empirically test their hypothesis, the price of a production input is regressed on the characteristics of that input. F-tests are used to determine if the results are consistent with theme one, implying a linear relationship between input prices and marginal implicit characteristic prices. Results from past research, including Waugh (1928), are consistent with theme one.

Ladd and Martin (1976) apply dual linear programming in a corn blending problem. The objective is to determine the optimal use of four carloads of corn based on the characteristics of the corn shipped. Shadow prices from the models represent implicit prices of corn characteristics. The shadow prices are interpreted as the change in net revenue from a one unit change in the characteristic. Results from the linear programming models illustrate how to quantify implicit corn characteristic prices. Ladd and Martin (1976) argue that given the current supply of corn, the price of corn should be equal to the sum of the characteristics' implicit prices. Statistical results from past research and linear programming results were consistent with themes one and two. Ladd and Martin's (1976) ICM model proved to be well suited for livestock price differential research. The ICM approach has been widely cited in the agricultural economics literature.

Applications of work derived from Lancaster (1966) and Rosen's (1974) seminal papers are distributed throughout the economic literature. Among the many applications of the hedonic price model, the most common have been those that examine real estate, automobile, and agricultural commodity prices. The literature reviewed in this section offers a historical perspective and a theoretical foundation for empirical livestock hedonic models.

2.2 Feeder Cattle Hedonic Studies

Numerous agricultural economics studies have been devoted towards estimating the determinants of feeder cattle prices. Feeder cattle hedonic studies have focused on a wide variety of characteristics including weight, sex, breed, body condition, frame size, muscling, and lot size. Later studies incorporated regional and temporal factors and have assessed the value of various value-added programs and sales. The literature on feeder cattle price determinants continues to be a topic pursued by many economists due to many innovations in the way beef is raised and produced, across all sectors of the beef industry. The literature on feeder cattle price determinants dates back far beyond the work reviewed here. The purpose of this section is to provide an overview of one of the most common applications of the hedonic approach in livestock research.

Buccola (1980) examines the impact feeder cattle characteristics have on break-even prices for cattle buyers and sellers. Buccola (1980) used the break-even model to determine how supply and demand factors impact feeder cattle prices. Break-even prices represent long-run reservation prices for cattle buyers and sellers. In the long-run, break-even prices represent the maximum price that a producer would be willing to bid (Buccola, 1980). In an auction setting, cattle buyers will bid according to anticipated costs of gain and handling fees (Buccola, 1980). The model estimates the effect of slaughter weight prices, production costs, both feed and non-feed costs, feedlot performance variables, and physical characteristics on price-weight relationships. The study uses twenty years of Virginia feeder cattle data. Market prices are regressed on feeder cattle characteristics. The price-weight slopes obtained from the original regression equations are taken and regressed on the hypothesized revenue-cost factors included in the conceptual model. The estimated equations represent marginal impacts on prices and the rate of change of feeder prices. The results show that choice feeder steer prices increase by $1.36 per hundredweight for every $1.00 per hundredweight increase in slaughter steer prices. Lightweight choice steers receive greater premiums relative to heavyweight choice steers when slaughter prices increase. Average Choice steer prices decrease by $8.33 per hundredweight for every $1.00 per bushel increase in corn prices. Increased corn prices resulted in larger discounts for lightweight cattle relative to heavyweight cattle. The results indicate that revenue-cost factors, slaughter cattle prices, feed prices, soil moisture conditions, and cattle inventory numbers, have a significant impact on feeder cattle prices. The results here show how a break-even analysis can be used to examine price differentials for different types of feeder cattle and the rate at which prices change for the corresponding classes. However, Buccola (1980) suggests that the break-even analysis may not be suitable for short-run estimation of prices, these short-run static relationships are addressed further in Faminow and Gum (1986).

Faminow and Gum (1986) extend the work of Buccola (1980) by estimating a short-run model of feeder cattle price differentials. Previous studies excluded nonlinear price-weight and price-lot size relationships; this study includes these nonlinear relationships for both weight and lot size. In the long-run, prices may experience a dynamic adjustment over time for different weight classes. This has caused issues in past studies (Faminow and Gum, 1986). The objective of their study is to estimate a short-run feeder cattle model. The main focus is placed on price-weight relationships for steers and heifers. The study uses 400 individual lots of feeder cattle from May 1984 and 1985. To determine how weight and lot size change over time the study includes an interaction term for year and weight and year and lot size. Results show that both interaction variables for steers are insignificant. The price-weight and price-lot size relationships do not change from 1984 to 1985. However, the quadratic terms for weight and lot size are significant. The results support the conclusions of Buccola (1980). The relationship between weight and price for heifers is almost linear in 1984, but concave in 1985. The relationship between weight and price for steers is convex. The quadratic term for lot size is significant, but Faminow and Gum (1986) suspect that there may be further variability across time and space.

Price differences between stocker and feeder cattle influence producer's decision to retain or sell cattle (Marsh, 1985). Price differences are further affected by regional differences in production practices. Marsh (1985) states that prices differences in general, should reflect the demand for and supply of different classes of calves (i.e. stocker and feeders). Marsh (1985) estimates monthly price differences between 300-500 lb. calves and 600-700 lb. steers. This study proposes a dynamic adjustment process in the estimation of monthly price differences. Previous studies work in a static environment. Marsh (1985) hypothesizes a dynamic adjustment, because calf-yearling price differences are expected to change with time as factors which impact production decisions adjust. The adjustments reflect expected slaughter prices, input costs, and time required in cattle feeding. For this reason, costs of gain and slaughter prices are included in the analysis.

Marsh (1985) estimates two structural price models, the first for 300-500 pound steer calves and the second for 600-700 yearling steers. The third price model estimates changes in premiums and discounts between calves and yearlings over time. The price of No. 2 yellow corn is used as a proxy to reflect cost of gain. The price of choice grade slaughter steers reflect cattle feeder expected output prices. Marsh (1985) notes that the expected signs of the coefficients are consistent with the theory. The positive and negative impacts of costs of gain and slaughter prices are greater for calves than those found for yearling cattle. For example, over a six-month period, results show that a $1 per bushel increase in the price of corn reduce calf prices by $5 per cwt, but yearling prices are only reduced by $3.65 per cwt (Marsh, 1985). This result reflects cattle feeding profitability; when input costs increase feeders place a heavier emphasis on feeding heavier yearlings (Marsh, 1985). The monthly price premiums and discounts adjust across time. For example, a 10% increase in corn prices decreases price premiums by 10% during a three month period, but reduces the premium by 26.7% during a twelve month period.

Schroeder et al. (1988) include important feeder cattle characteristics there were omitted from previous research. Previously omitted variables include: health, presence of horns, fill, lot uniformity, time of sale, market expectations, and seasonality for the omitted variables. The objective of this study is to identify factors influencing short-run feeder cattle prices sold at Kansas auctions. This study uses weekly Kansas feeder cattle data from 1986 to 1987. Schroeder et al. (1988) allow feeder cattle market forces to change over the course of the data set and the data set is stratified by sex and weight. Feeder cattle futures data is used as a proxy for expected output prices. Results show that weight have a significant nonlinear impact on price, which supports previous research. Large, uniform lots receive significant premiums. Cattle in poor health are discounted. Large farmed, heavy muscled cattle receive premiums relative to medium and light muscled cattle. Prices differ significantly across time of sale and sale location. Stratifying the data set by sex and weight allow for an improved estimation of price differentials, because different classes of cattle are destined for different segments of the industry (Schroeder et al., 1988). Many studies have incorporated a pricing model similar to the one originally developed in Schroeder et al. (1988) (Bailey, Peterson, and Brorsen, 1991; Williams et al., 2012; Zimmerman et al., 2012).

As research in the area of feeder cattle determinants was refined further, researchers began studying feeder cattle sold through different market outlets. Bailey, Peterson, and Brorsen (1991) compared feeder cattle prices that were sold through video and regional auctions. Specifically, this paper uses Superior Livestock Auction (SLA), and compared those prices with those received at Oklahoma City, OK; Greeley, CO and Dodge City, KS. The paper uses 1987 sales catalogue data collected from SLA and uses USDA AMS data for the three regional auctions. The paper compared net seller and buyer prices after adjustments were made for transaction costs, quality, and delivery dates. To account for quality differences in their comparison of feeder cattle prices a hedonic regression, similar to past studies, is specified. Results show a significant effect for the characteristics: weight, lot size, large framed, and flesh. The nearby futures price also had a significant effect. Results from the hedonic regression represent price differences between SLA and Dodge City due to quality variation.

Results showed that buyers paid a higher price for cattle sold through SLA auctions when compared to the adjusted prices received at the three regional auctions. Relative to the three regional auctions buyers paid between $4.62 and $16.87 per head more for cattle sold at SLA. The average adjusted price difference between SLA and Oklahoma City was $0.95 per hundred weight. Average adjusted price differences of $3.36 and $1.48 per hundred weight were found for Greeley and Dodge City. Results suggest that video auctions are more efficient in completing transactions (Bailey, Peterson, and Brorsen, 1991). Results show that SLA cattle received a higher price relative to the three regional markets.

Following Ladd and Martin’s (1976) Input Characteristic Model (ICM), Coatney, Menkhaus, and Schmitz (1996) include characteristic interdependencies in their analysis of feeder cattle price determinants. Previous studies failed to account for the indirect impact characteristics have through their direct impact on other characteristics. Coatney, Menkhaus, and Schmitz (1996) use breed as an example. They argue that breed has an indirect impact on price through its direct impact on frame size, muscling, and performance. The objective of this study is to account for total, direct, and indirect impacts that characteristics have on feeder cattle prices. The study estimates a hedonic system of equations and an Ordinary Least Squares single-equation model. The system of equations includes endogenous estimation of average flesh, weight, frame, and pencil shrink (Coatney, Menkhaus, and Schmitz, 1996). The system of equations approach allows the indirect impacts to be modeled in the hedonic regression equation. The signs of the coefficients from the single equation approach are consistent with the system of equations approach. However, there are inconsistencies with the magnitudes from the two approaches. The coefficients from the single equation are greater in magnitude. This study attributes these inconsistencies to the single equation not accounting for characteristic interdependencies. The coefficients for the single equation represent both the direct and the implicit indirect impact. The most significant indirect price impacts were those that had a direct impact on weight and frame size. The results determined that characteristic interdependencies are an important factor to consider when determining the value of livestock characteristics.

The identification of feeder cattle price determinants has been refined further in livestock marketing literature. More recently studies have determined the impact of value-added and certification programs. Zimmerman et al. (2012) and Williams et al. (2012) have made significant contributions to the topic of value-added programs. Zimmerman et al. (2012) examined the effect of value-added programs on calves sold through Superior Livestock Auctions. Previous research had estimated the value of value-added programs but failed to estimate the value of the value-added traits separately. The objective of Zimmerman et al. (2012) is to determine the effect of each value-added trait. The hedonic pricing model was estimated using SLA data from 2001 to 2010. This paper stratified the data by year and sex. The study estimates the effect of preconditioning, various vaccination programs, implants, age and source verification, certified natural, and non-hormone treated. Results suggest that buyers paid premiums for weaned calves that had received two rounds of vaccination. Significant premiums were found for certified natural and non-hormone treated cattle. Results indicated that health protocols and age and source verification provided the greatest premiums.

In addition to traits deemed important by previous research, Williams et al. (2012) estimates the effect that various weaning, vaccination, and certification programs have on feeder cattle sold in the Oklahoma Quality Beef Network (OQBN) program. OQBN sales require that cattle complete a specific set of health verifications and protocols. This research used data from sixteen Oklahoma auctions to estimate the feeder cattle hedonic model. Previous studies have directly estimated the effect of characteristics on feeder cattle prices. Williams et al. (2012) estimates the effect characteristics have on feeder cattle basis. In this study basis is calculated as the difference between the sale price and the weekly average Oklahoma City Stockyard price. Most results of the results for physical characteristics are consistent with previous research. Results indicate that cattle enrolled in the OQBN program received significant premiums. Calves meeting the vaccination protocols received premiums of $1.44/cwt, while calves that were weaned received a premium of $2.05/cwt. Lots that were age and source verified did not receive significant premiums.

By identifying key factors influencing the price of feeder cattle researchers have provided producers with information that allows for more effective production and marketing practices. The literature has also provided researchers with a well-documented approach for applying hedonic analysis to other segments of the beef industry. The hedonic pricing model has been extended to other classes of cattle, including cows, cow-calf pairs, and bulls.

2.3 Cow, Cow-Calf Pair, and Bull Hedonic Studies

Cows and bulls are important production inputs for cow-calf produces. They represent a substantial cost for those investing in beef herd animals and, in some situations, can be a vital source of income. In Oklahoma, cull animals (cows and bulls) represent 10-20 percent of total cow-calf operator revenues (Peel and Doye, 2008). The decision to purchase and cull cows is made through the interaction of many factors. Likewise, the sourcing of sire genetics comes with many tradeoffs. Price differentials among these two important production inputs led to the evaluation of cow and bull physical characteristics and the market factors surrounding them.

Before Mintert et al. (1990), little research had been devoted towards determining factors influencing cow prices. This lack of research is the primary motivation for an examination of cull cow price differentials. The objective of the study is to determine the value of cow characteristics and marketing factors. This study uses weekly data from seven Kansas auctions. The fall period is from October 1986 through December 1986. The spring period included in the study is from March 1987 to April 1987. The data set included 4,711 lots of cows composed of 7,103 head of cows. Following Ladd and Martin (1976) the price per hundredweight paid for a cow is equal to the sum of the marginal implicit value of characteristics and the value of market factors (Mintert et al., 1990).

Relative to the reference lot, cows with dressing of 40 and 42 received discounts of $2.61 per cwt and $1.66 per cwt. Cows with a dressing percentage of 48 and 50 received premiums of $1.93 per cwt and $3.36 per cwt, relative to the base dressing percentage of 45. The relationship between weight and price is nonlinear. As weight increases, discounts are assigned at a decreasing rate. Relative to single head lot sizes, lots sizes ranging from 11 to 15 received $1.25 per cwt premiums. Larger lot sizes receive significant premiums. Unhealthy cows receive significant discounts. Cows with bad eyes are discounted $9.00 per cwt. Relative to Hereford cows, Hereford-Angus crossed cows received small premiums. Angus cows did not receive significant premiums relative to Hereford cows. Exotic crosses received the highest premiums relative to Hereford cows. Pregnant cows received premiums relative to open cows. Premiums for bred cows decreased at an increasing rate as age increased. Cow sellers looking to maximize the price received should market healthy, high dressing cows in desirable lot sizes (Mintert et al., 1990).

Parcell, Schroeder, and Hiner (1995) estimate the determinants of Kansas cow-calf pairs. The study collects data from seven monthly Manhattan Kansas auctions. The spring data collection period was from January 1993 through April 1993. The fall period included in the data set was from October 1993 to December 1993. The data set contains 490 cow-calf pair lots made up of 2,086 individual pairs. The theoretical pricing model is an extension of the ICM model developed by Ladd and Martin (1976), where the price of a cow-calf pair is equal to the sum of the marginal implicit values of cow-calf pair characteristics.

The marginal yield of a characteristic, specified in this paper, is equal to the derivative of the total quantity of a characteristic with respect to the total amount of the input used in production. Some of the marginal implicit prices are hypothesized to be nonlinear, as a result, linear regression cannot be used to regress price on cow-calf characteristics; suggesting that the marginal implicit prices are a function of the quantity of the characteristics (Parcell, Schroeder, and Hiner, 1995). Similar to other studies, this study uses nonlinear terms for some of the characteristics in the estimated model. Cow age, calf weight, and pairs per pen are all included as quadratic terms. Monthly dummy variables were included to account for price seasonality. The model explained 74% of the variation in prices. This research found calf weight having a significant nonlinear impact on price. Pen sizes ranging from 9 to 12 pairs received the highest premiums. Cow age had a significant nonlinear effect on price, cows ranging from two years to nine years were discounted. Unhealthy cows were discounted $69.69 per pair. Results from this paper show unhealthy calves were discounted $132.29 per pair. The study found significant differences in cow-calf pair prices based on the characteristics of the animals sold. Among the characteristics examined, cow characteristics that had a significant impact included: health, frame, condition, breed, age, pregnancy, presence of horns, and pen size. Furthermore, calf weight, health, and frame were significant in determining prices.

Bulls contribute to the genetic makeup of future production outputs (Dhuyvetter et al., 1996). Bulls are valued based on the perceived value of specific physical and genetic traits. No past studies had examined the contribution of both genetic and physical attributes on bull prices. Dhuyvetter et al. (1996) identify factors influencing bull price differentials and estimate the marginal value of those found to be important. The demand for bulls is affected by bull characteristics and expected calf prices (Dhuyvetter et al., 1996). In this study bull characteristics are classified as physical, genetic, or performance characteristics. Following Ladd and Martin's (1976) ICM model, bull prices are a function of the marginal implicit prices of bull characteristics and the quantity of the characteristics that the bull possesses. The implicit money values of bull traits are estimated using regression. The data set includes 26 spring Kansas bull sales during 1993. The 26 sales include 1,650 individual animals.

The initial models, one model with bull EPDs the other without EPDs, are estimated using OLS. The paper later specifies a log-linear specification. The inclusion of EPDs caused breed to have no significant effect on bull prices. Buyers paid significant premiums for conformation, muscling, correctness, and disposition. This paper determined that age has a nonlinear impact on price; buyers pay premiums for older bulls at a decreasing rate. Performance factors are estimated separately by breed due to breed standards. Bulls with higher birth weights are discounted in both models. Discounts for higher birth weights were less when EPDs are included. This paper found buyers paying significant premiums for higher adjusted weaning weights. These results are consistent with both models. Milk EPDs had a significant impact on price. Significant marketing factors include sale, time of sale, catalog picture, proportion of semen rights retained, and percent of bulls with semen retention rights.

2.4 Summary

This literature review examined the development, implications, and applications of hedonic price models. Lancaster (1966) proposed a theoretical approach for evaluating utility bearing characteristics. Rosen's (1974) approach values a product as the sum of the prices for the individual characteristics. Ladd and Martin's (1976) ICM model of production inputs, similar to

Ladd and Suvannunt’s (1976) CGCM, states that the total price of an input is equal to the sum of the marginal money value of the products characteristics (Ladd and Martin, 1976).

Through the application of hedonic pricing techniques, derived from Lancaster’s (1966) and Rosen’s (1974) seminal papers, research has investigated the determinants of cattle at different stages of the beef industry. Studies included in this review of literature have followed Ladd and Martin’s (1976) approach to estimate the marginal implicit value of cattle characteristics. Livestock research has found that physical characteristics and marketing channels both play an important role in determining livestock prices.

One gap remains in livestock marketing research relating to livestock price determinants. The determinants of bred cow values have never been explicitly estimated in any past research. Research on bred cow prices should allow for a more comprehensive set of livestock price determinant studies. This study will add to the livestock marketing literature by determining the marginal value of bred cow characteristics and the marketing factors surrounding them. The work reviewed in this chapter provide insight towards characteristics and an overview of a methodology that needs to be given consideration in an analysis of bred cow price determinants.

CHAPTER III

PRICING MODEL

Bred cows are inputs into beef production. The characteristics bred cows possess, contribute to their total value as an asset. Additional value is added due to the future production input they carry at the time of purchase (i.e. the unborn calf). When producers invest in bred cows, they consider the discounted expected returns as well as the expected salvage value at culling. As a result, salvage value is expected to have a significant role in determining bred cow prices. This research uses cull cow prices as a proxy for expected salvage value.

Ladd and Martin (1976) took a product characteristic approach to farm production inputs. From there input characteristic model (ICM), two themes are formulated that have implications for livestock marketing research. The significant findings from Ladd and Martin's (1976) ICM model illustrate how the value of production inputs are equal to the sum of the value of the input's characteristics. The value of an inputs characteristics are equal to the amount of each characteristic multiplied the marginal implicit value of each trait (Ladd and Martin, 1976). Multiple regression has traditionally been used to estimate the marginal value of product characteristics.

Using Ladd and Martin's (1976) ICM framework the total value of a bred cow is equal to the sum of the total amount of each bred cow characteristic multiplied by the estimated implicit value of each attribute. Ladd and Martin (1976) provide a theoretical framework for researchers to model livestock price determinants.

Extensions of the ICM, specifically in the livestock research, have added to Ladd and Martin's (1976) original framework, which has equipped researchers with a readily adaptable methodology. Following the approach of previous studies (Faminow and Gum, 1986; Schroeder et al., 1988), bred cow prices reflect supply and demand conditions in a given market at a point in time. For any given auction, supply is fixed in the short-run and prices are determined by the demand for a set of bred cow characteristics. From Ladd and Martin (1976), the demand for an input is influenced by the inputs characteristics, which allows for price to be a function of physical characteristics. Through previous extensions of ICM (Schroeder et al., 1988; Bailey, Peterson, and Brorsen, 1991; Parcell, Schroeder, and Hiner, 1995; Dhuyvetter et al., 1996; Williams et al., 2012; Zimmerman et al., 2012), the price of a lot of bred cows can be specified as a function of physical characteristics (C), market forces (M), and salvage value (S), formulated as:

(1) $$Price_{it} = \sum_k V_{ikt}\, C_{ikt} + \sum_h R_{ht} M_{ht} + G_t S_t$$

where *i* refers to a lot of bred cows sold in week *t*, *k* refers to a specific bred cow trait, and *h* refers to market factors. The value of each bred cow characteristic is specified as V, and R represents the market forces. The effect of salvage value is represented by G. Factors included as market forces are price expectations, both input costs and output price expectations, sale location, and the week of sale. Equation (1) states that the price per head of a lot of bred cows sold equals the sum of the marginal implicit values of each lots characteristics times the yield of each characteristic (Ladd and Martin, 1976), the price effect of each market force (Mintert et al., 1990; Schroeder et al., 1988), and the expected salvage value.

Equation (1) can be estimated using multiple regression to determine the marginal value of bred cow characteristics. Previous research has included random effects for sale location and uses a mixed model approach to estimate the hedonic model (Williams et al., 2012). Similarly, a random effect for each sale location for each observed time period is incorporated into Equation (1). All other characteristics and market forces are treated as fixed effects.

The mixed model can be expressed as:

(2) $$Price = X\beta + Z\theta + \varepsilon$$

here *Price* is a vector of observations on the dependent variable, *X* is a matrix of independent variables, β is a vector of fixed effects parameters to be estimated, *Z* is a matrix of variables identifying each sale location for each week, θ is a vector of random effects parameters to be estimated, and ε is the random error term.

CHAPTER IV

MATERIALS AND METHODS

The USDA's Agricultural Marketing Service (AMS) collects and reports results from livestock sales across the country. Along with livestock, AMS provides reports on various agricultural commodities. Their reports provide industry producers with up to date news on current prices and market trends. In the state of Oklahoma, sales at seven livestock auctions are reported by AMS[1]. The AMS has reporters present on the day of each sale. Sale results are collected during the sale and are typically made public in the following days. The five most recent years of reports are available at the USDA's AMS website.

4.1 Data

This research uses fifteen years of AMS auction reports for the seven Oklahoma sales. This study collected weekly futures prices from the Livestock Marketing Information Center (LMIC). The staff at the Oklahoma City AMS granted access to their archive system; allowing the researchers to collect all of the relevant auction reports. Within the AMS auctions reports, bred cows are aggregated into homogenous groups and are reported as lots with an unknown head count. The cow reports include physical characteristics and prices for bred cows. The reports also include a section for cull cows; specifically, this research collected data from boning cull cow section. Table A.1 summarizes the seven Oklahoma sales and their corresponding file names.

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[1] Reporters at each sale are either Federal AMS employees or State Department of Agriculture, Food and Forestry employees as part of a Federal-State agreement.

Many of the file names for several of the Oklahoma sales have changed over time. Traditionally, the cow and feeder cattle sales are held on separate days. For some of the smaller auctions, the cow sales did not bring enough volume to justify having it on a different day. Table A.1 in the appendix summarizes which sales switched from a two-day sale to a one day sale. The AMS reports are in a text file format. After all the text files had been collected, they were processed into a usable form.

The LMIC, located in Lakewood Colorado, has been working with government agencies and land grant universities since its inception in 1955. Their primary objective is to work with members on livestock marketing issues and to provide information on livestock related topics. One of their most valued strengths is data collection and analysis. The LMIC staff developed an automated Excel program to process the AMS text files. In total, the program prepared close to 6,000 individual files. The format of the text files changed periodically, and the LMIC staff had to adjust the program. The process took several months to complete.

The LMIC Excel program prepared the text files and created Excel sheets for each year. However, many inconsistencies still existed once the Excel program finished processing. The combined bred cow Excel sheets were processed further in SAS Enterprise Guide 5.1, which took several weeks to complete. Many of the reports had observations that did not reflect the objectives of this research. For example, many reports listed cows that were sold as open in the bred cow section. It was determined that it would be appropriate to omit those observations with inconsistencies and errors. Those observations were omitted from the final data set. In total, 135 observations were deleted.

The seven Oklahoma auctions occur on different days of the week. The reports from the seven sales are combined to create weekly cross sections. The final data set includes 776 weeks comprised of 14,811 individual lots from January 5, 2000, to May 21, 2015. The price of a lot of bred cows ranged from $330/head to $3400/head. Bred cows offered have reported weights ranging from 700 to 1700 pounds. Complete summary statistics are included in Table 4.1. Averages of bred cow characteristics, stratified by sale location, can be found in Table A.2.

Table 4.1: Descriptive Statistics (N=14811)

Variable	Mean	Std. Dev.	Minimum	Maximum
Price ($/head)	936.67	390.41	330.00	3400.00
Age (yrs.)	5.58	2.38	1.00	10.00
Weight (lbs.)	1126.35	118.87	700.00	1700.00
Months Bred (months)	5.41	1.35	1.00	9.00
Volume (head)	267.29	234.58	8.75	2343.00
Feeder Futures ($/cwt.)	123.27	38.90	73.30	241.19
Corn Futures ($/bu.)	3.99	1.74	1.76	8.18
Cull Price ($/head)	638.29	237.66	317.00	1302.55

4.2 Description of Characteristics and Market Factors

The AMS sale reports include physical characteristics for each lot of bred cows sold. The physical characteristics include: age, months bred, weight, quality, and hide color. Market factors include location, volume, and time of sale. This research collected weekly corn and feeder cattle futures price data to be used as proxy variables for price expectations. The following sections summarize each characteristic used in the bred cow pricing model and provide hypotheses about the expected relationship.

4.2.1 Cow Age

Bred cow age is reported as a range of bred cow years. Each lot of bred cows has an assigned age range. Age ranges from two to ten years old. AMS reporters report prices for bred heifers. This research codes heifers as one-year-olds, for comparison. In this context, age is a reference for the number of calves born. AMS staff aggregate bred cows into lots of similar age classification. When sale volume is light, reporters are forced to place cows with varying ages in the same lots. For example, there are some recorded lots with age ranging from one to ten years. However, the average difference between the minimum and maximum of each lots age range is 1.65 years. The midpoint of each age range was used as the observation for each lot. The distribution of age midpoints is in Figure 4.1. This study hypothesizes that age will have a nonlinear impact on price. As bred cows age they will receive discounts at an increasing rate, due to the reduced useful life of that capital asset.

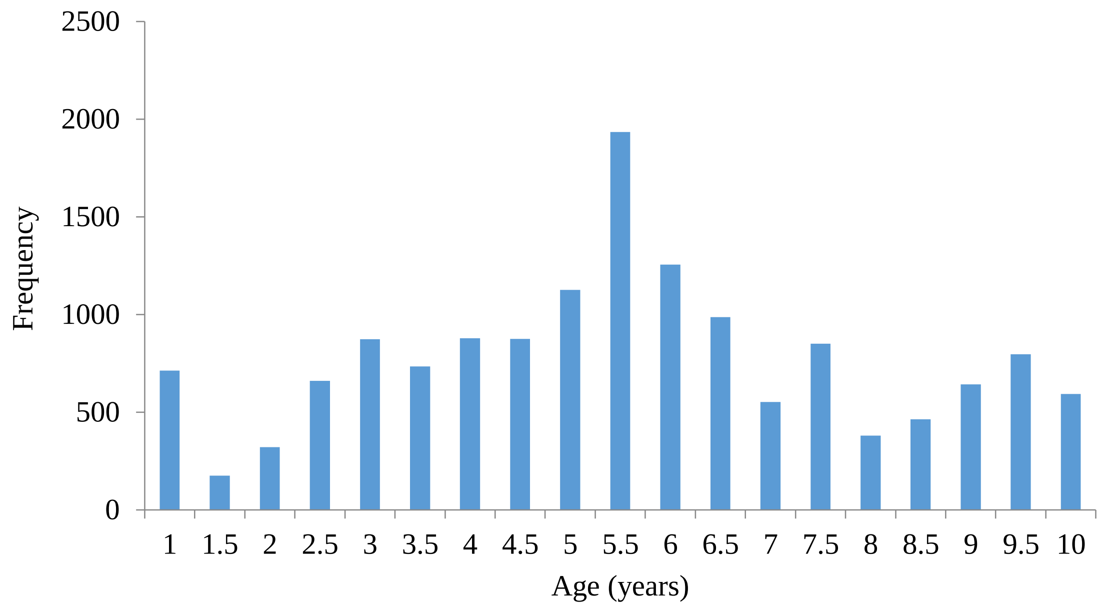

Figure 4.1: Frequency of age midpoints for bred cows

4.2.2 Cow Weight

Bred cow weight is reported as a range of bred cow weights. Each lot of bred cows has an assigned weight range. Weight ranges from 700 pounds to 1700 pounds. Similar to age, when sale volume is light reporters are forced to create lots with broad weight classifications. However, the average difference between the minimum and maximum of each lots weight range is 186.56 pounds. The midpoint of each weight range was used as the observation for each lot. The distribution of aggregated weight midpoints is reported in Figure 4.2. Cow weight is expected to have a positive, nonlinear impact on price. As weight increases, premiums will be assigned at a decreasing rate up to a maximum. Lighter weight cows might be viewed as unhealthy. Furthermore, buyers may be cognizant of the nutritional needs of heavier cows, which would lead to diminishing value as weight increases.

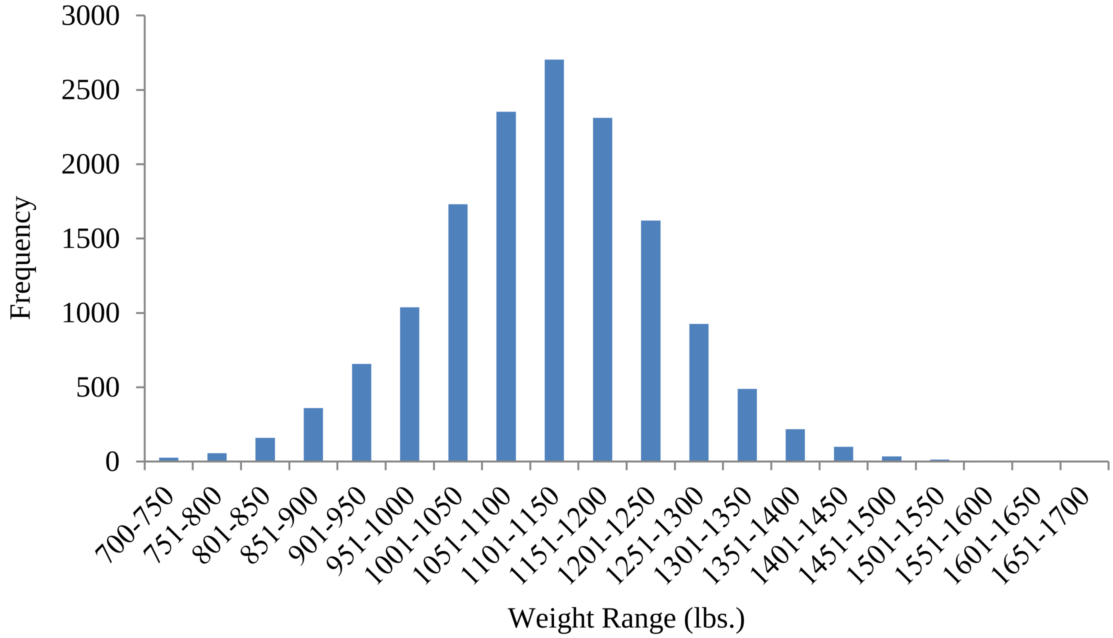

Figure 4.2: Frequency of weight midpoints for bred cows

4.2.3 Months Bred

Months bred is reported as a range. Months bred is verified by certified veterinarians at each sale location. When veterinarians are not present on the day of the sale, the bred cow section of the report is omitted. Each lot of bred cows has an assigned range of months bred. Months bred ranges from one to nine months. The average difference between the minimum and maximum of each lots months bred range is 2.24 months. The midpoint of each months bred range was used as the observation for each lot. Figure 4.3 provides the distribution of months bred midpoints. The majority of bred cow lots sold are six months bred. The risk of losing a calf is reduced as months bred increases. As a result, it is hypothesized that late gestating cows will receive a higher price.

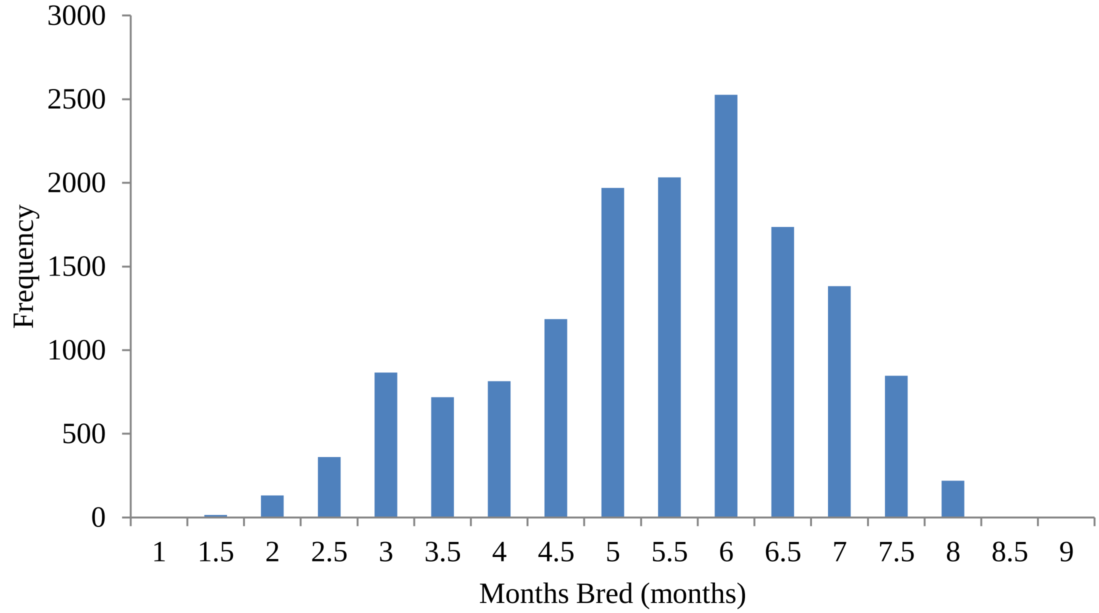

Figure 4.3: Frequency of months bred midpoints for bred cows

4.2.4 Cow Quality and Hide Color

Each lot of bred cows is assigned a measure of quality. AMS reports five quality classifications for bred cows: high, high-average, average, average-low, and low. Quality represents the overall quality of the entire lot. The classifications high-average and average-low are assigned when the quality across the whole lot is not consistent. The majority of bred cows are of average quality (Figure 4.4). This research hypothesizes that higher quality will result in premiums while lower quality cows will receive discounts. Quality has health, breeding, and calving implications, which leads to the hypothesized relationship between quality and price. In addition to quality, bred cows are also given a black or nonblack classification for the hide color of each lot. Some of the AMS auction reporters included comments on black-white faced cows, black-char cows, smoke colored cows, Longhorns, Brangus, Brahman, and other breeds. These observations were omitted from the final dataset because they were not consistently reported across all seven auctions. Many sales include all other breed and hide color identifiers in the nonblack classification. Figure 4.5 provides the frequency of black and nonblack bred cows. This research expects blacks to receive a higher price as compared to lots of nonblack cows.

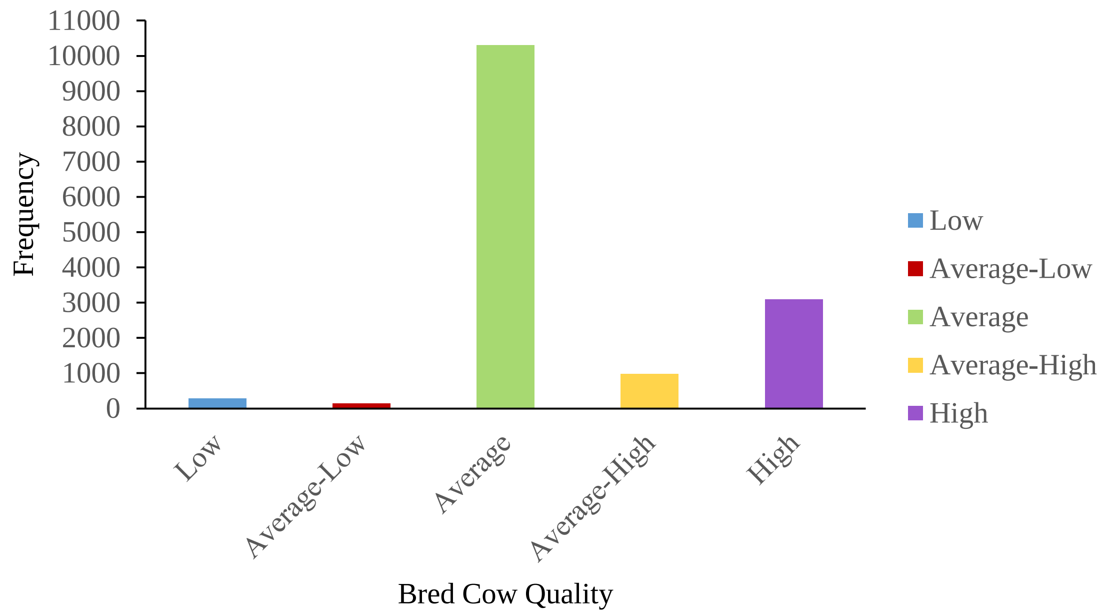

Figure 4.4: Frequency of quality for bred cows

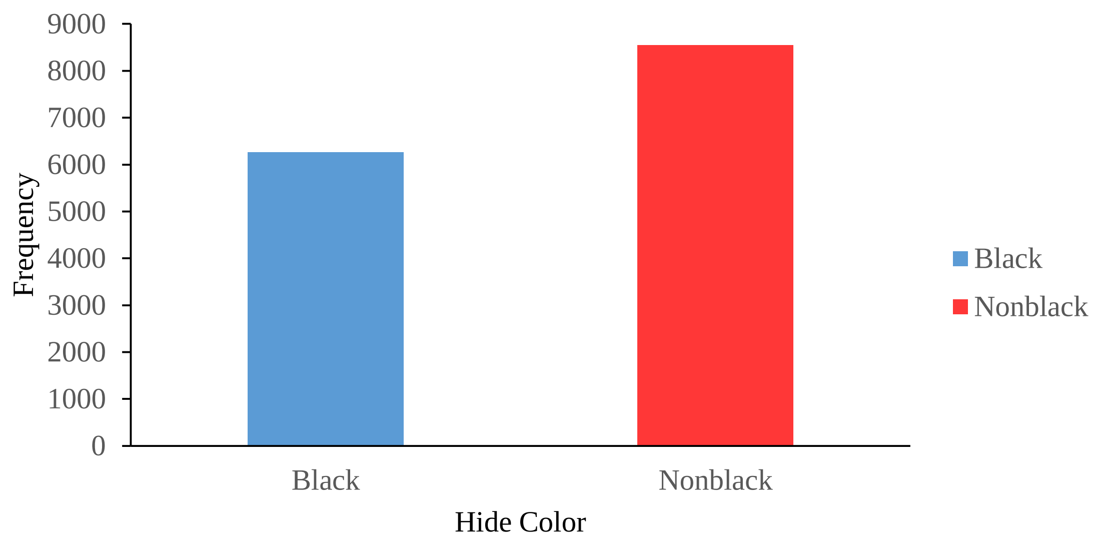

Figure 4.5: Frequency of hide color for bred cows

4.2.5 Sale Location

Seven Oklahoma auctions report to the AMS office in Oklahoma City. The seven auctions are Oklahoma City, Woodward, El Reno, Tulsa, McAlester, Ada, and Apache. Six of the sales were collected from January 5, 2000, to May 21, 2015. Tulsa was collected from January 8, 2002, to May 21, 2015. The Tulsa auction did not include all of the characteristics during the years 2000 and 2001. As a result, those years were removed from the final dataset. Figure 4.6 illustrates the percentage of lots sold from each of the seven Oklahoma auctions. Oklahoma City has the greatest percentage of lots while Tulsa has the smallest percentage of lots sold. It is expected that Oklahoma City will receive the lowest price, as compared to all other sales; Oklahoma City has the greatest number of lots offered which creates a supply effect on price. Furthermore, one can postulate that buyers prefer to buy cows in closer proximity to where production occurs (i.e. in closer proximity to the ranch).

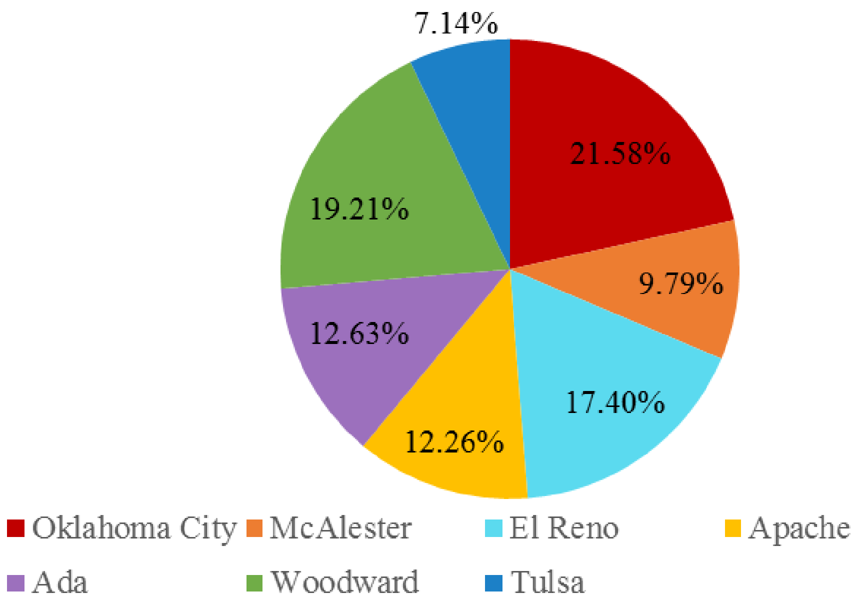

Figure 4.6: Percentage of lots sold from each sale location

4.2.6 Sale Volume

The AMS reports record the total number of cows and bulls sold at each auction. The reports also include the percentage of cows and bulls that are going to packing facilities. The total number of replacements sold at each auction can be calculated using total volume and percent to packers. Equation 3 calculates the total number of cows and bulls going to packing facilities.

(3) $$Slaughter\ Volume = Total\ volume * Percent\ to\ packers$$

The total number of replacements can be calculated using the results from Equation 3. Equation 4 calculates the total number of replacements sold.

(4) $$Replacement\ Cow\ Volume = Total\ Volume - Slaughter\ Volume$$

Replacement cow volume represents the number of bred cows and cow-calf pairs sold at each auction. This figure does not directly measure the number of bred cows sold, but it does give a measure of sale volume that can be used to represent supply at a particular auction location during a specific week.

4.2.7 Salvage Value

Equation 1 states that the expected salvage value of a bred cow contributes to the total value. The slaughter cow prices are reported for the four USDA quality grades. The four quality grades included are breakers, boners, leans, and lights. This research uses the Oklahoma City weekly average boning slaughter cow average dress price as a proxy for the expected salvage value. Cull cows classified as boning were selected because they accurately reflect the typical commercial beef cow at culling. While the percentage of cows marketed under each of the four AMS cull cow categories may fluctuate seasonally, on average roughly 33 percent of cull cows sold are classified as Boning in Oklahoma City (Peel and Doye, 2008). Cows classified as Boning have a body condition score between 5 and 7, depending on dressing percentage. Of the 776 weeks used, 26 weeks did not have an Oklahoma City sale. When Oklahoma City is missing the remaining six sales average boning cull value is used. There is expected to be a positive relationship between bred cow prices and cull cow prices. As the expected salvage increases, the value of a bred cow, viewed as a capital asset, is expected to rise.

4.2.8 Price Expectations

In the livestock marketing literature, researchers have incorporated price expectations to reflect changing market fundamentals. Buccola (1980) included slaughter cattle and corn futures prices in his analysis of feeder cattle break-even prices. Research has also argued that feeder cattle futures can be used as a proxy for changing market conditions (Schroeder et al., 1988).

Bailey, Peterson, and Brorsen (1991) included a nearby feeder cattle futures price in their comparison of video auction and regional auction prices. Similarly, feeder cattle and corn Chicago Mercantile Exchange (CME) futures prices are included as a measure of price expectations. Corn is the most accurate measure of expected input costs. Ideally, data for hay costs may be a more accurate measure of expected costs for cow-calf producers, but data on hay prices is not readily available or recorded on a weekly basis. Feeder cattle futures prices are a proxy for expected output prices, which research has argued is the best measure available. Feeder cattle prices represent changes in output prices over the collected time period. This study uses weekly futures prices collected from the LMIC. The futures price series was lagged one week. For a given week of bred cow sales the previous weeks closing feeder cattle and corn prices were used. There is expected to be a negative impact on price, as corn futures prices increase. Likewise, it is expected that there will be a positive effect on price as feeder cattle futures prices increase. These findings would be consistent with those of previous research (Buccola, 1980; Schroeder et al., 1988; Bailey, Peterson, and Brorsen, 1991; Zimmerman et al., 2012).

4.3 Summary of AMS Data

Table 4.2 provides a summary of the previously described traits. The physical characteristics collected from the AMS reports include: age, months bred, weight, quality, and hide color. Market forces include location, sale date, and price expectations. The weekly average Oklahoma City boning cull cow price is used as a proxy for the expected salvage value of bred cows. The data collected from the AMS auctions reports, processed by the LMIC, will be used to estimate the empirical bred cow hedonic model detailed in the following sections.

Table 4.2: Description of Characteristics

Characteristic	Description
Age	Age range
Weight	Weight range
Months Bred	Months bred range
Hide Color	Black
	Nonblack

Table 4.2: Description of Characteristics (continued)

Characteristic	Description
Quality	High
	High-Average
	Average
	Average-Low
	Low
Sale Location	Oklahoma City
	McAlester
	El Reno
	Apache
	Ada
	Woodward
	Tulsa
Cull Cow Price	Weekly average Oklahoma City boning cow price
	Six sale weekly average price boning cow price
Feeder Cattle Futures	Nearby CME feeder cattle futures price from previous week
Corn Futures	Nearby CME corn futures price from previous week

4.4 Methods and Procedures

From Ladd and Martin's (1976) ICM model and extensions of ICM in livestock research, Equation 1 was formulated to reflect the relationship between prices and bred cow characteristics and market forces. Previous research had taken a mixed model approach to estimate livestock hedonic pricing models (Williams et al., 2012). Similarly, Equation (2) reflects the mixed model approach. Using the framework presented in Chapter Three the basic bred cow model is formulated:

(5) $$Price = f(Age, Weight, MonthsBred, Quality, HideColor, Location, SalvageValue, PriceExpectations)$$

where *Price* per head of a bred cow lot is a function of physical characteristics, market forces, and expected salvage value.

4.4.1 Empirical Model

Price per head is the dependent variable in Equation (5). This research specifies a log-log functional form. The log-log functional form is a natural log transformation of the dependent variable and all non-binary independent variables. This specifications allows results to be interpreted in marginal terms rather than absolute.

Most previous livestock hedonic studies have found significant seasonality of livestock prices (Schroeder et al., 1988; Parcell, Schroeder, and Hiner, 1995; Mintert et al., 1990). Typically, this observed seasonality is modeled using monthly dummy variables. Research has also classified sales as spring and fall sales (Schroeder et al., 1988). To better understand the seasonality of bred cow prices, Equation (5) was originally estimated with monthly dummy variables and significant seasonality was observed. Results from the model that included monthly dummy variables suggested that prices were at their lowest in the months of May and June. Sine and Cosine terms that capture the same seasonal pattern were then fitted to account for seasonality. Results from the trigonometric functional form for seasonality agree with the dummy variable functional form. Model fit statistics for the two proposed forms of seasonality were similar. The unrestricted monthly dummy variable model had a -2 Log Likelihood value of -29,117.9 while the trigonometric functional form had a -2 Log Likelihood value of -29074.5. Since the data is weekly time-series, this research concluded that a trigonometric form of price seasonality was a more appropriate specification. The trigonometric functional form smooths the effect across weeks while the monthly dummy variables assign impactful estimates to each month. The empirical model to estimate is:

$$\ln(Price_{it}) = \beta_0 + \sum_{j=1}^{9} \beta_{1j} Age_{ijt} + \sum_{j=1}^{8} \beta_{2j} MBred_{ijt} + \sum_{j=1}^{9} \beta_{3j} Wt_{ijt} +$$

$$\sum_{j=1}^{4} \beta_{4j} Qlty_{ijt} + \beta_5 Hcolor_{it} + \sum_{j=1}^{6} \beta_{6j} Loc_{ijt} + \beta_7 \ln(Corn_{t-1}) + \qquad (6)$$

$$\beta_8 \ln(Feeder_{t-1}) + \beta_9 \ln(CPrice_t) + \sum_{j=1}^{2} \sum_{T=26}^{52} \left[\beta_{10j} Cos\left(\frac{2\pi w}{T}\right) + \beta_{11j} Sin\left(\frac{2\pi w}{T}\right)\right]$$

$$+\mu_{it} + \varepsilon_{it}$$

where i = each bred cow lot sold (i = 1, 2,…, 14811) and t denotes the week of the sale (t = 1, 2,…, 776). $Price_{it}$ is the price per head of a lot of bred cows i in week t, w is a weekly dummy variable (w = 1, 2,…, 52), T denotes the frequency ($T=26, 52$), μ_{it} is the random effect for each sale location for each week, and ε is the random error term. Descriptions of all variables are presented in Table 4.3.

Table 4.3: Description of Variables

Variable	Definition
$Price_{it}$	The average price per head of lot i at week t in year y ($/head)
Age_{ijt}	Ten binary variables (0 or 1) for age j=1,…,10; base=3
$MBred_{ijt}$	Nine binary variables (0 or 1) for months bred months bred j=1,…,9; base=6
Wt_{ijt}	Ten binary variables (0 or 1) for weight Weight is included as hundred pound ranges j=1,…,10 1=700-800 2=801-900 3=901-1000 4=1001-1100 5=1101-1200 6=1201-1300 7=1301-1400 8=1401-1500 9=1501-1600 10=1601-1700; base=901-1000
$Qlty_{ijt}$	Binary variables (0 or 1) for quality j=1,…,5 1=Low 2=Low-Average 3=Average 4=Average-High 5=High; base=Average
$HColor_{it}$	Hide color of each lot 0=nonblack 1=black
Loc_{ijt}	Binary variables (0 or 1) for sale location j=1,…,7 1=Ada 2=Apache 3=El Reno 4=Oklahoma City 5=Tulsa 6=McAlester 7=Woodward; base=Oklahoma City
$Corn_{t-1}$	The weeks closing corn futures price in week $t-1$
$Feeder_{t-1}$	The weeks closing feeder cattle futures price in week $t-1$
$CPrice_{it}$	The average Oklahoma City boning cull cow price in week t

Previous research has modeled age and weight as linear terms and often the significance of a quadratic terms was tested (Faminow and Gum, 1986; Schroeder et al., 1988; Parcell, Schroeder, and Hiner, 1995; Dhuyvetter et al., 1996; Williams et al., 2012). In doing so, researchers impose a functional form, which is convenient when data limitations are a concern.

This research includes weight and age as binary variables. Age was divided into ten separate binary variables. Since the midpoint of each age range was used as the observation, there were twenty values age could take. Age was rounded up to the nearest year. For example, a lot with an average age of 1.5 was rounded up to 2 years. Similarly, ten weight classes were included and assigned separate binary variables. Months bred ranges from one to nine months bred. The average months bred is used as the observation for each lot; this created observations that were in two-week increments. Months bred was rounded up to the nearest month. Nine separate binary variables were created for months bred. Summary statistics of physical characteristics, treated as separate binary variables, are included in Table 4.4.

Table 4.4: Summary Statistics of Physical Characteristics

Variable	Frequency	Percentage
Age (Base=3)		
1	713	4.81
2	496	3.35
3	1535	10.36
4	1612	10.88
5	2001	13.51
6	3190	21.54
7	1539	10.39
8	1230	8.30
9	1105	7.46
10	1390	9.38
Wt (Base=901-1000)		
700-800	82	0.55
801-900	519	3.50
901-1000	1696	11.45
1001-1100	4084	27.57
1101-1200	5016	33.87
1201-1300	2548	17.20
1301-1400	709	4.79
1401-1500	136	0.92
1501-1600	18	0.12
1601-1700	3	0.02
Mbred (Base=6)		
1	2	0.01
2	145	0.98

Table 4.4: Summary Statistics of Physical Characteristics (continued)

Variable	Frequency	Percentage
Mbred (Base=6)		
3	1229	8.30
4	1532	10.34
5	3156	21.31
6	4559	30.78
7	3120	21.07
8	1066	7.20
9	2	0.01
Qlty (Base=Average)		
High	3100	20.93
Average-High	980	6.62
Average	10303	69.56
Low-Average	140	0.95
Low	288	1.94
Breed (Base=Nonblack)		
NonBlack	8546	57.70
Black	6265	42.30

Of the 14,811 lots collected, the majority of them are reported as being of average and high quality. Summary statistics reveal that both classifications of hide color are well represented in the dataset. The majority of bred cows documented in this dataset are sold during their third trimester of pregnancy, 62.43% respectively. Most cows recorded here weigh between 900 and 1300 lbs. All ages are well represented, supporting the decision to separate age into binary variables. Section 4.2 summarized each characteristic recorded by AMS. The emphasis here, in Table 4.4, is to provide a summary of each characteristic after it has been aggregated and separated into its own unique binary variable.

The hedonic model was estimated using Maximum Likelihood Estimation (MLE) in SAS Enterprise Guide 5.1 using the MIXED procedure. To estimate Equation 5 an arbitrary reference lot of bred cows was chosen to avoid perfect multicollinearity. Three years of age was selected as the base age, while 901 to 1000 lbs. was chosen as the base weight class. Six months bred was selected as the base. Average quality was selected as the base quality. Oklahoma City was assigned as the base sale location. All estimated coefficients reflect price effects relative to the base lot.

4.4.2 Multicollinearity and Salvage Value

There was concern that some variables included in the empirical model might be correlated, which would lead to multicollinearity. This study suspected that the three price series included as independent variables might be correlated. Multicollinearity is a result of one variable being a linear combination of another variable (SAS Institute Inc. 2008). In the presence of multicollinearity, estimates are still unbiased, but standard errors are inaccurate. This research estimated correlation coefficients to diagnosis the problem of multicollinearity (Table 4.5).

Table 4.5: Correlation Coefficients (N=14811)

Variable	Age	Months Bred	Weight	Quality	Hide Color	Location	Cull Price	Feeder Futures	Corn Futures
Age	1.000	0.020**	0.406***	-0.210***	-0.148***	0.021***	-0.001	0.022***	-0.096***
Months Bred		1.000	0.149***	0.142***	-0.001	-0.027***	-0.004	-0.052***	0.018**
Weight			1.000	0.230***	0.099***	0.131***	0.163***	0.180***	0.017**
Quality				1.000	0.272***	0.051***	0.112***	0.112***	0.060***
Hide Color					1.000	0.137***	0.075***	0.078***	0.079***
Location						1.000	-0.072***	-0.054***	0.008
Cull Price							1.000	0.954***	0.431***
Feeder Futures								1.000	0.359***
Corn Futures									1.000

** indicates significantly different from zero at the 0.05 level.
*** indicates significantly different from zero at the 0.01 level.

The highest correlation coefficient occurred between cull price and feeder cattle futures price, which received an estimate of 0.954 (p-value <0.001). Two fixes can remedy multicollinearity. The first remedial measure is to redefine the problematic variables in the regression equation. This research determined that there was not a more appropriate way to define cull price and feeder cattle futures. The second fix is to drop the variable causing multicollinearity. The inclusion of feeder cattle futures as a proxy for market conditions is well documented in the literature (Buccola, 1980; Schroeder et al., 1988; Bailey, Peterson, and Brorsen, 1991; Zimmerman et al., 2012). This research concluded that the feeder cattle futures variable be included in the hedonic model.

In Chapter Three, it was proposed that bred cow prices are a function of physical characteristics, market forces, and the salvage value. Structurally it makes sense to include salvage value as a factor influencing bred cow value. However, econometrical issues arise when collinearity is present in the model. Implicitly, when the cull price series was included, it states that the cull price sets the market level for bred cow prices. This is difficult to justify because both prices, bred cow and cull cow, are discovered at the same time. It would be a stretch to argue that one causes the other. The boning cull cow price series is dropped from the empirical model. The cull cow price variable does not contribute any new significant information to the bred cow pricing model. Equation (1) is revised to express bred cow prices as a function of physical characteristics and market forces.

4.4.3 Heteroscedasticity

One major concern associated with the time-series, cross-sectional nature of the data used is heteroscedasticity. Results from a likelihood ratio test indicate the presence of heteroscedasticity arising from the variables sale volume, average weight, average age, and average months bred. The chi-square statistic for the likelihood ratio test is calculated as:

(7) $$\chi^2(4) = -28891.2_{UR} + 29074.5_{R} = 183.3$$

Comparing the chi-square statistic (183.3) to the critical chi-square value (9.48), this research concludes that heteroscedasticity is present. Heteroscedasticity is corrected for by specifying multiplicative heteroscedasticity in the variance equation for the four variables, defined in (Judge et al., 1985) as:

(8) $$E\left[e_{it}^2\right] = \sigma_{it}^2 = \exp[\alpha_1 + \alpha_2 Vol_{it} + \alpha_3 AvgAge_{it} + \alpha_4 AvgWt_{it} + \alpha_5 AvgMBred_{it}]$$

This form of heteroscedasticity is specified in the MIXED procedure by using the local option in the repeated statement, which produces exponential local effects (SAS Institute Inc., p. 5300).

CHAPTER V

RESULTS

The hedonic model formulated in Chapter Four was estimated using the MIXED procedure in SAS Enterprise Guide 5.1. This chapter presents findings and results for the characteristics described in the previous chapter. This research uses the fifteen years of AMS auction data to estimate coefficients for Equation (6). Contrary to previous studies, this study includes age, weight, and months bred as separate binary variables. Estimated coefficients explain the variation in natural logarithm bred cow prices. Coefficients for binary explanatory variables denote a percent premium or discount. Coefficients for the natural logarithm of continuous explanatory variables denote elasticities.

Results from the likelihood ratio test indicated the presence of heteroscedasticity; multiplicative heteroscedasticity was specified in the variance equation as a corrective measure. Correlation coefficients showed high correlation between the feeder cattle futures price and weekly average cull price variables. The cull price variable was dropped from the empirical model (Equation 6). Previous research supports the decision to include futures prices as proxy variables for price expectations (Buccola, 1980; Schroeder et al., 1988; Bailey, Peterson, and Brorsen, 1991; Zimmerman et al., 2012). Equation (1) is revised to express bred cow prices as a function of physical characteristics and market forces.

5.1 Model Results

Estimated coefficients, standard errors, and measures of significance are reported in Table 5.1. Most variables are statistically significant at the 1% level. There was not a significant difference between a lot of four-year-old and a lot of three-year-old bred cows. There was no significant difference between nine months bred and six months bred. All coefficients have the expected sign. The magnitude of some parameter estimates is not as expected. The following sections provide a detailed discussion of each variable included in the bred cow pricing model. The model was used to estimate the value of the base bred cow lot, accounting for seasonality and market factors, sold in the 20th week of the year 2015. To present an alternative interpretation of the results, Table A.3 provides an example of the dollar amount change in the estimated value of the base bred cow lot for a change in a bred cow characteristic, ceteris paribus.

Table 5.1: Hedonic Model Parameter Estimates

Variable	Estimate	Standard Error	T-value	P-value
Intercept	1.4959	0.0243	61.66	<0.0001
Age (Base=3)				
1	0.0326	0.0042	7.74	<0.0001
2	0.0124	0.0045	2.74	0.0061
4	0.0032	0.0031	1.01	0.3104
5	-0.0098	0.0031	-3.19	0.0014
6	-0.0336	0.0028	-12.14	<0.0001
7	-0.0701	0.0032	-21.62	<0.0001
8	-0.1141	0.0034	-33.69	<0.0001
9	-0.1704	0.0036	-47.17	<0.0001
10	-0.2336	0.0034	-68.32	<0.0001
Wt (Base=901-1000)				
700-800	-0.1163	0.0111	-10.45	<0.0001
801-900	-0.0495	0.0048	-10.37	<0.0001
1001-1100	0.0344	0.0027	12.58	<0.0001
1101-1200	0.0654	0.0029	22.79	<0.0001
1201-1300	0.0885	0.0032	27.47	<0.0001
1301-1400	0.1058	0.0041	25.66	<0.0001
1401-1500	0.1330	0.0068	19.65	<0.0001
1501-1600	0.1232	0.0155	7.96	<0.0001
1601-1700	0.1271	0.0394	3.23	0.0012

Table 5.1: Hedonic Model Parameter Estimates (continued)

Variable	Estimate	Standard Error	T-value	P-value
MBred (Base=6)				
1	-0.1232	0.0571	-2.16	0.031
2	-0.0787	0.0072	-10.91	<0.0001
3	-0.0672	0.0029	-23.35	<0.0001
4	-0.0415	0.0026	-15.82	<0.0001
5	-0.0163	0.0021	-7.96	<0.0001
7	0.019	0.0021	9.25	<0.0001
8	0.0357	0.0032	11.17	<0.0001
9	0.0007	0.0642	0.01	0.9909
HColor	0.0667	0.0017	39.16	<0.0001
Qlty (Base=Average)				
High	0.1374	0.0019	72.50	<0.0001
Average-High	0.0835	0.0029	28.59	<0.0001
Low-Average	-0.0620	0.0076	-8.11	<0.0001
Low	-0.1491	0.0055	-27.04	<0.0001
Loc (Base=Oklahoma City)				
El Reno	0.0197	0.0044	4.52	<0.0001
McAlester	0.0209	0.0048	4.34	<0.0001
Tulsa	0.0631	0.0050	12.73	<0.0001
Woodward	0.0643	0.0044	14.72	<0.0001
Ada	0.0345	0.0045	7.60	<0.0001
Apache	0.0437	0.0046	9.53	<0.0001
Cos26	-0.0150	0.0018	-8.16	<0.0001
Sin26	0.0166	0.0018	9.48	<0.0001
Cos52	0.0208	0.0019	11.14	<0.0001
Sin52	0.0539	0.0018	30.37	<0.0001
Feeder	1.1137	0.0055	203.52	<0.0001
Corn	-0.0891	0.0034	-26.06	<0.0001
Variance of Error Term				0.02265
Random Effect				0.00495
-2 Log Likelihood				-29074.5

5.1.1 Effect of Cow Age

Age had a significant impact on the price received for a lot of bred cows. Most age binary variables have a significant effect ($P < 0.0001$). There was no significant difference between a lot of four-years-old and a lot of three-year-old bred cows. Buyers seem to be indifferent between cows that are three and four years of age. Bred cows that have an average age less than three had a positive impact on price while those that were older than three had a negative impact on price. Bred cow lots sold as one-year-olds received the greatest premiums; their respective price was 3.26% higher than a lot of three-year-olds. Ten-year-old bred cows received a price that was 23.36% below the price of a lot of three-year-olds. Eight and nine-year-olds brought discounts of 11.41% and 17.04%, respectively. Results for age warrant further discussion on the estimated premiums for young bred cows and the discounts brought by older cows.

The magnitude of the effect for first calf heifers, classified as one-year-olds, was not as expected. In some sense age, recorded in years, may be too broad a scale to evaluate the value of heifers accurately. Age is more of a reference to the number of calves produced by a cow. In reality, a first calf heifer would, at the earliest, be around fifteen months of age at the time of conception, which would result in a calf around 24 months of age. There is a level of risk linked to first calf heifers. Buyers do not necessarily know what their purchased cow was bred to, which leads to performance uncertainties. In addition to calving problems, there is risk associated with the rebreeding of a heifer. However, this research suspects that this risk is overshadowed by the useful life of a young bred cow, which results in the higher estimated premium.

In Chapter One, it was noted that in Oklahoma auctions, there are two subclasses of bred cows sold. Producers are marketing both young replacement cows and older cull cows as bred. Older bred cows are assigned discounts at an increasing rate (Figure 5.1). Producers who are considering the marketing of older cull cows as bred should acknowledge the heavy discounts assigned as age increases. The price brought by a ten-year-old bred cow may be lower when compared to cull cow prices. On average, ten-year-old bred cows received a price that was $160.57/head higher than their respective weekly average Oklahoma City cull cow price. However, 96 lots of bred cows brought a price that was lower than their respective weekly average cull cow price. Producers should determine if there is enough added value to outweigh the heavy discounts brought by older cows. In some instances, it may be more beneficial for a producer to market their older cows as open rather than bred.

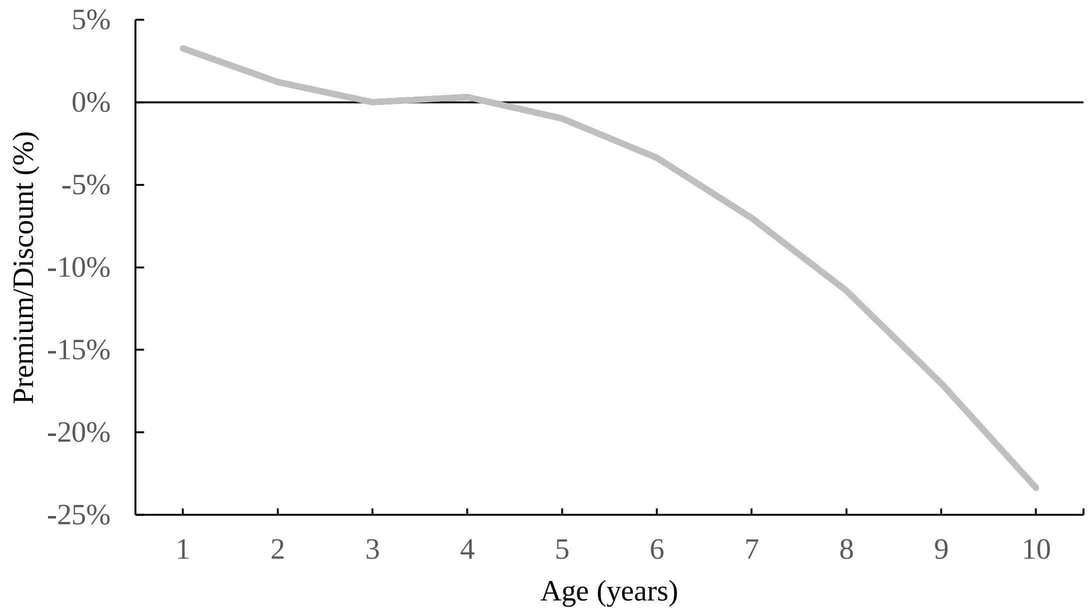

Figure 5.1: Effect of age, base age is 3 years

5.1.2 Effect of Cow Weight

Weight appears to have a positive but diminishing impact on price (Figure 5.2). All of the parameter estimates for the nine distinct hundred pound weight classes significantly affect price ($P<0.0001$). Cows in weight classes below the base weight class, 901 to 1000 lbs., received discounts while cows weighing more than the base weight class brought premiums. Cows weighing between 700 and 800 lbs. received a discount of 11.63%. Cows weighing between 1400 and 1500 lbs. received the greatest premium of 13.3%. In recent years, there has been a lot of discussion in the academic literature and popular press about optimal cow size and to some extent moderating the weight of the commercial beef cow. Results presented here suggest that buyers place the greatest value on cows weighing well above the average. However, the small marginal change in the value for cow weight indicates that the value reaches a maximum at higher weight classes. This research suspects that producers place greater value on heavier bred cows because of the perceived health implications associated with lighter weight cows. Additionally, producers may relate heavier cows to a heavier calf.

The small marginal change in the value of weight at heavier weight classes brings to question the significance of the three heaviest weight classes relative to one another. This research suspects that buyers don't discern value between the heaviest three weight classes. Furthermore, to test that the value of weight reaches a maximum at 1401 to 1500 lbs., the following joint hypothesis, Equation (9), was tested using the contrast statement in the MIXED procedure. To examine the hypothesis further, three pairwise hypotheses, Equations (10) to (12), were formulated to test the significance of any two weight classes separately.

(9) $$H_0: \beta_{24}Wt_{1401-1500} = \beta_{25}Wt_{1501-1600} = \beta_{26}Wt_{1601-1700}$$

(10) $$H_0: \beta_{24}Wt_{1401-1500} = \beta_{25}Wt_{1501-1600}$$

(11) $$H_0: \beta_{25}Wt_{1501-1600} = \beta_{26}Wt_{1601-1700}$$

(12) $$H_0: \beta_{24}Wt_{1401-1500} = \beta_{26}Wt_{1601-1700}$$

(13) $$H_a: Otherwise$$

Rejecting any of the null hypotheses would imply that producers maintain different values for the three heavies bred cow weight classes. Results for the four hypotheses are listed in Table 5.2.

Table 5.2: F-Test Results for Bred Cow Weight Classes

Equation Number	F-Value	P-Value	Conclusion
(9)	209.24	<0.0001	Reject H_0
(10)	0.37	0.5446	Fail to Reject H_0
(11)	63.31	<0.0001	Reject H_0
(12)	386.08	<0.0001	Reject H_0

Test results for the four hypotheses indicate that buyers value heavier bred cows differently relative to one another, with the exception of hypothesis (10). We fail to reject the null hypothesis (10). The result for hypothesis (10) shows that buyers do not value bred cows weighing between 1401 and 1500 lbs. differently from cows weighing between 1500 and 1600 lbs. Parameter estimates for weight indicate that the value of weight reaches a maximum at 1401 to1500 lbs. Results for the hypothesis test suggest otherwise. Buyers do not pay significantly more for cows weighing between 1401 and 1500 lbs. as compared to cows weighting between 1501 and 1600 lbs.

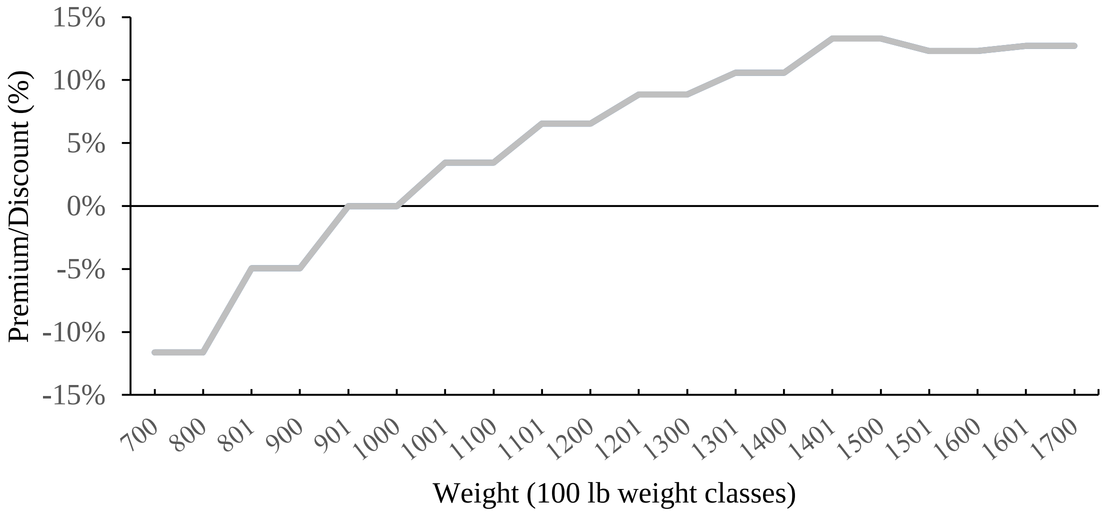

Figure 5.2: Effect of cow weight, base weight class is 901 to 1000 lbs.

5.1.3 Effect of Months Bred

All coefficient estimates for months bred have the expected sign. Most of the binary variables for months bred are statistically significant ($P<0.0001$). There was not a significant difference between nine months and six months bred. Of the 14,811 lots collected, only two lots were reported as nine months bred, which leads to an insignificant estimate. Cows that are less than six months bred received discounts while cows more than six months bred brought premiums. Cows that were one month bred received a price that was 12.32% below the price of a six-month bred cow. Lots that were eight months bred received the greatest premiums. Results reveal that producers place the highest value on late gestating cows. This result is likely due to the risk linked to early gestating cows. There is less risk of losing the calf and lower feed carrying cost prior to the calf's birth when producers purchase late gestating cows. The estimates for months bred indicate that the value increases at a decreasing rate up to a maximum at eight months bred (Figure 5.3).

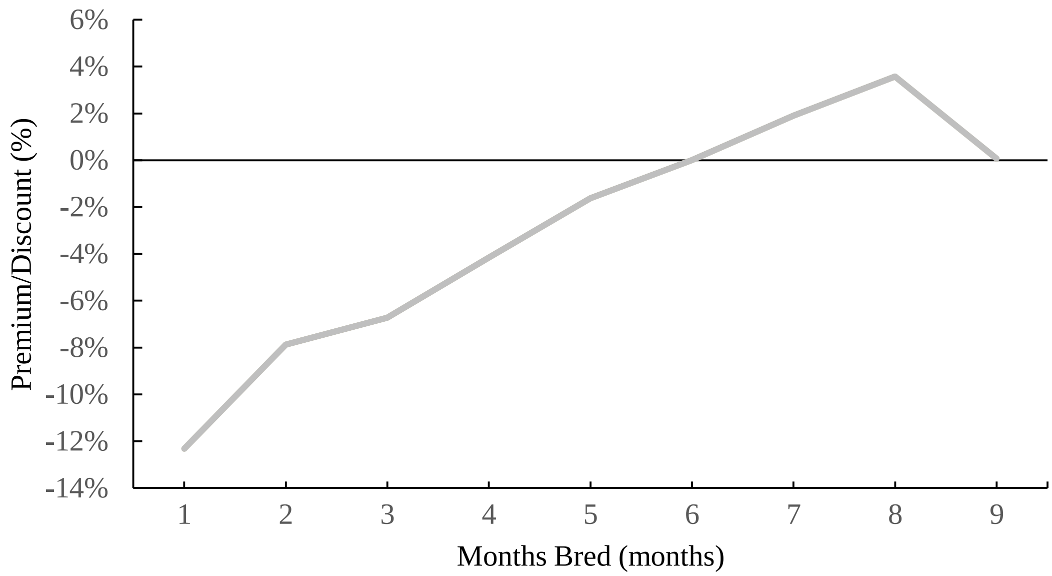

Figure 5.3: Effect of months bred, base months bred is 6 months

5.1.4 Effect of Cow Quality and Hide Color

All coefficients for hide color and quality are significant and have the expected sign. Most previous research has indicated that producers use hide color rather than breed to distinguish between classes of cattle (Williams et al., 2012). The only hide color reported for bred cows in AMS reports is black. The coefficient for hide color suggests that black cows bring a price 6.67% higher than nonblack cows.

One of the more subjective traits reported is the quality of the bred cows sold. There is no standard grading scale for bred cow quality. AMS reporters are consistent in their evaluation of cow quality which leads to an impactful variable. A premium of 13.74% is paid to high-quality cows. Low and low-average quality bred cows were given discount of 14.91% and 6.95, respectively. Cow quality has breeding, calving, and health implications. Producers purchasing bred cows for replacement cow purposes place greater value on black, high-quality cows. Producers marketing older cows as bred should consider the tradeoffs between improving cow quality and the costs linked to improving those traits which result in higher quality.

5.1.5 Effect of Sale Location

While prices vary across sale locations, quality and demographic characteristics of the bred cows sold seem to be fairly consistent across sales (Table A.2). This research postulates that bred cow markets are strong regional markets, which results in significant estimates (Table 5.1). Estimates for location were statistically significant (P<0.0001) suggesting there is a location effect across sales in Oklahoma. Relative to Oklahoma City, cows sold in all other locations received premiums ranging from 1.97 % at El Reno to 6.43% at Woodward. Oklahoma City is a leading market for feeder cattle. However, results suggest that Oklahoma City is not where buyers go to invest in bred cows. Furthermore, buyers may find it more convenient to purchase bred cows closer to home as compared to transporting cows from Oklahoma City and are willing to pay premiums for this convenience. Producers may prefer to invest in breeding animals in markets that are in closer proximity to where the majority of cows in Oklahoma are located (Figure 5.4).

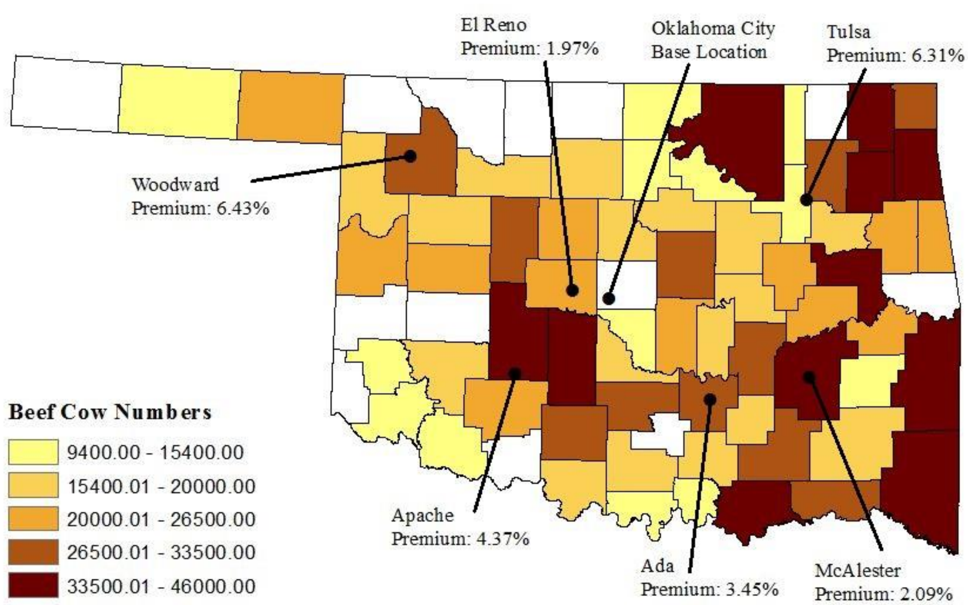

Figure 5.4: 2012 beef cow county estimates and sale location premiums
Data Source: USDA NASS

Figure 5.4 shows the distribution of beef cows across the state. Beef cows appear dispersed across Oklahoma, which may explain why all sales receive premiums compared to Oklahoma City. This research suspects that Woodward and Tulsa receive greater premiums due to their isolation from the other reporting auctions; the remaining five sales are all in closer proximity to at least one other sale location.

5.1.6 Price Expectations

This research used futures prices to account for changing market conditions across time. Coefficients for the CME feeder cattle and corn futures prices are statistically significant ($P<0.001$) and have the expected sign. The corn futures price was used to reflect changes in expected feed costs. The lagged corn futures price has a negative impact on bred cow prices. When the previous weeks corn futures price increases by 1%, bred cow value is expected to decrease by 0.089%. The feeder cattle futures price is commonly used as an intermediate product price (Schroeder et al., 1988). A 1% increase in the previous weeks closing feeder cattle futures price leads to a 1.11% increase in bred cow value. As feeder cattle value increases producers are willing to invest more money in bred cows.

5.1.7 Seasonality

This research uses sine and cosine terms to account for seasonal price variation. Results for the sine and cosine terms agreed with the original monthly dummy variables, which suggests that the sine and cosine terms accurately account for bred cow price variation across weeks. In order to illustrate the impact of price seasonality, the four estimated sign and cosine terms are plotted for a 52 week year (Figure 5.5). Prices are at their highest in the months of February and March. The results for months bred suggest that producers value late gestating cows. Producers who have a spring calving herd place the greatest value on late gestating cows in the months of February and March, because a calf will be born at a time that fits their calving schedule. This research suspects that prices are at their lowest in the summer due to limited forage; late gestating cow scheduled to calve in the summer would fall in between the two traditional calving seasons.

Prices experience a second low point in the fall, which might be related to increased volume similar to what has been documented for cull cow markets (Figure 5.6).

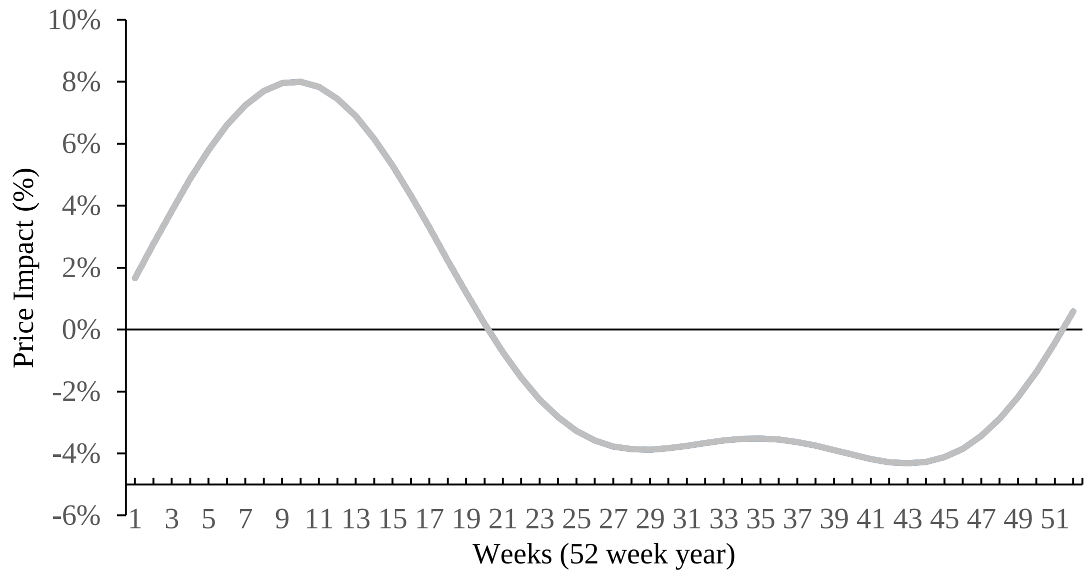

Figure 5.5: Bred cow price seasonality

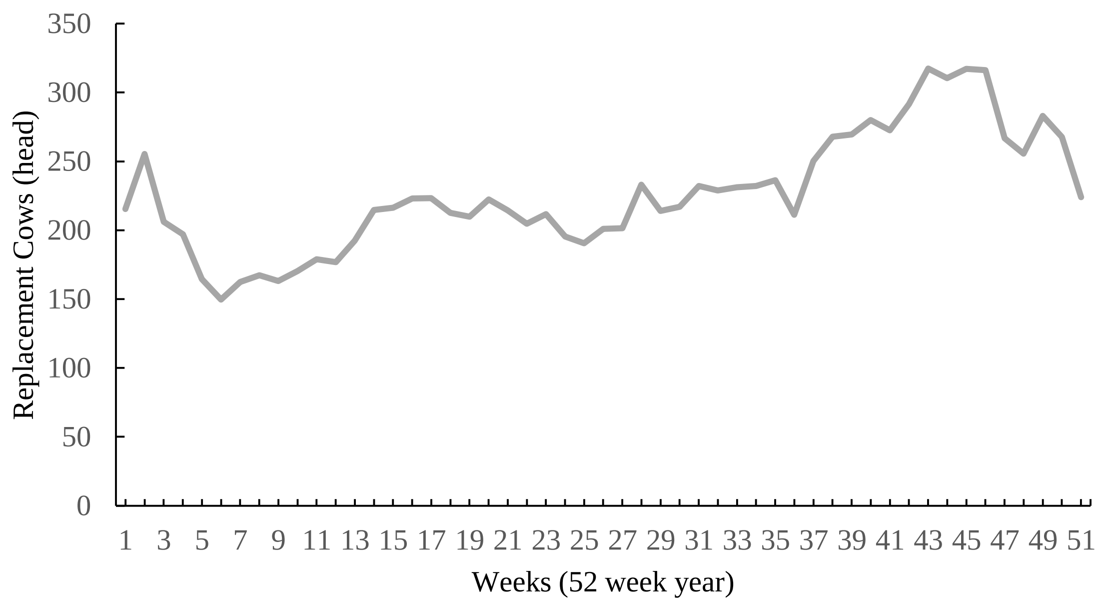

Figure 5.6 Average replacement cow sale volume for the seven Oklahoma auctions, 2000-2015

CHAPTER VI

CONCLUSIONS AND DISCUSSION

This research estimated the price determinants of bred cows sold in seven Oklahoma auctions. Previous studies have found that livestock characteristics have a significant role in determining prices. This paper addresses the question of how physical characteristics, temporal, and marketing factors influence the price of bred cows sold in auctions across the state of Oklahoma. Results and findings discussed in this research will help improve production decisions relating to cow retention, procurement and marketing.

To address the question presented here, a theoretical pricing model, similar to Schroeder et al. (1988), Williams et al. (2012), and Zimmerman et al. (2012) was formulated. Bred cow prices are a function of physical characteristics, market forces, and salvage value. Results from estimated correlation coefficients indicated that the cull cow price be dropped from the model. The theoretical bred cow pricing model was later revised to specify prices as a function of physical characteristics and market forces. Hedonic modeling was employed to estimate the final proposed pricing model.

Fifteen years of AMS auction reports were collected for the seven Oklahoma sales. The completed dataset includes 776 weeks comprised of 14,811 bred cow lots. Results reveal that physical characteristics have a statistically significant impact on bred cow prices. First calf heifers and two-year-old bred cows received significant premiums of 3.26% and 1.24%, respectively. Relative to nonblack cows, black-hided cows brought premiums of 6.67%.

Producers selling young beef replacement cows should market cows that are of average-high and high quality. Producers marketing their older cull cows as bred should weigh the significant premiums for improved quality against the costs of improving those quality measures that are improvable. Producers pay significant premiums for cows weighing more than 1000 lbs. Bred cows weighing between 1401 and 1500 lbs. had the greatest positive impact on price; their respective price was 13.30% higher than a lot of cows weighing between 901 and 1000 lbs. Producers place greater value late gestating cows as compared to six months bred cows.

The hedonic model estimated in this paper accounts for market forces, which include sale location and proxies for changing market conditions. Similar to previous studies, this research includes CME feeder cattle and corn futures prices to account for market expectations (Schroeder et al., 1988). Results for the two futures prices are consistent with previous research. Corn futures prices had an adverse impact on bred cow prices while feeder cattle futures prices had a positive impact. Results for sale location indicate that bred cows received premiums at all six locations when compared to the base sale.

6.1 Discussion

In an industry where marketing strategies are becoming increasingly more important, the information presented here may allow producers to improve upon their current practices. The results found in this research will benefit both buyers and sellers. Findings indicate that price incentives exist for producers to market bred cows with traits that buyers find desirable. This paper also has significant implications for future research.

Previous research has found that cull cow retention and delayed marketing as bred has the potential to be a profitable opportunity for Oklahoma producers. Amadou (2012) found that the most profitable retention strategy is one that retains cull cows for 63 days on pasture before marketing them as bred. Future studies should draw on conclusions found in this research and those found by Amadou (2012) and Amadou et al. (2014). The results found by both Amadou

(2012) and Amadou et al. (2014) paired with the premiums and discounts found in this study may aid producers in determining how much it pays to market cows as bred rather than cull cows.

6.2 Limitations

There are data limitations in this research. In addition to price, the characteristics age, weight, and months bred are reported as ranges for the aggregated bred cow lots. This study takes the midpoint of each range as the observation for each lot. In cases where an observed lot has a wide range reported for any of three characteristics, the midpoint may not accurately reflect that characteristics relationship with price.

In addition to the format of the bred cow sale reports, there may be relevant information not reported by the AMS staff. Specifically, it may be useful to know the frame size and muscling score of the bred cow lots. Frame size is a measure of the skeletal size of the animal. Larger framed cows will be in higher weight classes. Some buyers may in fact value medium and, to some extent, smaller-framed cows, as they may be a better fit for their production system. Data on frame size would allow this research to account for and model the interaction between cow weight and frame size.

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APPENDIX

Table A.1: Sale Locations and AMS File Names

Sale Location	File Name	Time Period	Sale Type
Oklahoma City	KO_LS155	2000-2015	Two Day
Tulsa	KO_LS760	2000-2015	One Day
McAlester	KO_LS752	2000-2015	One Day
El Reno	KO_LS156	2000-2010	Two Day
	KO_LS157	2010-2015	Two Day
Woodward	KO_LS753	2000-2005	One Day
	KO_LS152	2004-2015	Two Day
Tulsa	KO_LS760	2000-2015	One Day
Ada	KO_LS757	2000-2008	One Day
	KO_LS154	2008-2012	Two Day
	KO_LS757	2012-2015	One Day
Apache	KO_LS754	2000-2008	One Day
	KO_LS153	2008-2013	Two Day
	KO_LS754	2013-2015	One Day

Note – Sale type denotes if the cow and feeder cattle sales are held on the same day.

Table A.2: Summary of Data Collected by Sale Location, 2000-2015

	Sale Location:						
	Ada	El Reno	Apache	Tulsa	Woodward	Oklahoma City	McAlester
Number of Sales	625	650	618	525	667	725	584
Number of Lots	1871	2578	1817	1058	2846	3197	1451
Averages:							
Age (years)	5.27	5.48	5.51	5.70	5.76	5.82	5.26
Weight (lbs.)	1106.54	1114.66	1104.66	1142.65	1170.31	1115.28	1126.10
Months Bred (months)	5.26	5.57	5.39	5.36	5.38	5.22	5.92
Quality	3.50	3.49	3.25	3.28	3.61	3.40	3.33
Hide Color	1.57	1.49	1.11	1.27	1.65	1.45	1.10
Price ($/head)	975.62	938.52	869.31	957.75	980.53	848.47	1060.44
Sale Volume (head)	290.59	189.56	187.00	171.55	501.90	238.68	151.45

Table A.3: Example of the Dollar Impact of Bred Cow Characteristics

Characteristic	Estimate	Example $/Head	Characteristic	Estimate	Example $/Head
Age			*Weight*		
1	+3.26%	+$51.54	700-800	-11.63%	-$183.87
2	+1.24%	+$19.60	801-900	-4.95%	-$78.26
3	**Base**	**$1,581.00**	**901-1000**	**Base**	**$1,581.00**
4	-	-	1001-1100	+3.44%	+$54.39
5	-0.98%	-$15.49	1101-1200	+6.54%	+$103.40
6	-3.36%	-$53.12	1201-1300	+8.85%	+$139.92
7	-7.01%	-$110.83	1301-1400	+10.58%	+$167.27
8	-11.41%	-$180.39	1401-1500	+13.30%	+$210.27
9	-17.04%	-$269.40	1501-1600	+12.32%	+$194.78
10	-23.36%	-$369.32	1601-1700	+12.71%	+$200.95
Months Bred			*Location*		
1	-12.32%	-$194.78	Ada	+3.45%	+$54.54
2	-7.87%	-$124.42	Apache	+4.37%	+$69.09
3	-6.72%	-$106.24	El Reno	+1.97%	+$31.15
4	-4.15%	-$65.61	McAlester	+2.09%	+$33.04
5	-1.63%	-$25.77	**Oklahoma City**	**Base**	**$1,581.00**
6	**Base**	**$1,581.00**	Tulsa	+6.31%	+$99.76
7	+1.90%	+$30.04	Woodward	+6.43%	+$101.66
8	+3.57%	+$56.44	*Hide Color*		
9	-	-	Black	+6.67%	+$105.45
Quality			**Nonblack**	**Base**	**$1,581.00**
High	+13.74%	+$217.23			
Average-High	+8.35%	+$132.01			
Average	**Base**	**$1,581.00**			
Low-Average	-6.20%	-$98.02			
Low	-14.91%	-$235.73			

Note: - indicates an insignificant estimate for the corresponding characteristic.

Note: Base denotes the base value and characteristic for the bred cow reference lot described in Section 4.4.1

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