SALE PRICE RELATIONSHIPS TO PERFORMANCE CHARACTERISTICS AND GENETIC MERIT IN BEEF BULLS SOLD IN BEEF CATTLE IMPROVEMENT SALES AND TESTS IN THE SOUTHEAST USA FROM 1974 TO 2011

By

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Herd sires are an important investment for beef cattle producers in the Southeast United States of America (USA). For producers, bull selection decisions are critical to introduce new and compatible genetics into their cow herd. The impact of bull selection affects the cow herd and many calf crops when heifers by these herd sires are retained for breeding replacements. The objective of this study was to determine the relationships over time between bull sale prices and individual performance and measures of genetic merit for bulls sold in the state of Alabama, Mississippi, and North Carolina. The study was conducted using data from Beef Cattle Improvement Association (BCIA) and Beef Cattle Improvement Program (BCIP) bull sales from 1974 to 2011. All sales maintained a core set of qualifications. These were used in a hedonic pricing model to analyze their impact on the actual sale price for each bull.

DEDICATION

I would like to dedicate this research to my future wife, Lauren Bramblett, who supported my decision to pursue graduate school at Mississippi State University.

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CHAPTER I

INTRODUCTION

Producers spend years, even decades, establishing productive and profitable beef cow herds. There are many management practices that producers utilize in order to enhance profitability. Genetic improvement and crossbreeding are two such practices that are implemented via bull selection. Beef cattle operations in the Southeast United States of America (USA) have undergone changes throughout the years. The size and specialization of operations have increased and the use of contract production arrangements for risk management has been substantial (USDA/ERS, 2011; USDA/NAHMS, 2008). Likewise, genetic improvement programs have evolved over time.

State Beef Cattle Improvement Association (BCIA) sales have established a reputation of upholding a very strong marketing relationship between seedstock producers and commercial bull buyers and cattle producers. Bull test programs allow cattle producers the opportunity to compare their cattle directly to the cattle of other breeders (Mills, 2002). Beef cow operations declined from 901,870 in 1992 to 742,000 in 2010, whereas average beef cow herd size increased from 37.0 head to 42.3 head. Calf weaning weights increased while weaning age decreased from 1992 to 2010, suggesting improved genetic merit through sire selection and management practices. The percent of cattle operations that use artificial insemination has remained relatively constant from

1992 to 2010, 5.4 to 8.0 percent, respectively, suggesting that cows in the USA are still most commonly being inseminated by herd sires (McBride and Mathews, 2011).

This analysis addresses the purchasing and selling of herd sires. Bulls have a major impact on economic returns for cow-calf producers. Above its salvage value, the monetary value of a bull is determined by its expected contributions to the production of live calves and the genetic makeup of those calves. Bulls represent 50% of the genetic makeup of each calf crop and, for producers who retain heifers for breeding herd replacements, 90% of cow herd genetic change (Wagner et al., 1985). Bulls are an important investment for cow-calf producers because, over time, they introduce most of the genetic attributes into typical beef cow herds. Therefore, heritable bull traits should affect bull purchase prices.

Bulls possess a large number of traits to consider in pricing (Dhuyvetter et al., 1996). Historically, commercial cattle producers selected bulls predominantly based on visual appraisal (Corah et al., 1987). Visual-based selection is subjective and does not necessarily indicate genetic or performance potential of a bull's progeny. Factors affecting bull purchasing decisions include structural soundness, conformation, appearance, breed, temperament, price, reputation of breeder, weaning weight, yearling weight, birth weight, hip height, frame score, calving ease, feeder calf futures, and expected progeny differences (EPD) (USDA, 1994; Simms et al., 1994).

Purebred breeders are the principal bull suppliers. They need to be aware of the value of physical and genetic characteristics affecting bull prices to make informed economic decisions regarding the characteristics of bulls they produce and offer for sale. Because genetic changes take time to accomplish, seedstock breeders must be mindful of the various aspects of bull demand over time.

Purebred bull producer reputation is critical and has significant impact on bull prices (Commer et al., 1990; Lillywhite and Simonsen, 2008). The reputation of the seller may be significant for imprinting a trust or bond in the information and quality of bulls the seller consistently provides. In the past, livestock buyers assessed livestock largely on the basis of traits observable at the time of sale and the reputation of the breeder. Location (in-state versus out-of-state), the nature (commercial versus purebred), or the size (small versus large) of the buyer's operation have been shown to affect the prices paid for bulls (Chvosta et al., 2001).

Greer and Urick (1988) found that breeding bull prices were sensitive to calf prices and cowherd inventory. Kerr (1984) found that market mechanisms sufficiently guided the improvement of breeding animals. Clary et al. (1984), using a net present value approach, found that the bid price for breeding bulls increased with the genetic merit of the bull. Dhuyvetter et al. (1996) discovered that a variety of characteristics influence bull prices, including both EPD and simple performance measures. Holt et al. (2004) concluded that buyers were interested in bulls that were heavy in both weaning and yearling weights, and possessed quality expected progeny difference measurements.

The objective of this study is to examine the relationship between performance traits, EPD, and characteristics of bulls in relation to the effect they have on the bull's final auction price when sold in state BCIA-sanctioned sales, where specific eligibility guidelines were followed to qualify bulls for sale. It is important to examine the effects that individual bull characteristics have on bull prices in the Southeast USA to demonstrate to producers in the region the historical value placed on these attributes by bull buyers. This study will assist in efforts to explain the reasons why bull buyers decide to purchase a bull and the characteristics that beef bull producers need to emphasize for optimum bull value. The hypothesis for this study is that sale order, EPD, and final weight are significant in determining the price of bulls. This hypothesis is formed by evaluating the results of studies similar to this study performed around the nation over the last half century.

CHAPTER II

LITERATURE REVIEW

Relevant literature to this study can be grouped into the following categories: hedonic price theory and livestock price determinants. The review of hedonic pricing theory is covered in the first section to better understand the theory and applications behind developing hedonic pricing models and attributing values for certain bull characteristics and traits. The review of livestock price determinants explores previous research that utilizes price determining factors to improve understanding of sale prices and will be covered in the second section.

Hedonic Pricing Theory

Rosen (1974) was one of the first researchers to utilize hedonic theory. He developed a model for product differentiation based on the hedonic hypothesis that goods are valued for their utility-bearing attributes or characteristics. The goal of his study was to determine a mechanism for the observations in the competitive case and to use that structure to clarify the meaning and interpretation of estimated implicit prices. The model for Rosen's study depicted a description of competitive equilibrium in a plane of several dimensions where both buyers and sellers locate. Products in the class were described by numerical values of z, a class of commodities that were described by attributes or characteristics, and offer buyers packages of characteristics, in which product differentiation implies that a wide variety of alternative packages are available. Once price differences among goods are recognized as equalizing differences for the alternative packages they embody, economic content of the relationship between observed prices and observed characteristics become evident. His model introduces a market between buyers and sellers and producers to adapt their goods to exemplify final characteristics preferred by customers and receive profits for serving economic functions as intermediaries (Holt et al., 2004).

Hedonic pricing posits that the price of a good is the combination of the values of the individual characteristics that make up that good. Therefore, a good is a collection of characteristics that are sold as one basic unit for one observed price. The overall price of the good consists of the sum of the values of the individual characteristics. When the attribute price is not revealed directly, it is said to be an implicit price. It is the unobservable nature of bull attribute values, for example, that makes applied research necessary. Researchers can estimate implicit prices using statistical methods such as regression analysis. Although the values of attributes that bulls possess are not directly observed, comparing the observed prices paid for bulls with different attributes allows for estimation of the implicit prices that buyers were willing to pay for the various attributes (Smith, 2007). Producers ultimately make their purchasing decisions based on the demand of beef by the consumers who purchase the beef in the retail outlet.

A study conducted by Coatney et al. (1996) used hedonics in a study to statistically account for selected characteristic interdependencies that could be associated with the pricing decisions of feeder cattle buyers. This study assessed the magnitude of the direct, total indirect and total price impacts of selected interrelated and independent factors on the overall price paid for a given lot of feeder cattle. Feeder cattle markets were analyzed at the micro level so the model could account for interdependencies in order to determine the source(s) of indirect price impact(s) of changes in exogenous variables in price. The empirical model included physical characteristics, market factors, marketing techniques, seller-added characteristics, climate/environment influences, and seller characteristics, along with possible interdependencies that are indicative of forward contract transactions, including video markets.

Sales data on individual lots sold were gathered from the Superior Livestock Satellite Video Auction. Feeder cattle consisted of 2,441 sale lots and 790 lots that were not sold. These lots represented the entire population of 3-stage Superior Livestock Satellite Video Auction feeder cattle offered for sale in 1992. A least squares model was used to adjust for the possibility of equations being related through nonzero covariances associated with error terms across different equations and to account for structural simultaneity of equations. Results suggested that frame score variance, cattle originating from hot relative to cold regions, proportion of polled animals related to non-polled, cash expectations, distance hauled, sex slide, and weight slide were all statistically significant in describing price. Coatney et al. (1996) described physical characteristics of feeder cattle and market factors exhibited the largest numbers of significant direct price determinants. These results suggested that an increase in average frame score, average weight, average flesh score, and pencil shrink each negatively impacted price.

Livestock Price Determinants

Researchers, producers, and cattle buyers have been trying to pinpoint cattle price determinants for some time. Research continues because there are constantly changing market conditions, marketing methods, and available quantified cattle traits. The cattle industry needs to be able to quantify these determinants and use them to be more efficient throughout the industry. To accomplish this task, analyses must be performed on available cattle price data in the context of market and industry structure and conditions to assess the driving forces in cattle purchasing decisions.

Ordinary least squared regression has been documented by researchers as a method to analyze bull sale data effectively (Commer et al., 1990; Turner et al., 1991; Holt et al., 2004; Dhuyvetter et al., 2005). Regression analysis is concerned with the study of the dependence of one variable, the dependent variable, on one or more other variables, the explanatory variables, with a view to estimating and/or predicting the mean or average value of the former in terms of the known or fixed values of the latter (Gujarati and Porter, 2009).

Warren (1957) reported three factors accounting for 70% of the total variation in sale price of 64 performance-tested bulls in Alabama in 1956. These factors were average daily gain (ADG) on test, conformation score, and weight per day of age. Another study by Marlowe (1969) conducted from 1959 through 1968 limited the variables used in the study to the ones that were made available in the sale catalog for the buyer to see at the time of the sale. In this study, there were 16 variables observed: (1) herd of origin, (2) year of the sale, (3) order within the sale, (4) preweaning ADG, (5) weaning grade, (6) 365-d weight, (7) 140-d test ADG, (8) end-of-test final grade, (9) lifetime ADG (birth to end of test), (10) sale weight, (11) sale age, (12) pedigree evaluation for dwarfism, (13) flesh condition, (14) masculinity development, (15) tail setting, and (16) horned or polled condition of the Herefords. Results of this study found the most important criterion in bull selection among both Angus and Hereford bull buyers was type and conformation as evaluated by a numerical grade. The Marlowe (1969) study found that bull buyers considered size second in importance only to conformation when purchasing herd sires.

Also noted was weaning weight having little emphasis on price. Age was noted as having less importance when determining price for Hereford bulls.

A study conducted by VanTassell and Bessler (1988) found that bull prices lag behind feeder and slaughter cattle prices because bulls are purchased as capital assets and producers' price expectations of future cattle prices do not change instantaneously. Also, they reported the price of slaughter bulls has a more immediate, but shorter lived, effect upon the price of purebred bulls than feeder or slaughter steer prices. They also reported that prices of purebred bulls moved simultaneously with changes in cow-calf pair prices because these prices contain producers' expectations of the value of breeding stock as well as the value of calves. The study confirmed what they had hypothesized.

A 10-yr study published in 1989 involving 566 Angus, Charolais, Simmental, and Hereford bulls determined the effect of breed on performance parameters and their influence on sale price (Cassady et al., 1989). Performance traits analyzed in this study included: (1) 140-d post weaning ADG, (2) 140-d feed to gain ratio, (3) lifetime weight per day of age, (4) adjusted 365-d weight, (5) performance index, (6) frame score, and (7) scrotal circumference. Main effects (breed and year) were significant for 140-d ADG, lifetime weight per day of age, 140-d feed to gain ratio, and adjusted 365-d weight and for frame score and scrotal circumference. Sale price ratio was positively correlated with performance index, adjusted 365-d weight, 140-d ADG, frame score, and negatively correlated with 140-d feed to gain ratio.

Dhuyvetter et al. (1996) described bulls as being an important investment for commercial beef cattle producers because, over time, bulls introduce most of the new genetic attributes into typical beef cow herds. Additionally, the authors suggested that heritable bull traits determine bull prices and bulls possess a large number of traits to consider in pricing. The important bull price determinants included: (1) bull hair coat color, (2) horn status, (3) conformation, (4) muscling, (5) disposition, (6) age, (7) birth weight, (8) weaning weight, (9) milk EPD, (10) birth weight EPD, (11) weaning weight EPD, (12) sale location, (13) order in which bull was sold, (14) whether or not the bull was pictured in the catalog, and (15) whether or not a percentage of semen rights were retained by the seller. The data collection included 26 purebred beef bull sales in Kansas during the spring of 1993. One-thousand seven-hundred bulls were included representing 7 beef breeds. Incomplete data resulted in 1,650 observations used in the study. The average price paid per bull was $2,306.10. Prices ranged from $650 to $20,000 per bull with 93.6% of the prices in the $1,001 to $5,000 range. Average birth weight was 38.6 kg and adjusted weaning weight was 295.7 kg. The bulls averaged 449-d old with an age range of 298 to 1,136 d. The pricing model was specified as follows:

Bull Price = f (Physical and Genetic Characteristics, Expected Performance Characteristics, Marketing Factors). Eq. 1

Dhuyvetter et al. (1996) concluded bull price was determined by genetic, physical, and expected performance characteristics of the bull and by marketing techniques not necessarily related to the quality of the bull. Breed had no effect on price. Buyers paid premiums for black Simmental, Gelbvieh, and Limousin bulls relative to other hair coat colors within these breeds. Polled bulls received premiums. Premiums were paid for bulls receiving higher subjective ratings for conformation, muscling, and disposition. Price was nonlinearly related to age, indicating producers paid a premium for older bulls, with the premium decreasing as the age increased. Price was negatively correlated with birth weight EPD for most breeds. Birth weight EPD were statistically different for only 3 of the breeds. Bull prices were positively correlated with adjusted weaning weight. Prices were positively correlated with weaning weight EPD for all breeds and statistically different for all breeds except Charolais and Red Angus. Milk production EPD significantly affected bull prices in 3 of the breeds and was positively correlated with price. Expected progeny differences were statistically significant in explaining prices for Angus, Gelbvieh, and Simmental bulls. Bull prices varied considerably among sales indicating seller reputation, location, and marketing factors not included in the analysis significantly impacted price. Bull prices declined as the sale progressed.

More recently Dhuyvetter et al. (2005) re-examined the economic values of EPD and how they relate to the values assigned to actual weights. They also assessed the impact that ultrasound EPD had on Angus bull prices. The pricing model for this analysis was as follows:

Bull Price = f (Actual production measures, Production EPD, Ultrasound EPD, Marketing factors, Sire, Sales). Eq. 2

Purebred bull purchasers used information from both actual physical characteristics and EPD when making bull purchasing decisions. Buyers seemed to pay particular attention to birth weight EPD, adjusted yearling weights, and ultrasound ribeye EPD.

Taylor et al. (2006) examined price determinants from 1995 to 2002 on quarter horses associated with the Championship Show held in Oklahoma City, OK. Approximately 20% of the horses that entered the ring were competitively bid on and bought back by their owners. Stated reasons for this were lack of information on the horses being sold, difficulty in measuring horse’s potential, or an overvaluation by the owner. Lange et al. (2010) examined price determinants in ranch horses at two Texas auctions from 2005 to 2009. A hedonic pricing model was used to determine parameters affecting horse price. The parameters that significantly affected price included horse color, sex, age-sex interaction, sale order, and consigning ranch.

Seller identity is critical and has a significant impact on bull prices (Commer et al., 1990). Reputation of sellers may be important for instilling trust in information provided by sellers, customer service, business integrity, and recognition for bull quality (Dhuyvetter et al., 1996). Seller reputation was analyzed by Commer et al. (1990) by surveying 48 experienced bull breeders and evaluated them based on: (1) show ring promotion, (2) advertising program, (3) business longevity, (4) public relations activity, and (5) breeder integrity. Quantitative data regarding breeders were unavailable. Surveys were conducted by trained Mississippi Cooperative Extension Service employees, and evaluations were made individually with no cross consultation among the 3 livestock specialists. The initial models used within the analysis consisted of bull price as the dependent variable and yearling weight ratio and frame score as independent variables. To evaluate the breed reputation, data for all bulls tested and sold at the Hinds Community College Evaluation Center, Raymond, MS from 1983 through 1985 were analyzed. All data were obtained from the center personnel. Ordinary least squares (OLS) regression was performed for the analysis. The variable related to breeder promotion was transformed into a set of indicator variables. Breeder reputation was found to be an important factor in determining bull price. Two simplified regression equations were obtained in which slightly over 94% of the variation in breeder reputation was explained by combinations of independent variables including: advertising program, show ring promotion, and breeder integrity. The mean price received by breeders with excellent promotion scores (9.67 to 10.0) was a $600.82 premium per bull over the price received by breeders with general promotion programs.

Schmitz et al. (2003) reported that seller reputation may impact prices received for stocker cattle. However, it was unclear which marketing mechanism generated the greatest benefit from a positive reputation effect. Producer reputation can influence a buyer's bid price in video auctions, private treaty, or perhaps in local sale barn sales (Thrift and Thrift, 2011). Development of a good relationship between cow-calf producers and buyers takes time and increases likelihood but does not warrant higher premiums for preconditioned calves. Significance of several Midwest, Rocky Mountain, and Northwest region sale variables suggest that buyers recognize the reputations of breeders and are willing to pay premiums or discounts for comparable animals sold at different sales (Dhuyvetter et al., 2005).

Seller reputation was also analyzed by categorizing the consigners of two ranch horse sales, resulting in 1038 horses being sold over a 5-yr period from 2005 to 2009, into groups by the number of animals sold in each sale (Lange et al., 2010). Ranches with 20 or fewer horses across all 10 sales were compiled into one category. The significant results for consigning ranch variables included an $1121.44 per horse premium for Ranch 2 over Ranch 1 and a $2778.08 per horse discount for Ranch 9 compared to Ranch 1.

CHAPTER III

SALE PRICE RELATIONSHIP TO PERFORMANCE CHARACTERISTICS AND GENETIC MERIT IN BEEF BULLS SOLD IN BEEF CATTLE IMPROVEMENT ASSOCIATION SALES IN THE SOUTHEAST USA FROM 1974 TO 2011

Introduction

Beef cattle improvement association sponsored tests and sales are utilized throughout the USA to evaluate performance characteristics and genetic merit of growing cattle in homogenous conditions. Some of the first bull test stations were initiated in the early 1950s to demonstrate performance traits and educate cattle producers (Warwick and Cartwright, 1955). Price determinants have been evaluated in feeder calves (Turner et al., 1991; Coatney et al., 1996), heifers (Parcell et al., 2006), and bulls (Warren, 1957; Greer and Urick, 1988; Commer et al., 1990; Dhuyvetter, et al., 1996; Chvosta et al., 2001; Dhuyvetter, et al., 2005; Smith and Foster, 2007; Lillywhite and Simonsen, 2008). Consignment and performance bull test sales are well-known means of facilitating market interaction between sellers of purebred cattle and buyers. Eligibility may vary from sale to sale but generally requires the bull to be healthy and to meet minimum performance standards (Lillywhite and Simonsen, 2008).

Beef Improvement Program Outline

Beef cattle producers generally strive to establish more efficient methods of producing quality cattle. Some of the most important factors that affect production are management, environment, and genetics. These factors affect both bulls and cows from a production standpoint. In 1968, the Beef Improvement Federation (BIF) was founded. Its members were a combination of representatives from many different purebred cattle breeds associations, state BCIA, academic colleagues, and industry partners. The BIF began developing principles for providing standardized indicators of cattle's genetic performance (BIF, 2010). The first guidelines for the national sire evaluations were published in May 1971. They were based on sound principles and the experience of the dairy cattle industry, which promoted the use of mixed-model sire evaluation procedures. From these guidelines, a transition from subjective evaluation to more objective assessment of breeding value in the beef industry has taken place with the aid of technology. The goal of genetic improvement programs is to produce the most accurate genetic predictions of breeding value for animals available as breeding stock for traits of economic importance in commercial beef production (BueLingo Beef Cattle Society, 2010).

General eye appeal, structural soundness, docility, frame size, and balance are traits that a producer can visualize when observing cattle. Visual appraisal is not always indicative of genetic potential a bull may pass on to his progeny. When visual appraisal and objective performance are combined to create a more accurate form of analysis, there is much more to be told about the expectancy of the progeny. According to BIF guidelines, to select a sire that will increase net return from calf production, a producer must select a herd sire with certain goals in mind (BIF, 2010). For use as terminal sires, select bulls with EPD for calving ease direct, birth weight, growth, and carcass merit that are appropriate for the breed and age of their mates, prevailing environmental challenges, and market requirements. For sires that will produce replacement daughters and progeny for sale, add maternal traits to the selection criteria listed. In any of these cases a producer should choose bulls that have appropriate frame size, muscling, and body capacity. With the BIF guidelines for selecting a herd sire in mind, it is obvious that making a decision to purchase a herd sire comes after several steps of evaluation including genotypic and phenotypic traits of bulls. A goal for the evaluation of this data is to be able to take the results of this data set and assist beef cattle producers in their breeding and purchasing decisions for their marketable herd sires.

State BCIA sales have established a reputation of upholding a very strong marketing relationship between seedstock producers and commercial bull buyers. Bull test programs allow cattle producers the opportunity to compare their cattle to the cattle of other breeders (Mills, 2002). Little research has been conducted looking at multiple state BCIA and Beef Cattle Improvement Program (BCIP) sales over the history of the sale programs. Further, a large majority of bull price analysis has been conducted in regions outside the southeastern USA. Bull sale analysis is warranted to compare the Southeast USA to other regions within the USA. Results from this study can be utilized by bull producers as well as buyers to assist them in understanding some of the traits found to be significant price determinants. More precisely, the focus of this research is hedonic analysis of bull prices in the Southeast USA.

Materials and Methods

Animal Care and Use Committee approval was not obtained for this study because data were from an existing database. Analyzed records were recorded by BCIA/BCIP sale personnel during public livestock auction. Data were extracted from sale catalogs and sale summaries from each sale. The authors did not have direct control over the care of the animals included in this study.

Individual Sales

Data were collected from 3 different state BCIA/BCIP bull sale programs. The states included in this research are Alabama, Mississippi, and North Carolina, with one consignment and one bull test sale from Mississippi [Mississippi BCIA (MBCIA) Sale model 1, 1980, 1982 to 1985, 1993 to 1995, 1998, 1999, 2003 to 2011 ; MBCIA Sale model 2, 1993 to 1995, 1998, 1999, 2003 to 2011; Hinds Community College Bull Evaluation Test (HCCBET) Sale, 1991, 1994 to 2002, 2009], two bull test sales from Alabama [North Alabama Bull Evaluation Center (NABEC) Sale, 1988 to 2011; Auburn University Bull Test (AUBT) Sale, 1975, 1979, 1981 to 2001, 2003, 2004], and three bull test sales from North Carolina [Butner Performance Tested Bull (BPTBS) Sale, 1990, 1991, 1993, 1995 to 2010; Piedmont Performance Tested Bull (PPTBS) Sale, 1974 to 1999; Waynesville Performance Tested Bull (WPTBS) Sale model 1, 1981 to 2011; WPTBS model 2, 1989 to 2011]; Table 1.

The MBCIA was founded in 1968. The association is described as an agricultural society made up of cattlemen and cattlewomen joined together for the improvement of their own herds and the herds of beef cattle throughout the state by the systematic recording and use of individual production records. One of the first goals of the association was to form a sale that could be utilized by Mississippi cattle producers. This type of sale would allow producers to market their bulls to other producers in Mississippi and across the country. On the second Thursday of November, 1969, MBCIA sponsored its first bull sale. This was the first sale in Mississippi to require performance information. Gold and silver seals were initially assigned to the bulls to rank their performance, but this stopped in 1990. The MBCIA bull sale program has evolved throughout its tenure to stay current with the qualification trends. This successful sale continues to provide purebred breeders the opportunity to market their bulls with performance information to other producers, purebred and commercial, for the improvement of their herds. This sale is currently hosted in Raymond, MS and has been held in conjunction with the HCCBET sale since the spring of 2008.

The HCCBET hosted their first bull sale in March, 1983. The bull evaluation facility consists of 8 pens, which can accommodate approximately 100 bulls. Purebred breeders from Mississippi and surrounding states consign bulls to the test. Performance information was collected and computed by personnel at HCCBET. Starting in October, after a 21-d warm-up period, bulls were tested in lots and full fed on a twice daily grain-based feeding program in feeding bunks in an open barn. Test length started at 140 d, but was shortened to 112 d. Performance records recorded included adjusted 205-d body weight (BW), test ADG, and end of test BW, adjusted 365-d BW, weight per day of age, performance ratios for the previously mentioned records, yearling hip height, adjusted hip height, frame score, scrotal circumference, and performance index on each animal. The index was calculated from 1983 to 1990 as:

$$\frac{2 * \text{yearling weight ratio} + 1 * \text{average daily gain ratio on test}}{3}$$

The index was calculated from 1991 to present as:

$$\frac{2 * \text{weight per day of age ratio} + 1 * \text{average daily gain ratio}}{3}$$

Sale order was establish based on index value, larger values selling first, from 1983 to 1992. From 1993 to 2003 the sale order was established by adding weight per day of age and ADG, then ordering them based on increased value of that summation. In 2008 the sale order was again rearranged by index number, then by breed. Performance data were collected over four 28-d periods and at the completion of the test a public auction was held. The HCCBET is currently the only centralized grain-based bull test operating in Mississippi. The location of the HCCBET sale is in Hinds County, MS near the city of Raymond.

The AUBT, begun in 1951, was the oldest continuous performance bull test in the USA when the test was closed in 2004. Extension specialists with the Alabama Cooperative Extension Service supervised the test beginning in the early 1980s. Bulls were housed at the Beef Cattle Evaluation facility on the Auburn University campus. The facility, constructed in 1978, consisted of 8 pens with 12 Calan-gates (American Calan, Northwood, NH) installed in each pen. Individual feed intake was measured for a maximum of 96 bulls per evaluation. One evaluation was held each year. Bulls had inside and outside access with inside pen dimensions of 6.1-m wide by 9.1-m long. Water access was adequate and shared between 2 pens. Outside pen dimensions and make up changed over the years to maximize bull health and minimize environmental impact. Until 2002, outside pens consisted of a dirt and stone foundation. In 2002, common bermudagrass (Cynodon dactylon) was planted to minimize nutrient runoff and rock upheaval and improve foot health of bulls. Length and width of the outside pens varied throughout the years for health and soundness of the bulls. Outside pens were improved to 54.9-m wide by 92.7-m long and divided into three 18.3-m strips. Bulls were allowed access to 1 strip per pen weekly. This allowed grass coverage to be maintained for the duration of the test.

From 1977 to 1989, the length of the AUBT was 140 d. In 1990, the test length was shortened to 112 d. In 2000, the test length was again shortened to 84 d. Bulls were fed twice daily with access to ad libitum amounts of feed. Enough feed was placed in each bunk to ensure 0.45 to 2.27 kg remained in each bunk prior to the next feeding. Feed weights were recorded at each feeding. Orts were taken as necessary. Throughout the years, the composition of the feed has remained fairly consistent. Diet ingredients changed due to availability and cost. All diets were formulated for a constant level of total digestible nutrients (TDN) and crude protein (CP). Bulls were sold at the Ham Wilson Livestock Arena in Auburn, AL. The last two years of the test, the bulls were hauled to Cullman, AL to be sold at the Cullman Stockyards. Both locations were open to the public.

The NABEC is conducted on the Donaldson farm in Cullman, AL. The NABEC was established in 1972. Bulls are managed in outside paddocks located on steep inclines making for better physical condition. The bulls are marketed each year at the Cullman Stockyards, Cullman AL. The stockyard is open to the public.

The North Carolina BCIP's primary purpose is to serve as an educational aid for the genetic improvement and promotion of beef cattle. The purpose of the bull test program is to standardize environmental conditions and feed for evaluating post-weaning performance and to provide useful records for the consigner to use in evaluating and planning his breeding program. The purpose of the sale program is to provide a source of and market for performance tested bulls and to promote the use of genetic evaluation technologies. The North Carolina BCIP has sponsored grain-based bull tests in 5 locations throughout North Carolina over the last 43 yr. Currently, the program sponsors 2 grain-based bull tests. Consigners to the bull tests must be members of the North Carolina Cattlemen's Association and have their entire herds enrolled in the North Carolina BCIP, their respective breed association's performance testing program, or a comparable program. There is no restriction on numbers of bulls that may be consigned by a breeder as long as space is available. The maximum number of bulls being tested at the 2 locations are 100 (Butner, NC) and 60 (Waynesville, NC). The bulls are fed a grain-based ration once daily. Sale order within breed is established based on an index, which gives one-third weighting to ADG ratio and two-thirds weighting to adjusted yearling weight ratio.

The BPTBS originated in Rocky Mount, NC in 1969 where the bulls were tested by age in 6 test groups. Bulls were started on feed and given a 19-d adjustment period prior to starting the 140-d feed test. The days on test was later reduced to 112 d. Bulls were fed in approximately 0.4-ha lots per group with open shelters over feed bunks. The top 75 percent of bulls, based upon weight per day of age were offered in the sale. Sale order was established first by breed on a rotational basis and then by highest weight per day of age. The location of the test was moved from the Rocky Mount location to the Butner Beef Cattle Field Laboratory, which is managed by North Carolina State University Agricultural Research Service, in Oxford, NC.

The first bulls were tested at the Butner Performance Bull Test in August 1985. Granville County Livestock Arena was the first host of the sale and is the current location of the BPTBS. The test is sponsored by the North Carolina BCIP and conducted through the cooperative efforts of North Carolina Cooperative Extension, North Carolina Department of Agriculture and the North Carolina Cattlemen's Association. The sale was delayed from Saturday to Monday in 1996 because of an ice storm, and in 2009 weather conditions and a traffic accident prevented some customers from attending the sale. In 2010 a $1,500 floor price was set for all bulls sold through the sale.

The Waynesville Performance Test Bull Sale (WPTBS) originated in Waynesville, NC at the Mountain Research Station operated by the North Carolina

Department of Agriculture. The sale location originated at the Western North Carolina Agriculture Center in Asheville, NC. The test is sponsored by the North Carolina BCIP and conducted through the cooperative efforts of North Carolina Cooperative Extension, North Carolina Department of Agriculture and the North Carolina Cattlemen's Association. Bulls were delivered to the test station, ear tagged, vaccinated 2-wk prior, and sorted by age within breed to 4 test groups. After a 2-wk adjustment period, the bulls were weighed and started the 140-d test which was later reduced to 112 d. The bulls were fed a complete mixed ration. The 1998 sale started video sale of the bulls, where the bulls were filmed previously and the video footage was played during the auction. Time was allotted during the morning for bulls to be viewed. The sale location also moved to the Haywood County Agriculture and Activities Center in Waynesville, NC. In 2010 a $1,500 per bull floor price was set for all bulls sold through the sale.

In addition to the 2 currently active bull test programs in North Carolina, a third discontinued bull test is reported in this study. The PPTBS originated in Statesville, NC in 1973. The sale was conducted at the Iredell County Fairgrounds in Statesville, NC. Bulls were delivered to the test station, ear tagged, weighed, and allotted by age to 6 test groups. All bulls were given a 3-wk adjustment period prior to beginning the 140-d feed test. The bulls were fed a full feed complete mixed ration. Bulls were fed in approximately 1.2-ha lots per group with open shelters and self-feeders. In 1994, the lot size was decreased to 0.5-ha. The test is sponsored by the North Carolina BCIP and conducted through the cooperative efforts of North Carolina Cooperative Extension, North Carolina Department of Agriculture and the North Carolina Cattlemen's Association. The last test and sale was concluded in 1999.

Market Characteristics

All data from this study were collected on bulls sold through Mississippi and Alabama BCIA and North Carolina BCIP. Each of the cattle evaluation centers and consignment sales followed the BIF Guidelines (BIF, 1970, 1972, 1976, 1981, 1986, 1990, 1996, 2000, and 2010). All bulls were consigned by individual breeders in the Southeast USA. A total of 10,108 bulls were consigned to 7 different bull evaluation centers or a BCIA consignment sale in 3 different states in the Southeast USA from 1969 to 2011. Sales were advertised through their respective BCIA or BCIP and open to the public. Spring, autumn, and winter sales were included in the data set. Cattle breeds were representative of British, Continental, and Brahman-influence. All bulls had recently passed a breeding soundness examination (Ball, 1983). Bulls that were not structurally sound, exhibited poor disposition, or that did not meet qualifications for sale were removed from their respective sales. Bulls that were "pulled out" or "no sale" were removed from the analysis. Bulls with missing price values were also removed from the analysis. All bulls were sold through competitive bidding and sold individually.

Explanatory Variable Categories

Variables believed to influence a buyer's decision to purchase a bull were used in 8 different hedonic pricing models. These variables were also chosen because they were consistent with economic theory or used in previous bull price determinant studies. Explanatory variables were categorized into 3 general areas: bull-specific, economic, and sale-specific variables (adapted from Lillywhite and Simonsen, 2008). Bull-specific variables include variables that identify performance and genetic characteristics of a particular bull. Included in this category were the following: sale order percentile (SOP), age in days (AID), actual birth weight (ABW), adjusted 205-d weaning weight (WW), final BW (FW), visual score (VS), scrotal circumference (SC), frame score (FS), birth weight EPD (BWEPD), weaning weight EPD (WWEPD), yearling weight EPD (YWEPD), milk EPD (MILKEPD), and breed (BBRD). The economic variable was: average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK (WFCP). The sale-specific variable was: individual sale. Beyond the variables defined here, there were other variables that were available for the bull buyers; however, they were removed due to insufficient observations, multicollinearity, and confounding with other variables.

Bull-specific Variables

The SOP was derived from the actual sale order of the bulls. Sale order was specified with the variable indicating the percentile rank of the sale order for each sale. This correction follows a previous study (Parcell et al., 2006). The percentile ranking specification accounts for different lot numbers across sales. Actual birth weight was grouped into 3 categories (light, moderate, and heavy) based on BWLT being less than 31.71 kg and BWHV being greater than 40.82 kg. This process was completed for each of the 7 sales. Light (BWLT) and heavy (BWHV) ABW categories were analyzed as 2 binary variables using dummy variables compared to the default moderate birth weight (BWMD) category. Weaning and final weights each illustrated a nonlinear relationship with bull price and were therefore transformed logarithmically. Breed was categorized by sale. Each sale was evaluated for the best representation of breeds in each sale, and the most represented breeds were categorized for the analysis as binary dummy variables. All remaining breeds were categorized as other breeds and set as the default. Frame size was grouped into 3 categories (small, moderate, and large) based on FSSM being less than 5.0

and FSLG being greater than 7.0. This process was completed for 3 of the 7 sales in which adequate FS observations were present. The small (FSSM) and large (FSLG) FS categories were analyzed as 2 binary dummy variables compared to the default moderate FS category. Visual scores were recorded for certain sales and were incorporated into the model when a sufficient number of observations were available. Different VS collection techniques were implemented at different sales. All VS utilized were standardized to a 1 to 10 scale, with 1 representing the least favorable score and 10 representing the most favorable score. Visual score depicted a nonlinear relationship and was transformed to a logarithmic form for correction. Scrotal circumference was measured for each bull and recorded for certain sales. It was added into the model when a sufficient number of observations were available. Scrotal circumference also depicted a nonlinear relationship and was transformed to a logarithmic form for correction. The EPD independent variables included BWEPD, WWEPD, YWEPD, and MILKEPD and were only available in the more recent years (1989 to 2012) for some of the sales (MBCIA, NABEC, BPTBS, and WPTBS). The EPD values ranged from negative to positive values, which cause problems with model specification when values are transformed. To allow for use of the negative values, a constant was added to all EPD values to make all these values positive and preserve the variance (Parcell et al., 2006). The BWEPD was nonlinear and thus transformed as logarithmic. The YWEPD and MILKEPD also illustrated nonlinear relationships with bull price and were subjected to logarithmic transformations. Other bull-specific variables available to bull buyers were removed from the analysis due to insufficient observations or multicollinearity concerns with previously presented independent variables.

Economic Variables

The WFCP was utilized as the economic variable to account for market characteristics over time and price inflation associated with a 40-yr time span. The WFCP was chosen because of the availability of the historical data and its representation of general cattle market trends (Livestock Meat and Wool Market News, 2012). The feeder calf price used in the analysis was the average weekly 226.8 to 272.2 steer price immediately preceeding each bull sale from Oklahoma City, OK. Producer price index for all farm products was originally included in the analysis as a second economic variable but was removed due to correlation and multicollinearity with WFCP.

Sale-specific Variable

Each sale was categorized as a binary dummy variable in the general model with the MBCIA sale as the default. After further analysis of the original model, it was determined that allowing each sale a separate model as depicted by Turner et al. (1991) explained the data more efficiently considering the differences in the individual sale markets. Thus, due to the inherent differences among individual sales (markets, promotion, sale management, and time span of data), each sale was analyzed in a separate pricing model.

Pricing Model

The basic premise of the hedonic pricing method is the price of a marketed good is related to its characteristics. Hedonic modeling refers to the theoretical and practical application of assigning economic value to each characteristic of a bundle of characteristics that is marketed as one product (Parcell et al., 2006). Prices used in the models represent the price per head for individual bulls. Hedonic price determination followed the framework (Rosen, 1974; Ladd and Martin, 1976) of earlier studies. Recent bull price studies (Turner et al., 1991; Dhuyvetter et al., 1996; Chvosta et al., 2001; Dhuyvetter et al., 2005; Jones et al., 2008; Lillywhite and Simonsen, 2008) set the outline for models developed in this analysis. A general model of bull price was developed by eliminating variables based on multicollinearity and exhibiting inadequate observation numbers. Each sale was assigned a binary variable. Combining the sales as one model inaccurately described the data because of differences in variable representation and years being represented. Therefore, this general model was then used to derive unique models for each sale depending on the data availability for each sale. The general bull price regression model was as follows:

Price Model: BP = f (SALE, SOP, AID, BWLT, BWHV, WW, FW, YW, FSSM, FSLG, SC, BWEPD, YWEPD, MILKEPD, WFCP, VS, BBRD). Eq. 3

Where: BP = actual bull price per head in dollars;

SALE = series of binary variables 0 or 1, with MBCIA as default;

SOP = sale order percentile;

AID = bull age in days on the day of the sale;

BWLT = birth weight category less than 31.71 kg;

BWHV = birth weight category greater than 40.82 kg;

WW = adjusted 205-d weaning weight;

FW = final BW;

YW = adjusted 365-d weight;

SC = bull scrotal circumference;

BWEPD = birth weight EPD with constant added;

YWEPD = yearling weight EPD with constant added;

MILKEPD = maternal milk EPD with constant added;

WFCP = average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK;

VS = visual score of bulls on the day of the sale as determined by 3 trained sale personnel;

BBRD = series of binary variables 0 or 1 with other breeds as default;

FSSM = frame score category less than 5.0;

FSLG = frame score category greater than 7.0.

To evaluate the effects of each of these variables on actual bull price, PROC REG and PROC CORR in SAS (SAS Inst. Inc., Version 9.2; Cary, NC) were used to estimate the effects the explanatory variables had on BP. Hypothesized relationships for the regression model (Table 2) were as follows:

1. The SOP coefficient was expected to have a negative association with BP (Figure 1). Commonly, better quality bulls are associated with the beginning of the sale order. Previous studies have determined that BP decreased as cattle sales progressed (Turner et al., 1991).

2. The AID coefficient was expected to have a positive association with BP (Figure 2). Bull buyers seem to desire older bulls which have met sexual maturity and can effectively service larger number of females (Dhuyvetter et al., 1996).

3. The BWLT and BWHV coefficients were expected to both have negative associations with BP (Figure 3). Both extremely light and heavy calves are undesirable traits for bull buyers.

4. The WW, YW, and FW coefficients were expected to have positive associations with BP (Figure 2). Calves are marketed in many commercial

settings as weaned calves deeming an elevated WW a desirable trait for herd sires. Increased YW is desirable when keeping or marketing progeny post-weaning. Greater FW are often associated with an elevated sale price in bulls.

5. The SC coefficient was expected to have a positive association with BP (Figure 2) due to greater SC measurements correlating to heifers reaching puberty earlier as well as enhanced sperm-producing capacity.

6. The BWEPD, YWEPD, and MILKEPD coefficients were expected to have negative (Figure 3), positive (Figure 2), and positive (Figure 2) associations, respectively, with BP. Greater BWEPD values are expected to be discounted as bull buyers view this as an indication of greater potential risk of dystocia in females bred to the bull in question. The YWEPD and MILKEPD were both expected to command premium BP as their values increased.

7. The WFCP coefficient was expected to show a positive association with BP (Figure 2). As WFCP increases, cattle producers may have greater returns to invest in herd bulls and place more value on quality genetics to produce more and heavier future calf crops.

8. The VS coefficient was expected to have a positive association with BP (Figure 2). Studies have determined (Commer et al., 1990) that bull buyers emphasize visual appraisal in bull purchasing decisions.

9. The frame score coefficients were expected to have a negative association with BP (Figure 2). Extreme FS have been traditionally avoided.

10. The BBRD coefficient was expected to lead to some positive and negative associations based on previous research (Dhuyvetter et al., 1996).

As mentioned previously, the bull sales were modeled separately by location because each sale had a unique market environment. Sales were also modeled separately within sale (Dhuyvetter et al., 1996) due to EPD values not being available for bulls in years prior to 1989. Model 1 contained bull-specific performance measures and the economic variable without EPD values, and model 2 included EPD values.

Data were analyzed using PROC REG and PROC CORR in SAS to estimate the regression coefficients of the explanatory variables and to determine the expected sign of the Pearson correlation between the dependent variable, BP, and the individual explanatory variables. The models were developed using OLS regression with both actual and logarithmic transformed BP. A likelihood ratio test indicated rejection of the linear form of BP in favor of the log form at the 0.05 level for each model. Consequently, the reported models explain the logarithm of BP. Residual analysis consisted of regressing the error term of the variable under consideration. Statistically significant parameter estimates indicated problems associated with the functional form of the variables being examined. Quadratic, square-root, logarithmic, and reciprocal transformations were engaged in a trial and error approach to adjust the functional form of individual variables as the residual analysis indicated was necessary to properly form to the linear regression line. Graphically the variables were plotted and evaluated for normality. Statistically the rule of thumb that says a variable is reasonably close to normal if its skewness and kurtosis have values between -2.0 and 2.0 (Gujarati and Porter, 2009). Residual analysis indicated that logarithmic transformations were necessary for the following variables: BP, SOP, AID, WW, FW, YWEPD, MILKEPD, VS, CS, and WFCP.

Regression model dependent and independent variables were tested for normality by evaluating skewness and kurtosis values using PROC UNIVARIATE in SAS. The regression models were tested for the presence of heteroscedasticity using White's Test. The heteroscedasticity-consistent covariance matrix method 3 (HCCM3) was used in all models for correction (MacKinnon and White, 1985; Long and Ervin, 2000). Regression models were also examined for existence of autocorrelated error terms. First, residuals of each variable were plotted against the dependent variable, and then the Durbin-Watson test statistic was used to test for autocorrelation in each model. When autocorrelation was detected, the specifications of the model were then re-evaluated and variables were transformed to correct for autocorrelation. The Durbin-Watson test statistic used to test for first-order autocorrelation fell within the inconclusive range for autocorrelation for all models. Residual analysis performed on the models corrected for possible autocorrelation and revealed no functional form specification problems. To address multicollinearity, correlation coefficients > 0.7 and variance inflation factors (VIF) > 5.0 were utilized to determine the presence of multicollinearity. If multicollinearity presented a problem, the models and variables were re-evaluated and either variables were removed from the models or allowed to stay in the models as in the case of categorical binary dummy variables. Extreme outliers for all variables were determined using a box-plot in SAS. After outliers were detected they were removed from all models. Statistical significance was defined at a $P < 0.05$ value.

The individual sale models were as follows:

MBCIA Models:

$$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \text{BWLT} + \beta_3 \times \text{BWHV} + \beta_4 \times \log \text{WW} + \beta_5 \times \log \text{FW} + \beta_6 \times \log \text{VS} + \beta_7 \times \log \text{WFCP} + \beta_8 \times \text{BBRD(Angus)} + \beta_9 \times \text{BBRD(Charolais)} + \beta_{10} \times \text{BBRD(Hereford)} + \beta_{11} \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 4}$$

$$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \log \text{WW} + \beta_3 \times \log \text{FW} + \beta_4 \times \log \text{BWEPD} + \beta_5 \times \log \text{YWEPD} + \beta_6 \times \log \text{VS} + \beta_7 \times \log \text{WFCP} + \beta_8 \times \text{BBRD(Angus)} + \beta_9 \times \text{BBRD(Charolais)} + \beta_{10} \times \text{BBRD(Hereford)} + \beta_{11} \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq.5}$$

HCCBT Model:

$$\text{Log BP} = \beta 0 + \beta 1 \times \log \text{SOP} + \beta 2 \times \text{BWLT} + \beta 3 \times \text{BWHV} + \beta 4 \times \log \text{WW} + \beta 5 \times \log \text{FW} + \beta 6 \times \log \text{WFCP} + \beta 7 \times \text{BBRD(Angus)} + \beta 8 \times \text{BBRD(Charolais)} + \beta 9 \times \text{BBRD(Hereford)} + \beta 10 \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 6}$$

AUBT Model:

$$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \log \text{AID} + \beta_3 \times \log \text{WW} + \beta_4 \times \log \text{FW} + \beta_5 \times \log \text{WFCP} + \beta_6 \times \text{BBRD(Angus)} + \beta_7 \times \text{BBRD(Charolais)} + \beta_8 \times \text{BBRD(Hereford)} + \beta_9 \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 7}$$

NABEC Model:

$$\text{Log BP} = \beta_0 + \beta_1 \times \text{SOP} + \beta_2 \times \text{BWLT} + \beta_3 \times \text{BWHV} + \beta_4 \times \log \text{AID} + \beta_5 \times \log \text{WW} + \beta_6 \times \text{FSSM} + \beta_7 \times \text{FSLG} + \beta_8 \times \log \text{FW} + \beta_9 \times \log \text{BWEPD} + \beta_{10} \times \log \text{YWEPD} + \beta_{11} \times \log \text{WFCP} + \beta_{12} \times \text{BBRD(Angus)} + \beta_{13} \times \text{BBRD(Charolais)} + \beta_{14} \times \text{BBRD(Limousin)} + \beta_{15} \times \text{BBRD(Simmental)} + \varepsilon \text{ Eq.} \qquad \text{Eq. 8}$$

BPTBS Model:

$$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \text{BWLT} + \beta_3 \times \text{BWHV} + \beta_4 \times \log \text{AID} + \beta_5 \times \log \text{WW} + \beta_6 \times \text{FSSM} + \beta_7 \times \text{FSLG} + \beta_8 \times \log \text{FW} + \beta_9 \times \log \text{SC} + \beta_{10} \times \log \text{BWEPD} + \beta_{11} \times \log \text{YWEPD} + \beta_{12} \times \log \text{WFCP} + \beta_{13} \times \text{BBRD(Angus)} + \beta_{14} \times \text{BBRD(Charolais)} + \beta_{15} \times \text{BBRD(Gelbvieh)} + \beta_{16} \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 9}$$

PPTBS Model:

$$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \log \text{AID} + \beta_3 \times \log \text{WW} + \beta_4 \times \log \text{FW} + \beta_5 \times \text{FSSM} + \beta_6 \times \text{FSLG} + \beta_7 \times \log \text{WFCP} + \beta_8 \times \text{BBRD(Angus)} + \beta_9 \times \text{BBRD(Charolais)} + \beta_{10} \times \text{BBRD(Hereford)} + \beta_{11} \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 10}$$

WPTBS Model:

$$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \text{BWLT} + \beta_3 \times \text{BWHV} + \beta_4 \times \log \text{AID} + \beta_5 \times \log \text{WW} + \beta_6 \times \text{FSSM} + \beta_7 \times \text{FSLG} + \beta_8 \times \log \text{FW} + \beta_9 \times \log \text{WFCP} + \beta_{10} \times \text{BBRD(Angus)} + \beta_{11} \times \text{BBRD(Charolais)} + \beta_{12} \times \text{BBRD(Gelbvieh)} + \beta_{13} \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 11}$$

Eq. 10. $$\text{Log BP} = \beta_0 + \beta_1 \times \log \text{SOP} + \beta_2 \times \text{BWLT} + \beta_3 \times \text{BWHV} + \beta_4 \times \log \text{AID} + \beta_5 \times \log \text{WW} + \beta_6 \times \text{FSSM} + \beta_7 \times \text{FSLG} + \beta_8 \times \log \text{FW} + \beta_9 \times \log \text{BWEPD} + \beta_{10} \times \log \text{YWEPD}\ \beta_{11} \times \log \text{WFCP} + \beta_{12} \times \text{BBRD(Angus)} + \beta_{13} \times \text{BBRD(Charolais)} + \beta_{14} \times \text{BBRD(Gelbvieh)} + \beta_{15} \times \text{BBRD(Simmental)} + \varepsilon \qquad \text{Eq. 12}$$

Results and Discussion

The results and discussion will be divided into two sections. Results will be explained first, and discussion will be reported second. The results from the individual pricing models are presented as follows: first, parameter estimates from price determinant models are discussed on a price per head basis; second, the results are compared to other relevant price determination studies. The pricing models for each sale are addressed separately. Summary statistics of selected data are provided in Table 1.

Results

MBCIA Sale Pricing Models

There were several variables that affected price of bulls when EPD values were not included in model 1. Variables affecting BP include SOP, BWHV, WW, FW, VS, WFCP, BBRD-Hereford, BBRD-Simmental (Table 2). The MBCIA sale pricing model explained approximately 56% of the variation in individual BP when EPD were not included. Sale order percentile was significant ($P < 0.01$) and negatively impacted BP as expected. A 1.0% increase in SOP resulted in a 0.04% decrease in BP. Three of the four performance measures (BWHV, WW, and FW; $P < 0.01$) exhibited an expected positive relationship to BP. The BWLT category was not different ($P = 0.16$) compared with the moderate ABW category; however the BWHV category resulted in a 5.12% decrease in BP compared to the moderate ABW category. The WW was significant ($P < 0.01$) and positively impacted BP. A 1.0% increase in WW resulted in a 0.33% increase in BP. Final weight was significant ($P < 0.01$) and positively affected BP. A 1.0% increase in FW resulted in a 0.79% increase in BP. Visual score was also significant ($P < 0.01$) for BP and positively affected BP as expected. A 1.0% increase in VS resulted in a 0.12%

increase in BP. As expected, WFCP was significant (P < 0.01) and positively associated with BP. A 1.0% increase in WFCP resulted in a 0.57% increase in BP. Hereford and Simmental bulls were discounted (P < 0.01) 8.23% and 12.05%, respectively, relative to the other breeds category. In addition, Angus (P = 0.35) and Charolais (P = 0.97) were each not different from the other breeds category.

There were numerous variables that affected BP in the MBCIA Model 2. Variables impacted by BP include SOP, WW, FW, BWEPD, VS, WFCP, and BBRD-Angus, BBRD-Simmental (Table 3). Model 2 for MBCIA explained approximately 57% of the variation of individual BP. Sale order percentile was significant (P < 0.01) and negatively affected BP. A 1.0% increase in SOP resulted in a 0.04% decrease in BP. As in model 1, performance measures (WW and FW) remained significant (P < 0.01) and positively impacted BP. A 1.0% increase in WW resulted in a 0.34% increase in BP. A 1.0% increase in FW resulted in a 0.82% increase in BP. The BWEPD was significant (P < 0.05) and negatively impacted BP. A 1.0% increase in BWEPD resulted in a 1.67% decrease in BP. The YWEPD were not significant (P = 0.65) in describing BP. Visual score was significant (P < 0.01) and positively affected BP. A 1.0% increase in VS resulted in a 0.14% increase in BP. The WFCP was significant (P < 0.01) and positively associated with BP. A 1.0% increase in WFCP resulted in a 0.52% increase in BP. Angus and Simmental (P < 0.01) bulls were different from the other breeds category. Angus bulls garnered a premium of 7.11% compared to the other breeds category. Simmental bulls were discounted 10.61% compared to the other breeds category.

HCCBET Sale Pricing Model

Variables that explained BP included: BWLT, BWHV, WW, FW, WFCP, and BBRD (Table 4). The HCCBET pricing model explained 54% of the variation in individual BP. Sale order percent was not significant ($P = 0.76$) in determining BP. The BWLT category was not different ($P = 0.25$) from the moderate ABW category. The BWHV category ($P < 0.05$) negatively impacted BP and resulted in a 2.31% decrease in BP compared to the moderate ABW category. As expected, WW was significant ($P < 0.01$) and positively affected BP. A 1.0% increase in WW resulted in a 0.50% increase in BP. Final weight was significant ($P < 0.01$) and positively impacted BP. A 1.0% increase in FW resulted in a 1.08% increase in BP. The WFCP was significant ($P < 0.01$) and positively affected BP. A 1.0% increase in WFCP resulted in a 0.47% increase in BP. Angus ($P < 0.01$) and Charolais ($P < 0.01$) bulls differed from the other breeds category, resulting in a 6.29% and 8.32% premium, respectively, compared to the other breeds category. Hereford ($P = 0.56$) and Simmental ($P = 0.47$) bulls did not differ from the other breeds category.

AUBT Sale Pricing Model

Traits impacting BP included SOP, AID, FW, WFCP, and BBRD-Hereford (Table 5). The AUBT pricing model explained approximately 48% of the variation in individual BP. Sale order percentile was significant ($P < 0.01$) and negatively impacted BP. A 1.0% increase in SOP resulted in a 0.08% decrease in BP. Age in days was significant ($P < 0.01$) and negatively affected BP unexpectedly. A 1.0% increase in AID resulted in a 0.67% decrease in BP. Also unexpectedly, WW was not significant ($P = 0.57$) when explaining BP. As expected, FW was significant ($P < 0.01$) and positively affected BP. A 1.0% increase in FW resulted in a 1.96% increase in BP. As expected, WFCP was significant (P < 0.01) and positively impacted BP. A 1.0% increase in WFCP resulted in a 0.66% increase in BP. Angus (P = 0.29), Charolais (P = 0.26), and Simmental (P = 0.73) bulls were not different from the other breeds category; however, Hereford (P < 0.01) bulls resulted in a 0.06% discount compared to the other breeds category.

NABEC Sale Pricing Model

Traits impacting BP in the NABEC pricing model include SOP, BWHV, AID, WW, FSLG, FW, BWEPD, WFCP, and BBRD-Angus, BBRD-Charolais (Table 6). The NABEC sale pricing model explained 42% of the variation in BP. The SOP was significant (P < 0.01) and negatively impacted BP. A 1.0 unit increase in SOP resulted in a 0.22% increase in BP. The BWLT (P = 0.44) category did not differ from the moderate ABW category; however BWHV (P < 0.01) category differed from the moderate ABW category resulting in a negative effect on BP. The BWHV classification resulted in a 3.86% discount compared to the moderate ABW category. Age in days (P < 0.05) positively impacted BP. A 1.0% increase in AID resulted in a 0.45% increase in BP. The WW was not significant (P = 0.12). The FSSM category did not differ (P = 0.32) from the moderate FS category for BP. The FSLG category was different (P < 0.01) and resulted in a 3.31% premium when compared to the FSMD category. Final BW was significant (P < 0.01) and positively affected BP. A 1.0% increase in FW resulted in a 0.89% increase in BP. The BWEPD was significant (P < 0.01) and negatively impacted BP. A 1.0% increase in BWEPD resulted in a 2.14% decrease in BP. The YWEPD was not significant (P = 0.06). As expected, WFCP was significant (P < 0.01) and positively impacted BP. A 1.0% increase in WFCP resulted in a 0.71% increase in BP. Angus (P <

0.01) and Charolais ($P < 0.01$) bulls differed from the other breeds category and garnered premiums of 6.93% and 7.50%, respectively. Limousin ($P = 0.63$) and Simmental ($P = 0.74$) did not differ from the other breeds category.

BPTBS Pricing Model

There were several variables that significantly affected the price of bulls in the BPTBS pricing model. Variables impacting BP included SOP, BWLT, AID, FSSM, FW, BWEPD, YWEPD, WFCP, and BBRD-Angus (Table 7). The BPTBS model explained approximately 39% of the variation in individual BP. Sale order percentile was significant ($P < 0.01$) and negatively affected BP. A 1.0% increase in SOP resulted in a 0.09% decrease in BP. The BWLT category differed ($P < 0.05$) from the moderate ABW category and garnered a 2.9% premium compared to the moderate ABW category. The BWHV weight category was not different ($P = 0.20$) from the moderate ABW category. Age in days was significant ($P < 0.05$) and negatively affected BP. A 1.0% increase in AID resulted in a 0.52% decrease in BP. Surprisingly, WW was not significant ($P = 0.16$) for BP. As anticipated, FSSM differed ($P < 0.01$) from the moderate FS category. A FSSM bull resulted in a 6.9% discount for BP compared to the moderate FS category. The FSLG bulls did not differ ($P = 0.38$) in BP compared to the moderate FS category. Final weight was significant ($P < 0.01$) and positively impacted BP. A 1.0% increase in FW resulted in a 1.59% increase in BP. In addition, SC was not significant ($P = 0.41$) when explaining BP. The BWEPD was significant ($P < 0.01$) and negatively affected BP. A 1.0% increase in BWEPD resulted in a 2.49% decrease in BP. Additionally, YWEPD was significant ($P < 0.01$) and unexpectedly impacted BP negatively. A 1.0% increase in YWEPD resulted in a 0.55% decrease in BP. As anticipated, WFCP was significant

(P < 0.01) and positively affected BP. A 1.0% increase in WFCP resulted in a 0.62% increase in BP. Angus differed (P < 0.01) from the other breeds category and resulted in a 12.87% premium in comparison to the other breeds category. Charolais (P = 0.08), Gelbvieh (P = 0.39), and Simmental (P = 0.29) bulls did not differ from the other breeds category.

PPTBS Pricing Model

Traits affecting BP in the PPTBS pricing model included SOP, AID, FW, FSSM, FSLG, WFCP, and BBRD-Angus, BBRD-Hereford (Table 8). The PPTBS pricing model explained approximately 51% of the variation in BP. As expected, SOP was significant (P < 0.01) and negatively impacted BP. A 1.0% increase in SOP lead to a 0.12% decrease in BP. Age in days was significant (P < 0.01) and negatively impacted BP. A 1.0% increase in AID resulted in a 0.53% decrease in BP. Unexpectedly, WW was not significant (P = 0.67), and therefore had no impact on BP. Final BW was, however, significant (P < 0.01) and resulted in a positive effect on BP. A 1.0% increase in FW led to a 1.04% increase in BP. The FSSM differed (P < 0.01) from the moderate FS category and resulted in a discount of 5.73% comparatively. The FSLG category differed (P < 0.05) from the moderate FS category and resulted in a 2.74% premium when compared to the FSMD category. As hypothesized, WFCP was significant (P < 0.01) and positively impacted BP. A 1.0% increase in WFCP resulted in a 0.54% increase in BP. Angus (P < 0.01) and Hereford (P < 0.01) bulls differed from the other breeds category and resulted in 4.81% and 5.06% premiums, respectively, compared to the other breeds category. Charolais (P = 0.89) and Simmental (P = 0.18) bulls did not differ from the other breeds category.

WPTBS Pricing Models

There were several traits that affected BP in the WPTBS pricing model1. This model explained approximately 36% of the variation in BP. Variables impacted by BP include SOP, AID, FSSM, FW, WFCP, and BBRD-Angus, BBRD-Charolais (Table 9). The SOP affected ($P < 0.01$) BP negatively. A 1.0% increase in SOP resulted in a 0.05% decrease in BP. The BWLT ($P = 0.89$) and BWHV ($P = 0.93$) category was not different from the moderate birth BW category. As expected, AID was significant ($P < 0.01$) and negatively impacted BP. A 1.0% increase in AID resulted in a 0.78% decrease in price. Unexpectedly, WW was not significant ($P = 0.36$) and did not affect BP. The FSSM category was significant ($P < 0.05$) and resulted in a 5.34% discount when compared to the moderate FS category. However, the FSLG category was not different ($P = 0.05$) from the moderate FS category. As expected, FW was significant ($P < 0.01$) and positively affected BP. A 1.0% increase in FW resulted in a 1.10% increase in BP. As hypothesized, WFCP was significant ($P < 0.01$) and positively impacted BP. A 1.0% increase in WFCP led to a 0.56% increase in BP. Angus ($P < 0.01$) and Charolais ($P < 0.05$) bulls were significant and garnered 8.31% and 5.27% premiums, respectively. Gelbvieh ($P = 0.58$) and Simmental ($P = 0.93$) were not different from the other breeds category for BP.

There were several traits that affected BP in the WPTBS2. This model explained approximately 37% of the variation in BP. Variables impacted by BP included AID, WW, FW, BWEPD, WFCP, and BBRD-Angus, BBRD-Charolais (Table 10). Unexpectedly, SOP did not affect ($P = 0.12$) BP. The BWLT ($P = 0.72$) and BWHV ($P = 0.23$) categories did not differ from the moderate ABW category in BP. As expected, AID was significant ($P < 0.01$) and negatively impacted BP. A 1.0% increase in AID resulted in a 1.36% decrease in BP. As expected, WW was significant ($P < 0.05$) and positively impacted BP. A 1.0% increase in WW resulted in a 0.06% increase in BP. The FSSM ($P = 0.20$) and FSLG ($P = 0.77$) categories did not differ from the moderate FS category for BP. Final weight was significant ($P < 0.01$) and positively affected BP. A 1.0% increase in FW resulted in a 1.28% increase in BP. Birth weight EPD was significant ($P < 0.01$) and negatively affected BP. A 1.0% increase in BWEPD resulted in a 6.13% decrease in BP. Yearling weight EPD did not affect ($P = 0.14$) BP. As hypothesized, WFCP was significant ($P < 0.01$) and positively impacted BP. A 1.0% increase in WFCP lead to a 0.39% increase in BP. Angus ($P < 0.01$) and Charolais ($P < 0.01$) were significantly different from the other breeds category and garnered 13.9% and 10.2% premiums, respectively. Gelbvieh ($P = 0.55$) and Simmental ($P = 0.85$) did not differ from the other breeds category.

Discussion

The discussion section will first give a brief overview of differences and commonalities among the research and model specifications utilized in this study and those reported in the literature. Second, each explanatory variable will be discussed individually and compared to results found in similar reports. Explanatory variables will be divided into sections including: bull-specific, economic, and sale-specific variables.

Little research has been conducted in the Southeast USA analyzing BP determinants for bulls sold in performance BCIA/BCIP-sanctioned sales. Analyzing bull sales in Alabama, Mississippi, and North Carolina gives an adequate analysis of the Southeast USA. Different model specifications have been used throughout literature to explain price determinants in the cattle industry. The hedonic pricing model has been commonly used to evaluate BP in sales throughout the USA. Model specifications have been used to accurately select the appropriate model to analyze a particular data set. Model specifications were thoroughly evaluated to ensure the correct, model and variable, tests and transformations were conducted to provide the most accurate results.

Bull-specific Variables

Purebred breeds of cattle can be described with specific strengths and weaknesses. Knowing each breed of cattle possess different characteristics allows the assumption that breed characteristics can be quantified and a dollar value can be associated with categorical breeds. Several studies have evaluated bull sales within a single breed (Greer and Urick, 1988; Dhuyvetter et al., 2005; Jones et al., 2008; McDonald, 2010) and among multiple breeds (Cassady et al., 1989; Dhuyvetter et al., 1996; Holt et al., 2004; Parcell et al., 2006; Smith and Foster, 2007; Lillywhite and Simonsen, 2008) to analyze effects of different explanatory variables on cattle sale price. Breed has been shown to produce premiums and discounts compared to a default category (Dhuyvetter et al., 1996). For every sale in this study, BBRD was significant and was associated with premiums or discounts regardless of whether or not EPD were included and excluded from the models. Angus and Charolais bulls received premiums, however Simmental bulls received discounts. Hereford bulls received premiums in 2 models and a discount in 1 model.

Sale order in which bulls are sold is included as an independent variable when explaining BP by many researchers (Dhuyvetter et al., 1996; Jones et al., 2008; McDonald, 2010). Sale order of cattle has been noted to positively affect price as sales progress (Schroeder and Graff, 2000) as well as depress sale prices for bulls sold at the end of sale (Vanek et al., 2008). Consistently, sale order is a significant factor for BP.

Sale order percent was significant and negatively affected BP (Figure 4) for all sales except HCCBET and WPTBS2. One explanation for SOP not being significant is that these sales have traditionally grouped the SOP based on breed. This could have an impact on SOP knowing that better performing and quality bulls could be later in the sale order because their breed is not first to sell.

Age in days has been reported to positively impact BP for older bulls compared to younger bulls (Dhuyvetter et al., 1996; Chvosta et al., 2001; Jones et al., 2008). Age in days was significant for all sales in which AID was included in the model. Interestingly, AID negatively impacted BP (Figure 4) in 5 of the 6 sales. For the NABEC model, AID positively impacted BP (Figure 5). Positive and negative impacts on BP can be explained by bull buyers seeking different qualities in bulls. Bulls are marketed as virgin or previously used as service bulls. Cattle producers may view virgin bulls as being able to minimize disease transmission. Previously serviced bulls may be seen as bulls that met standards for the breeder to be used as a service bull. Bull buyers attending these sales did so knowing that the primary sale offering was generally less than 2 yr of age. They also may have been seeking younger bulls to breed to heifers.

Bulls classified into BWLT or BWHV categories were expected to receive discounts because of the qualities associated with extremely light or heavy ABW. Bull ABW has traditionally resulted in negative effects on price because of warranted values associated with low ABW bulls. Dhuyvetter et al. (1996) reported an increase in ABW to have a significantly negative effect with BP for 4 of 7 breeds evaluated in the study. The BWLT category was evaluated in 6 of the 9 models. The BWLT category positively impacted BP in 1 sale and was not significantly different ($P > 0.16$) from the moderate ABW category in the remaining models. Even though discounts were expected for the

BWLT category, it is not surprising to see a premium associated with light weight calves because of widespread educational efforts prevalent in Extension programming in favor of light ABW calves to reduce calving difficulty. The BWHV category was expected to also be associated with discounts because of potential for heavier birth weight calves. The BWHV category was analyzed in 6 of the 9 models and negatively impacted BP in 3 sales (MBCIA1, HCCBET and NABEC). Bull buyers from this study show that they are seeking bulls with lower birth weights considering the premium associated with BWLT and the discount associated with BWHV.

Adjusted 205-d weaning weight has been noted for positively impacting BP (Dhuyvetter et al., 1996). Performance measures indicative of growth should traditionally have a positive effect on BP. For 4 of the 9 models, WW positively impacted BP (Figure 5) as expected. For 5 of the 9 models, WW was not significant and did not affect BP. However, in the five models (AUBT, NABEC, PPTBS, BPTBS, and WPTBS1) where WW was not significant and did not affect BP, FW was significant and positively impacted BP. Perhaps bull buyers viewed FW as an overall indication of growth potential compared to WW.

As expected, FW was significant and positively affected BP (Figure 5) for all 9 models. This result suggests bull buyers are consistently appraising bulls for FW and condition of bulls on sale day, and this can be a major factor in determining BP. Results from this study correspond with literature for BP determinants noting that general eye-appeal is a significant factor in bull purchasing decisions (Commer et al., 1990).

The BWEPD were evaluated in 4 of the 9 models and was significantly negatively associated with BP (Figure 6) in each model. The BWEPD explanatory variable was represented in each of the three states with sales suggesting that BWEPD is consistently impacting BP negatively across the Southeast USA. This result was expected based on the literature for BWEPD on BP (Dhuyvetter et al., 1996, 2005; Jones et al., 2008). The YWEPD was also represented in the same 4 models as BWEPD. Three of the models resulted in YWEPD not having a significant impact on BP, and for 1 of the models YWEPD negatively impacted BP (Figure 4) unexpectedly. One explanation for this result could be that in the BPTBS model, FW was significant and positively associated with BP. This could indicate that buyers at this particular sale are focusing more on actual simple performance measures rather than EPD. Jones et al. (2008) reported YWEPD as significant and resulted in a $613 premium above the mean for BP.

Frame score was divided into 3 categories (FSSM, FSMD, and FSLG). The FSSM and FSLG categories were analyzed comparatively to the moderate category to quantify differences in FS associated with extremely small and large FS categories. As expected, FSSM resulted in a negative impact on BP when compared to the moderate category in 3 (BPTBS, PPTBS, WPTBS1) of the 5 models in which FS was analyzed. The other 2 models NABEC and WPTBS2) resulted in affects that were not significant. The FSLG category was analyzed in the same 5 models. For 2 of the 5 models FSLG was associated with premiums and for the remaining 3 there were no differences. Suppositions can be made that smaller-framed bulls are less desirable, and large frame score bulls are more desirable. Comparably, small frame feeder calves have been reported to be discounted relative to medium and large frame calves (Reuter et al., 2011).

The VS has been reported to have significant value when determining BP (Warren, 1957; Corah et al., 1987; Commer et al., 1990). Visual scores were only available for the MBCIA models and resulted in a positive impact on BP (Figure 5) in both models 1 and 2. Dhuyvetter et al. (1996) concluded that conformation, muscle, and disposition influenced BP. Results from this study again suggest that bull buyers value quality genetics and general eye-appeal as well. Visual score was not available in sufficient observations for the other models and was therefore not analyzed. Scrotal circumference has been noted to not have a significant impact on BP (Irsik et al. 2008). Scrotal circumference was only available for evaluation in the BPTBS and was not significant in explaining BP. This could be explained by bulls having to meet minimum requirements for SC to enter the bull sales. Bull buyers may not evaluate the SC size as long as it meets a minimum standard.

Economic Variable

The economic variable WFCP was added to all of the models to account for fluctuations and trends in the feeder calf market over time. The WFCP was expected to have a positive relationship with BP. This prediction held true after analyzing WFCP in all models and determining a strong ($P < 0.01$) positive impact on BP (Figure 5). This finding is logical because if calves are being sold for increased premiums, then cow-calf producers have additional money to spend on quality bulls. They may also want to increase future calf weights to capitalize on relatively greater calf prices and believe purchasing herd sires from BCIA or BCIP sponsored sales is a means to achieve greater pounds of calf to be marketed in the future. This is consistent with Greer and Urick, (1988) when they described breeding BP to be sensitive to calf prices and cow herd inventory.

Sale-specific Variable

Individual sales were analyzed separately to capture specific marketing attributes that each sale represented. Significant explanatory variables and comparable R2 values to other BP determinant studies infers model specifications and variable transformations were appropriate and evaluated each of the models correctly. The overall analysis of data was not designed to make strong comparisons across models because of differences associated with each one of the models and sale locations. Additionally, sale years were not equally represented, and observation numbers differed for explanatory variables.

Implications

The main objective of this study was to evaluate BP determinants in performance BCIA/BCIP-sanctioned bull sales in the southeastern USA. Although some explanatory variables produced unexpected results, this study allows cattle producers and sale managers in the southeastern USA the opportunity to compare results from similar data evaluated in other regions for BP. Results from this study confirm that just because each bull sale develops its own set of characteristics influencing BP, these characteristics are formed by the individual buyers which are probably influenced by sale managers. Each sale manager may emphasize different traits when assisting buyers with bull buying decisions. Performance measures as well as genetic predictors proved significant for explaining BP. This implies most bull buyers are looking for bulls with quality genetics that can be utilized within their cow herds and also visual characteristics to achieve longevity via structural soundness and market acceptance of resulting feeder calves.

Bull breeders should be able to take the findings from this study and evaluate current breeding and marketing strategies. Breeders that fall short in reporting data or including collected data in sale promotion may want to reconsider for future bull sales. It is important to note not all variables cataloged for each bull were available to be entered into each model because of data limitations, such as missing observations. Therefore, not all variables available to bull buyers were included in each of the models due to model specifications. Some variables not quantified were seller reputation, promotional efforts, structural correctness, disposition, color, carcass characteristics, feed efficiency, and buyer competition as possibilities for explaining some of the indescribable variation within each of the models. This study has furthered the knowledge of BP determinants in performance oriented BCIA/BCIP-sanctioned bull sales in the southeastern USA. Ultimately, the results of this study can be utilized by bull breeders and buyers alike to make improved decisions in bull breeding and selection for beef cow-calf operations.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary

The general objective of this study was to determine the relationships that exist between BP and individual bull performance characteristics and genetic merit. The study also evaluated the effect economic and sale-specific factors had on BP. Information included in this study will afford cattle producers, researchers, and cooperative Extension personnel the information to better evaluate the market for bulls in the Southeast USA.

Conclusions

Bull price determinants have been demonstrated to be effective in better understanding the market for bull sale consigners as well as buyers. Based on the results of this data, conclusions can be made regarding the similarities and differences in the bull market for bulls sold through BCIA/BCIP-sanctioned bull sales in the Southeast versus bulls sold in other regions throughout the USA. These results indicate that bull buyers emphasize individual performance measures and economic variables when making bull purchase decisions.

These results indicate that bull buyers in the Southeast USA are emphasizing SOP, BBRD, FW, ABW, BWEPD, FS, and WFCP. Simple performance measures are shown to have value when buyers are making their bull purchase decisions. Cooperative extension education efforts may need to be reevaluated to educate bull producers and buyers on the value of other bull traits. Each bull breeder and buyer is different, and quantifying the thought process of these individuals can be a challenge. Further research is warranted to better understand the bull market in the USA and specifically in the southeastern USA. More in depth evaluations of genetic parameters is needed to better understand the value of the large amounts of data that are currently available to bull breeders and buyers.

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APPENDIX A

TABLES

Table 1 Years and observations represented in price determination models

Sale	Years	n
MBCIA1[1]	1980, 1982 to 1985, 1993 to 1995, 1998, 1999, 2003 to 2011	633
MBCIA2[2]	1993 to 1995, 1998, 1999, 2003 to 2011	527
HCCBEC[3]	1991, 1994 to 2002, 2009	429
AUBT[4]	1975, 1979, 1981 to 2001, 2003, 2004	1,673
NABEC[5]	1988 to 2011	1,406
BPTBS[6]	1990, 1991, 1993, 1995 to 2010	745
PPTBS[7]	1974 to 1999	1,238
WPTBS1[8]	1981 to 2011	650
WPTBS2[9]	1989 to 2011	394

[1]MBCIA1: Mississippi Beef Cattle Improvement Association model where expected progeny differences (EPD) were not included
[2]MBCIA2: Mississippi Beef Cattle Improvement Association model where EPD were included
[3]HCCBEC: Hinds Community College Bull Evaluation Center
[4]AUBT: Auburn University Bull Test
[5]NABEC: North Alabama Bull Evaluation Center
[6]BPTBS: Butner Performance Tested Bull Sale
[7]PPTBS: Piedmont Performance Tested Bull Sale
[8]WPTBS1: Waynesville Performance Tested Bull Sale model where EPD were not included
[9]WPTBS2: Waynesville Performance Tested Bull Sale model where EPD were included

Table 2 Definitions of explanatory variables and their expected signs

Variable	Definition	Expected Sign
BBRD	Breed binary variables = 1 if bull is the breed, otherwise = 0; other breeds category (default), Angus, Charolais, Hereford, Simmental	?
VS	Subjective visual score obtained by 3 trained technichians (1 = poor to 10 = best)	+
AID	Age in days of bulls on sale day	+
BWLT	Actual birth weight (kg) less than 31.71 kg	-
BWHV	Actual birth weight (kg) greater than 40.82 kg	-
WW	Adjusted 205-d weaning weight (kg)	+
FW	Final sale weight (kg)	+
FSSM	Frame score (1 = short to 10 = tall) less than frame score 5	-
FSLG	Frame score (1 = short to 10 = tall) greater than frame score 7	+
BWEPD	Expected progeny differences for birth weight (kg)	-
YWEPD	Expected progeny differences for yearling weight (kg)	+
SALE	Sale binary variables = 1 if bull was sold in sale, otherwise = 0	?
SOP	Percent within the sale order in which bull sold	-
WFCP	Average weekly feeder cattle price ($/45.4 kg) for calves sold at public auction in Oklahoma City, OK	+

Table 3 Estimated coefficients associated with Mississippi Beef Cattle Improvement Association bull sale price determination model 1

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	-1.02104	0.27273	-3.74	0.0002
Percent sale order	Log	%	-0.04155	0.01307	-3.18	0.0016
BWLT[1]	Linear/none	Binary	-0.01915	0.01367	-1.40	0.1616
BWHV[1]	Linear/none	Binary	-0.05105	0.01123	-4.55	0.0001
Adjusted 205-d weaning weight	Log	kg	0.33311	0.09061	6.68	0.0003
Final sale weight	Log	kg	0.79450	0.06559	12.11	0.0001
Visual score	Log	Subjective rating	0.12323	0.04423	2.79	0.0055
WFCP[2]	Log	$/45.4 kg	0.57741	0.04510	12.80	0.0001
BBRD-Angus[3]	Linear/none	Binary	0.01470	0.01587	0.93	0.3546
BBRD-Charolais[3]	Linear/none	Binary	-0.00072	0.02198	-0.03	0.9735
BBRD-Hereford[3]	Linear/none	Binary	-0.08231	0.02395	-3.44	0.0006
BBRD-Simmental[3]	Linear/none	Binary	-0.12051	0.02428	-4.96	0.0001
n		633				
R^2		0.5586				

[1]BWLT and BWHV are binary variables for light and heavy actual birth weight, respectively, compared to moderate actual birth weight

[2]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK

[3]BBRD is a binary variable representing breed of bull

Table 4 Estimated coefficients associated with Mississippi Beef Improvement Association bull sale price determination model 2

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	2.42435	1.31321	1.85	0.0654
Percent sale order	Log	%	-0.04450	0.01493	-2.98	0.0030
Adjusted 205-d weaning weight	Log	kg	0.33759	0.09860	3.42	0.0007
Final sale weight	Log	kg	0.81954	0.06855	11.96	0.0001
Birth BW EPD[1]	Log	kg	-1.67392	0.66733	-2.51	0.0124
Yearling BW EPD[1]	Log	kg	-0.05115	0.11573	-0.44	0.6587
Visual score	Log	Subjective rating	0.13931	0.05003	2.78	0.0056
WFCP[2]	Log	$/45.4 kg	0.52226	0.06150	8.49	0.0001
BBRD-Angus[3]	Linear/none	Binary	0.07106	0.02100	3.38	0.0008
BBRD-Charolais[3]	Linear/none	Binary	0.04450	0.02601	1.71	0.0876
BBRD-Hereford[3]	Linear/none	Binary	-0.06178	0.03294	-1.88	0.0612
BBRD-Simmental[3]	Linear/none	Binary	-0.10613	0.02998	-3.54	0.0004
n		527				
R^2		0.5698				

[1]EPD: expected progeny differences

[2]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK

[3]BBRD is a binary variable representing breed of bull

Table 5 Estimated coefficients associated with Hinds County Community College Bull Test Sale price determination model

Independent variable	Transformation	Unit	Parameter estimate	SE	t-Value	*P*-Value
Intercept	-	-	-2.03810	0.24995	-8.15	0.0001
Percent sale order	Log	%	0.00443	0.01452	0.30	0.7606
BWLT[1]	Linear/none	Binary	0.01591	0.01392	1.14	0.2540
BWHV[1]	Linear/none	Binary	-0.02313	0.01110	-2.08	0.0376
Adjusted 205-d weaning weight	Log	kg	0.50060	0.09418	5.32	0.0001
Final sale weight	Log	kg	1.08090	0.09753	11.08	0.0001
WFCP[2]	Log	\$/45.4 kg	0.46837	0.05684	8.24	0.0001
BBRD-Angus[3]	Linear/none	Binary	0.06291	0.01495	4.21	0.0001
BBRD-Charolais[3]	Linear/none	Binary	0.08324	0.01598	5.21	0.0001
BBRD-Hereford[3]	Linear/none	Binary	0.01537	0.02660	0.58	0.5637
BBRD-Simmental[3]	Linear/none	Binary	-0.01574	0.02156	-0.73	0.4657
n		468				
R^2		0.5417				

[1]BWLT and BWHV are binary variables for light and heavy actual birth weight, respectively, compared to moderate actual birth weight
[2]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK
[3]BBRD is a binary variable representing breed of bull

Table 6 Estimated coefficients associated with Auburn University Bull Test Sale price determination model

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	-1.76232	0.39833	-4.42	0.0001
Percent sale order	Log	%	-0.07803	0.01129	-6.91	0.0001
Age in days	Log	d	-0.67447	0.15913	-4.24	0.0001
Adjusted 205-d weaning weight	Log	kg	0.06072	0.10788	0.56	0.5736
Final sale weight	Log	kg	1.96656	0.15419	12.75	0.0001
WFCP[1]	Log	$/45.4 kg	0.65572	0.03705	17.70	0.0001
BBRD-Angus[2]	Linear/none	Binary	0.01185	0.01119	1.06	0.2900
BBRD-Charolais[2]	Linear/none	Binary	-0.01366	0.01220	-1.12	0.2632
BBRD-Hereford[2]	Linear/none	Binary	-0.05623	0.01521	-3.70	0.0002
BBRD-Simmental[2]	Linear/none	Binary	-0.00427	0.01255	-0.34	0.7336
n		1,673				
R^2		0.4799				

[1]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK
[2]BBRD is a binary variable representing breed of bull

Table 7 Estimated coefficients associated with North Alabama Bull Evaluation Sale price determination model

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	2.42758	1.22995	1.97	0.0486
Percent sale order	Linear/none	%	-0.00219	0.00015	-13.9	0.0001
BWLT[1]	Linear/none	Binary	0.00949	0.01220	0.78	0.4365
BWHV[1]	Linear/none	Binary	-0.03857	0.00937	-4.12	0.0001
Age in days	Log	d	0.45153	0.21233	2.13	0.0336
Adjusted 205-d weaning weight	Log	kg	0.14984	0.09349	1.60	0.1092
FSSM[2]	Linear/none	Binary	-0.01962	0.01959	-1.00	0.3167
FSLG[2]	Linear/none	Binary	0.03306	0.01008	3.28	0.0011
Final sale weight	Log	kg	0.89858	0.18195	4.94	0.0001
Birth BW EPD[3]	Log	kg	-2.14308	0.56911	-3.77	0.0002
Yearling BW EPD[3]	Log	kg	-0.14626	0.07924	-1.85	0.0651
WFCP[4]	Log	$/45.4 kg	0.71386	0.05118	13.95	0.0001
BBRD-Angus[5]	Linear/none	Binary	0.06932	0.01742	3.98	0.0001
BBRD-Charolais[5]	Linear/none	Binary	0.07500	0.01954	3.84	0.0001
BBRD-Limousin[5]	Linear/none	Binary	0.01070	0.02212	0.48	0.6285
BBRD-Simmental[5]	Linear/none	Binary	0.00654	0.01960	0.33	0.7387
n		1,406				
R^2		0.4196				

[1]BWLT and BWHV are binary variables for light and heavy ABW, respectively compared to moderate ABW
[2]FSSM and FSLG are binary variables representing small and large frame score, respectively compared to moderate frame score
[3]EPD: expected progeny differences
[4]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK
[5]BBRD is a binary variable representing breed of bull

Table 8 Estimated coefficients associated with the Butner Performance Bull Test Sale price determination model

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	5.47766	1.66941	3.28	0.0011
Percent sale order	Log	%	-0.09601	0.01405	-6.83	0.0001
BWLT[1]	Linear/none	Binary	0.02955	0.01500	1.97	0.0493
BWHV[1]	Linear/none	Binary	-0.01780	0.01411	-1.26	0.2073
Age in days	Log	d	-0.52201	0.20902	-2.50	0.0128
Adjusted 205-d weaning weight	Log	kg	-0.18620	0.13163	-1.41	0.1576
FSSM[2]	Linear/none	Binary	-0.06856	0.01453	-4.72	0.0001
FSLG[2]	Linear/none	Binary	0.01284	0.01450	0.89	0.3762
Final sale weight	Log	kg	1.59353	0.20758	7.68	0.0001
Scrotal circumference	Log	cm	0.15311	0.18642	0.82	0.4117
Birth BW EPD[3]	Log	kg	-2.48775	0.73784	-3.37	0.0008
Yearling BW EPD[3]	Log	kg	-0.54827	0.09582	-5.72	0.0001
WFCP[4]	Log	$/45.4 kg	0.61590	0.08592	7.17	0.0001
BBRD-Angus[5]	Linear/none	Binary	0.12871	0.02831	4.55	0.0001
BBRD-Charolais[5]	Linear/none	Binary	-0.07572	0.04426	-1.71	0.0875
BBRD-Gelbvieh[5]	Linear/none	Binary	0.02791	0.03277	0.85	0.3947
BBRD-Simmental[5]	Linear/none	Binary	-0.03609	0.03390	-1.06	0.2874
n		745				
R^2		0.3855				

[1]BWLT and BWHV are binary variables for light and heavy ABW, respectively compared to moderate ABW
[2]FSSM and FSLG are binary variables representing small and large frame score, respectively compared to moderate frame score
[3]EPD: expected progeny differences
[4]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK
[5]BBRD is a binary variable representing breed of bull

Table 9 Estimated coefficients associated with the Piedmont performance Bull Test Sale price determination model

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	0.99264	0.39711	2.50	0.0126
Percent sale order	Log	%	-0.12403	0.01330	-9.32	0.0001
Age in days	Log	d	-0.53552	0.19688	-2.72	0.0066
Adjusted 205-d weaning weight	Log	kg	-0.04501	0.10584	-0.43	0.6707
Final sale weight	Log	kg	1.03606	0.15802	6.56	0.0001
FSSM[1]	Linear/none	Binary	-0.05727	0.01354	-4.23	0.0001
FSLG[1]	Linear/none	Binary	0.02738	0.01256	2.18	0.0295
WFCP[2]	Log	$/45.4 kg	0.53932	0.03746	14.40	0.0001
BBRD-Angus[3]	Linear/none	Binary	0.04814	0.01714	2.81	0.0051
BBRD-Charolais[3]	Linear/none	Binary	0.00300	0.02260	0.13	0.8945
BBRD-Hereford[3]	Linear/none	Binary	0.05063	0.01900	2.66	0.0078
BBRD-Simmental[3]	Linear/none	Binary	-0.02668	0.01974	-1.35	0.1767
n		1,238				
R^2		0.5148				

[1]FSSM and FSLG are binary variables representing small and large frame score, respectively compared to moderate frame score

[2]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK

[3]BBRD is a binary variable representing breed of bull

Table 10 Estimated coefficients associated with the Waynesville Performance Bull Test Sale price determination model 1

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	1.09346	0.39429	2.77	0.0057
Percent sale order	Log	%	-0.05229	0.01496	-3.49	0.0005
BWLT[1]	Linear/none	Binary	0.00316	0.02238	0.14	0.8878
BWHV[1]	Linear/none	Binary	-0.00115	0.01401	-0.08	0.9344
Age in days	Log	d	-0.78232	0.19668	-3.98	0.0001
Adjusted 205-d weaning weight	Log	kg	0.01973	0.02149	0.92	0.3590
FSSM[2]	Linear/none	Binary	-0.05344	0.02245	-2.38	0.0176
FSLG[2]	Linear/none	Binary	0.02726	0.01388	1.96	0.0500
Final sale weight	Log	kg	1.10078	0.18046	6.10	0.0001
WFCP[3]	Log	$/45.4 kg	0.55581	0.08198	6.78	0.0001
BBRD-Angus[4]	Linear/none	Binary	0.08308	0.01759	4.72	0.0001
BBRD-Charolais[4]	Linear/none	Binary	0.05269	0.02135	2.47	0.0139
BBRD-Gelbvieh[4]	Linear/none	Binary	0.01374	0.02478	0.55	0.5796
BBRD-Simmental[4]	Linear/none	Binary	-0.00196	0.02121	-0.09	0.9263
n		650				
R^2		0.3555				

[1]BWLT and BWHV are binary variables for light and heavy ABW, respectively compared to moderate ABW
[2]FSSM and FSLG are binary variables representing small and large frame score, respectively compared to moderate frame score
[3]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK
[4]BBRD is a binary variable representing breed of bull

Table 11 Estimated coefficients associated with the Waynesville Performance Bull Test Sale price determination model 2

Independent variable	Transformation	Unit	Parameter estimate	SE	t- Value	*P*- Value
Intercept	-	-	14.1453	2.20339	6.42	0.0001
Percent sale order	Log	%	-0.02770	0.01804	-1.54	0.1255
BWLT[1]	Linear/none	Binary	-0.00986	0.02725	-0.36	0.7178
BWHV[1]	Linear/none	Binary	0.02029	0.01691	1.20	0.2310
Age in days	Log	d	-1.32511	0.23999	-5.52	0.0001
Adjusted 205-d weaning weight	Log	kg	0.05974	0.02565	2.33	0.0204
FSSM[2]	Linear/none	Binary	-0.10960	0.08549	-1.28	0.2006
FSLG[2]	Linear/none	Binary	0.00524	0.01826	0.29	0.7743
Final sale weight	Log	kg	1.27837	0.22856	5.59	0.0001
Birth weight EPD[3]	Log	kg	-6.13350	1.08802	-5.64	0.0001
Yearling weight EPD[3]	Log	kg	0.16934	0.11362	1.49	0.1370
WFCP[4]	Log	$/45.4 kg	0.39671	0.10394	3.82	0.0002
BBRD-Angus[5]	Linear/none	Binary	0.13952	0.02875	4.85	0.0001
BBRD-Charolais[5]	Linear/none	Binary	0.10185	0.03381	3.01	0.0028
BBRD-Gelbvieh[5]	Linear/none	Binary	0.02184	0.03617	0.60	0.5463
BBRD-Simmental[5]	Linear/none	Binary	0.00664	0.03462	0.19	0.8479
n		394				
R^2		0.3746				

[1]BWLT and BWHV are binary variables for light and heavy ABW, respectively compared to moderate ABW
[2]FSSM and FSLG are binary variables representing small and large frame score, respectively compared to moderate frame score
[3]EPD: expected progeny differences
[4]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK
[5]BBRD is a binary variable representing breed of bull

Table 12 Summary statistics for all models

Variable	n	Mean	SD	Minimum	Maximum
Mississippi Beef Cattle Improvement Association bull sale model 1					
Percent sale order	633	50.06	29.25	1.05	100
Adjusted 205-d weaning weight	633	290.69	35.85	206.38	434.09
Actual sale weight	633	673.61	98.67	442.25	1070.48
Visual score	633	5.95	1.46	2	10
WFCP[1]	633	5.95	1.46	2	10
BBRD-Angus[2]	403	-	-	-	-
BBRD-Charolais[2]	44	-	-	-	-
BBRD-Hereford[2]	48	-	-	-	-
BBRD-Simmental[2]	38	-	-	-	-
BBRD-Other[2]	100	-	-	-	-
Mississippi Beef Cattle Improvement Association bull sale model 2					
Percent sale order	527	50.61	28.9	1.39	100
Adjusted 205-d weaning weight	527	295.08	34.66	224.53	434.09
Actual sale weight	527	679.05	103.4	442.25	1070.48
Visual score	527	5.91	1.4	2.3	9
WFCP[1]	527	97.88	23.24	62.32	154.36
Birth weight EPD[3]	527	102.81	1.82	97.4	109.2
Yearling weight EPD[3]	527	156.68	24.95	87.4	207
BBRD-Angus[2]	368	-	-	-	-
BBRD-Charolais[2]	37	-	-	-	-
BBRD-Hereford[2]	28	-	-	-	-
BBRD-Simmental[2]	31	-	-	-	-
BBRD-Other[2]	63	-	-	-	-
Hinds County Community College bull test sale					
Percent sale order	468	51.88	29.35	1.12	100
BWLT[4]	62	-	-	-	-
BWMD[4]	303	-	-	-	-
BWHV[4]	68	-	-	-	-
Adjusted 205-d weaning weight	468	278.99	38.24	171.91	396.44
Actual sale weight	468	591.7	74.13	371.95	775.64
WFCP[1]	468	90.7	13.34	62	104.82
BBRD-Angus[2]	245	-	-	-	-
BBRD-Charolais[2]	81	-	-	-	-
BBRD-Hereford[2]	19	-	-	-	-
BBRD-Simmental[2]	36	-	-	-	-
BBRD-Other[2]	87	-	-	-	-
Auburn University bull test sale					
Percent sale order	1673	50.5	28.88	1.25	100
Age in days	1673	408.02	32.22	314	527
Adjusted 205-d weaning weight	1673	297.85	36.68	208.65	419.12
Actual sale weight	1673	586.81	60.19	419.12	801.5
WFCP[1]	1673	84.14	17.58	25.35	110.81

Table 12 Continued

BBRD-Angus[2]	631	-	-	-	-
BBRD-Charolais[2]	289	-	-	-	-
BBRD-Hereford[2]	132	-	-	-	-
BBRD-Simmental[2]	305	-	-	-	-
BBRD-Other[2]	316				
	North Alabama bull evaluation sale				
Percent sale order	1406	50.73	28.82	1.1	100
BWLT[4]	225	-	-	-	-
BWMD[4]	969	-	-	-	-
BWHV[4]	212	-	-	-	-
Age in days	1406	441.69	23.56	379	499
Adjusted 205-d weaning weight	1406	306.75	36.37	147.42	442.71
FSSM[5]	237	-	-	-	-
FSMD[5]	866	-	-	-	-
FSLG[5]	303	-	-	-	-
Actual sale weight	1406	308.91	35.67	147.42	435.9
Birth weight EPD[3]	1406	102.14	1.85	96	109
Yearling weight EPD[3]	1406	150.19	28.08	85	217
WFCP[1]	1406	99.3	20.92	65.13	137.46
BBRD-Angus[2]	704	-	-	-	-
BBRD-Charolais[2]	303	-	-	-	-
BBRD-Simmental[2]					
	262	-	-	-	-
BBRD-Limousin[2]	55	-	-	-	-
BBRD-Other[2]	82	-	-	-	-
	Butner performance bull test sale				
Percent sale order	745	47.84	28.43	1.16	100
BWLT[4]	121	-	-	-	-
BWMD[4]	512	-	-	-	-
BWHV[4]	112	-	-	-	-
Age in days	745	444.13	31.43	324	504
Adjusted 205-d weaning weight	745	311.47	31.59	226.8	428.19
FSSM[5]	14	-	-	-	-
FSMD[5]	596	-	-	-	-
FSLG[5]	135	-	-	-	-
Actual sale weight	745	581.19	52.05	442.25	773.37
Scrotal circumference	745	37.02	2.41	30	45
Birth weight EPD[3]	745	102.26	1.9	95.1	108.5
Yearling weight EPD[3]	745	154.61	27.06	95.2	215
WFCP[1]	745	94.89	16.61	61.13	134.25
BBRD-Angus[2]	521	-	-	-	-
BBRD-Charolais[2]	30	-	-	-	-

Table 12 Continued

BBRD-Gelbvieh[2]	55	-	-	-	-
BBRD-Simmental[2]	109	-	-	-	-
BBRD-Other[2]	30	-	-	-	-
	Piedmont performance bull test sale				
Percent sale order	1238	50.84	28.79	1.47	100
Age in days	1238	413.61	35.55	343	779
Adjusted 205-d weaning weight	1238	289.11	37.36	204.12	428.19
Actual sale weight	1238	521.24	64.51	360.61	746.16
FSSM[5]	203	-	-	-	-
FSMD[5]	861	-	-	-	-
FSLG[5]	174	-	-	-	-
WFCP[1]	1238	73.8	19.67	25.15	105
BBRD-Angus[2]	622	-	-	-	-
BBRD-Charolais[2]	70	-	-	-	-
BBRD-Hereford[2]	262	-	-	-	-
	Waynesville performance bull test sale model 1				
Percent sale order	650	51.94	28.99	2.13	100
BWLT[4]	104	-	-	-	-
BWMD[4]	433	-	-	-	-
BWHV[4]	113	-	-	-	-
Age in days	650	417.45	39.12	330	507
Adjusted 205-d weaning weight	650	252.8	102.71	39.46	410.95
FSSM[5]	59	-	-	-	-
FSMD[5]	472	-	-	-	-
FSLG[5]	119	-	-	-	-
Actual sale weight	650	543.34	61.05	396.44	746.16
WFCP[1]	650	91.98	16.67	62	133.03
BBRD-Angus[2]	360	-	-	-	-
BBRD-Charolais[2]	55	-	-	-	-
BBRD-Hereford[2]	57	-	-	-	-
BBRD-Simmental[2]	107	-	-	-	-
BBRD-Other[2]	71	-	-	-	-
	Waynesville performance bull test sale model 2				
Percent sale order	394	50.02	28.28	2.7	100
BWLT[4]	61	-	-	-	-
BWMD[4]	274	-	-	-	-
BWHV[4]	59	-	-	-	-
Age in days	394	431.41	37.56	358	507
Adjusted 205-d weaning weight	394	228.08	121.41	39.46	410.95
FSSM[5]	17	-	-	-	-
FSMD[5]	298	-	-	-	-
FSLG[5]	79	-	-	-	-
Actual sale weight	394	561.64	58.98	412.77	715.77
Birth weight EPD[3]	394	102.34	1.73	96.4	106.7

Table 12 Continued

Yearling weight EPD[3]	394	155.59	29.03	96	209
WFCP[1]	394	98.04	15.91	62	133.03
BBRD-Angus[2]	239	-	-	-	-
BBRD-Charolais[2]	24	-	-	-	-
BBRD-Gelbvieh[2]	39	-	-	-	-
BBRD-Simmental[2]	68	-	-	-	-

[1]WFCP is a variable representing the average weekly feeder cattle price for calves sold at public auction in Oklahoma City, OK.
[2]BBRD is a binary variable representing breed of bull
[3]EPD: expected progeny differences.
[4]BWLT, BWMD, and BWHV are binary variables for light, moderate, and heavy actual birth weight, respectively.
[5]FSSM, FSMD, and FSLG are binary variables representing small, moderate, and large frame score categories, respectively.

APPENDIX B

FIGURES

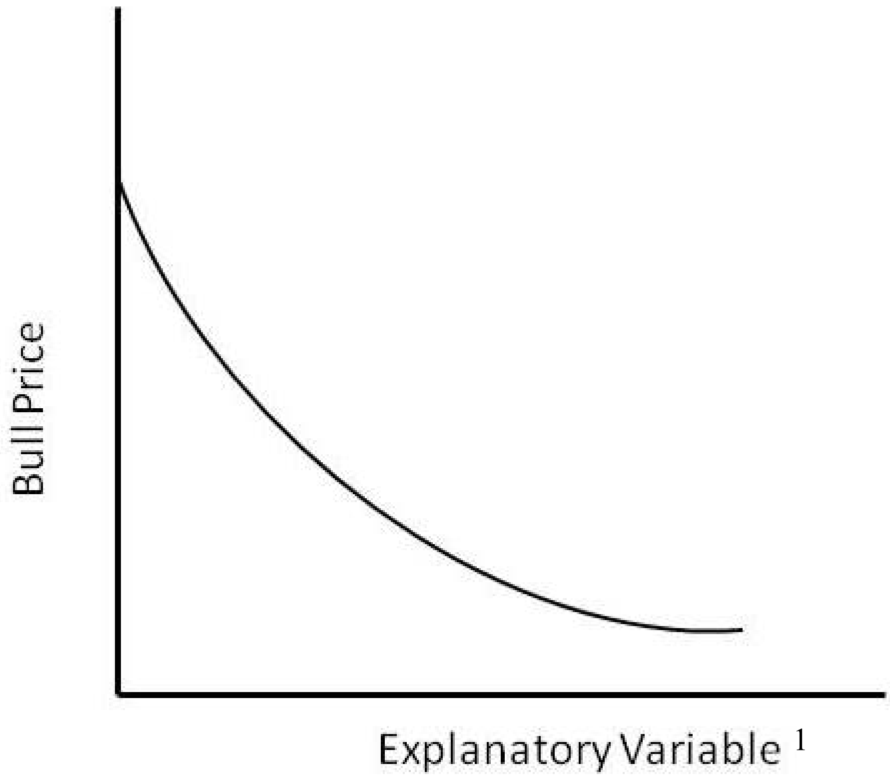

Figure 1 Expected negative bull price relationship to explanatory variables

[1]Explanatory variable: Sale order percent

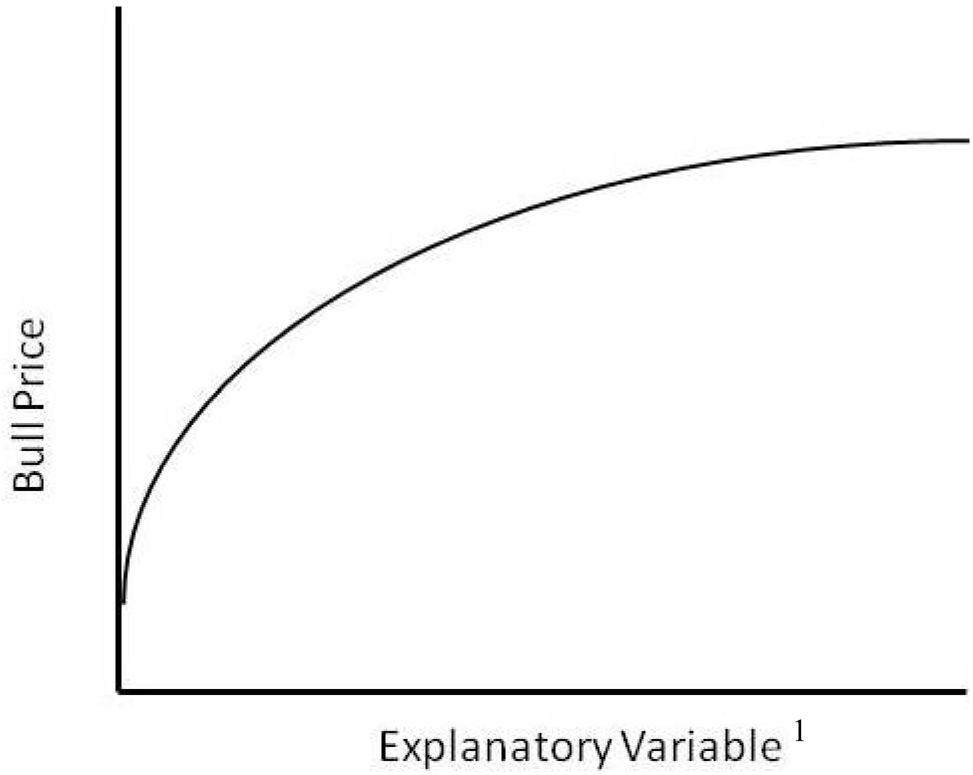

Figure 2 Expected positive bull price relationship to explanatory variables

[1]Explanatory variables: Yearling weight expected progeny differences, adjusted 205-d weaning weight, frame score, final sale weight, scrotal circumference, age in days, weekly feeder cattle (227 to 272 kg) price immediately preceding each bull sale in Oklahoma City, OK

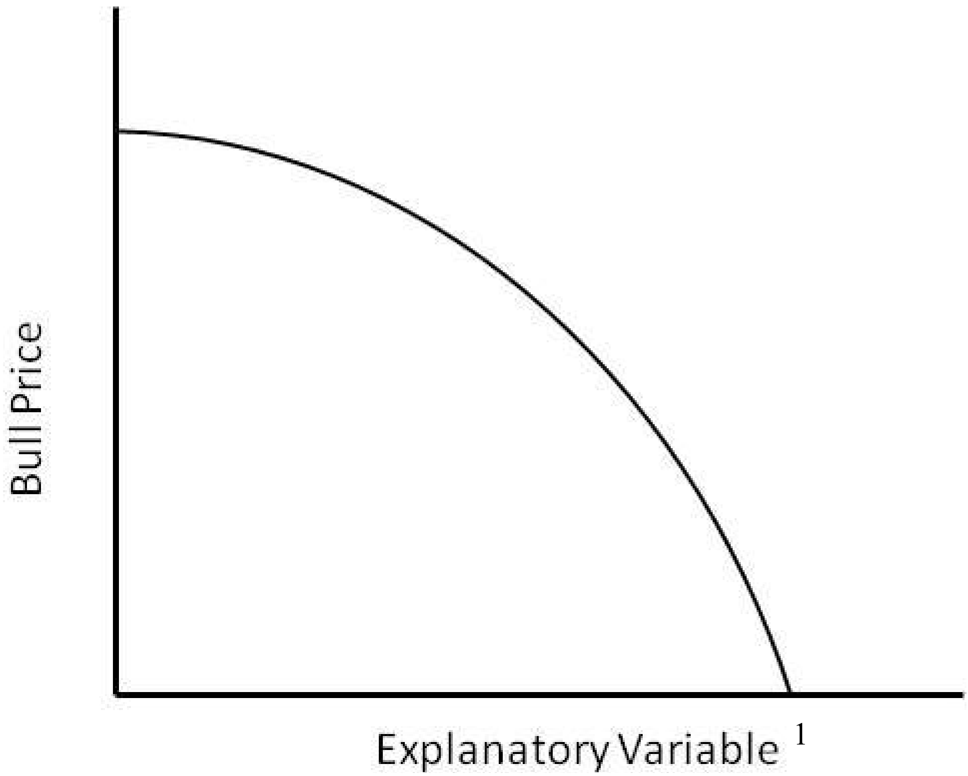

Figure 3 Expected negative bull price relationship to independent variables

[1]Independent variables: Actual birth weight, birth weight expected progeny differences

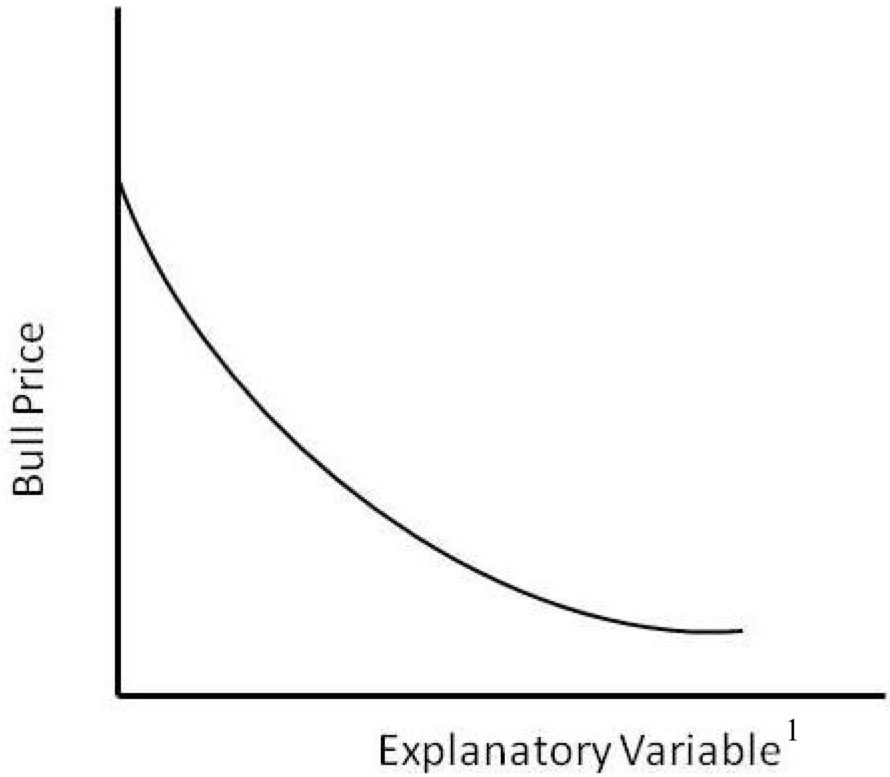

Figure 4 Actual negative bull price relationship to explanatory variables

[1]Explanatory variables: Sale order percent, age in days, yearling weight expected progeny differences

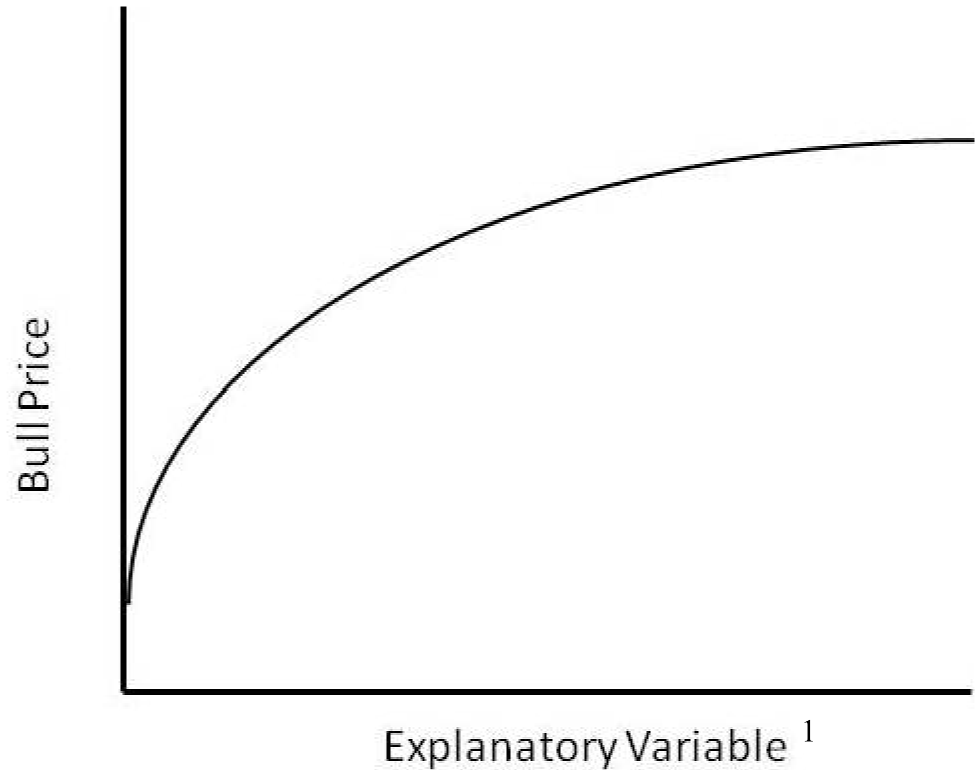

Figure 5 Actual positive bull price relationship to explanatory variables

[1]Explanatory variables: Age in days, adjusted 205-d weaning weight, final sale weight, frame score, visual score, weekly feeder cattle (227 to 272 kg) price immediately preceding each bull sale in Oklahoma City, OK

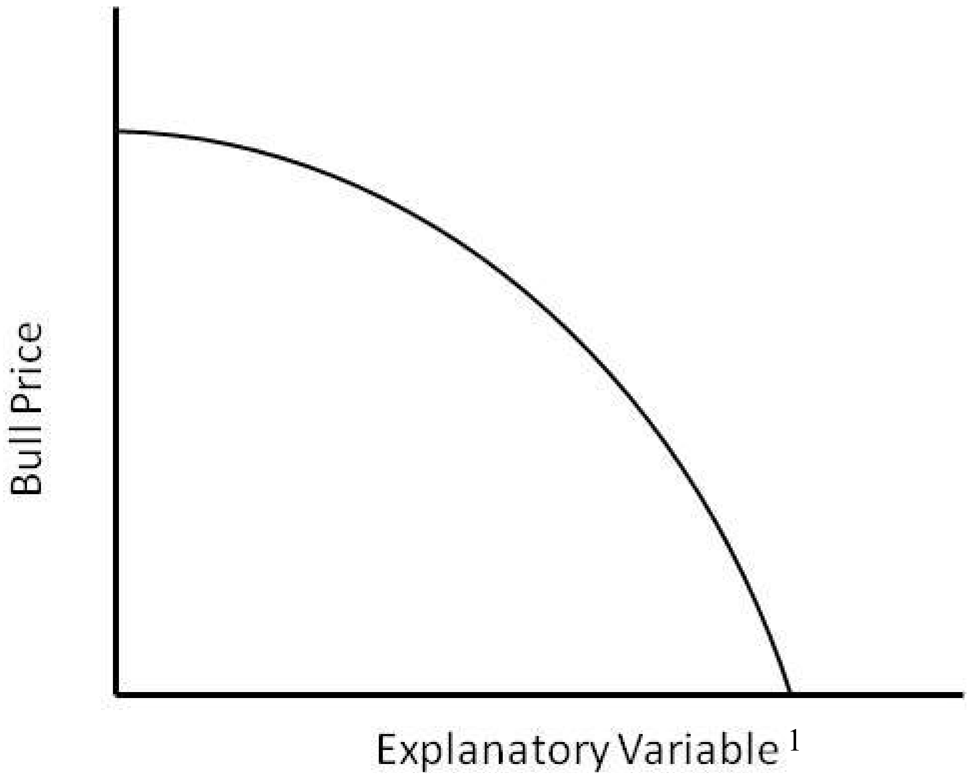

Figure 6 Actual negative bull price relationship to independent variables

[1]Independent variables: Actual birth weight, birth weight expected progeny differences