HEDONIC PRICING MODELS TO

ESTIMATE TRAITS VALUABLE TO BEEFMASTER BULL BUYERS

A Thesis

by

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ABSTRACT

Sire selection is a large financial investment for beef cow operations. Seedstock cattle producers desire knowledge regarding which traits impact differences in value or sale price among their customers. Bull sale data were collected from a purebred Beefmaster ranch in central Texas for five consecutive years (2012-2016, n = 521 records of 19 to 27 month old bulls). The buyers were classified by the sale host based on knowledge about their cow herds as (1) commercial or (2) seedstock/purebred; all bulls marketed were purebred and able to be registered by Beefmaster Breeders United,. Data for these two buyer groups were analyzed separately through various hedonic models to understand important attributes affecting sale price. Each model utilized the same categorical variables, but alternate continuous variables were evaluated as: (1) animals' performance trait values, (2) animals' ratio values, or (3) animals' EPD values, with a final prediction model developed for each buyer type. The final commercial buyer model had an R^2 value of 85%, but the final purebred buyer model had an R^2 value of 44%, indicating that bull price predictions in this dataset were easier to determine among commercial buyers. Commercial buyers placed more emphasis ($P < 0.05$) on the physical traits through conformation score on a 4-point scale (score 2 discounts of \$1079.00 to \$910.77 depending on the model), sire ($P < 0.001$) and maternal grandsire ($P = 0.001$) pedigree information, ribeye area ratio (-\$40. 64 ± 14.667 for each 1% point increase), and quadratic form of weaning weight EPD (\$4.86 ± 1.770). Purebred producers placed more emphasis ($P < 0.05$) on the birth season (age category) in which

bulls were born ($3349.07 to $4810.73 higher for spring born bulls depending on the model), consignor or owner of the animal (-$2669.66 to -$2201.45 less for other consignors compared to the host ranch depending on the model), birth weight EPD (-$2793.00 to -$983.06 for each 1-lb increase), and quadratic form of yearling weight EPD ($8.13 to $10.47 depending on the model). In this dataset of Beefmaster bulls, class of buyer showed substantial differences in information preferences, and different levels of predictability; this is not surprising and is likely true in most breeds from different goals and intended uses across bull buyers.

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All work for the thesis was completed independently by the student based on animal records provided by the host sale ranch and breed association data. This work was supervised by a thesis committee consisting of Dr. Andy Herring and Dr. James Sanders of the Department of Animal Science and Dr. David Anderson of the Department of Agricultural Economics.

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INTRODUCTION

Beef cattle producers can make more precise management and marketing/purchasing decisions by understanding the factors that drive the values of their animals, as well as overall market conditions. Feeder calf prices are known to be determined by factors such as sex, age, weight, breed type, color, horned status, health, amount of condition, muscle score, and frame score. Some of these factors are more influential than others depending on what type of sale is taking place, what type of cattle are being sold, region in which the sale occurs, and lot size. It has been reported that actual performance measures of a bull, as well as various EPD values, will drive the value of British and Continental bulls. Additionally, non-animal factors are known to influence the selling price of seedstock bulls, such as breeder reputation. As with the sale of feeder calves and fed cattle, purebred bull producers that better understand factors affecting sales prices and buyer preferences can also make more precise production and marketing decisions. Although value determinants of Brahman influenced females have been studied to some extent, few studies have been conducted to determine value for *Bos indicus* influenced breeding bulls. This study evaluated traits that influenced sale prices of registered Beefmaster bulls from a private, annual consignment auction (2012-2016) regarding buyers classified as commercial vs. seedstock.

LITERATURE REVIEW

Factors that influence the sale price of feeder calves

Phenotype is important since this is how the majority of feeder calves are sold in the United States. When buying cattle through local livestock auctions, buyers must analyze these traits in a matter of seconds in order to make a decision on whether to bid on the animal or not. Barham and Troxel (2007) looked at many factors that influence price in feeder cattle sold at weekly Arkansas livestock auctions. They found that heifer calves were heavily discounted and bulls received a slight discount as compared to steers; heifers sold for $112.81/cwt, whereas bulls sold for $117.93/cwt and steers for $124.20/cwt. Many other researchers also found that steers demanded the highest price, followed by bulls, and lastly heifers received the lowest prices (Ervin et al., 2006; Leupp et al., 2009).

These calf sex differences could be due to expected production costs of the animals. On average, heifers can be expected to have a lower selling price, because they deposit more fat in relation to muscle, have lower feed conversion rates, and have the possibility of being bred. Bull discounts are likely due to the cost of and risk involved with castration at heavier body weights as well as decreased feed efficiency while they are healing. The price demanded by each sex class are significantly different when compared to each other. Sex is one of the first traits that are physically observed when a calf is being sold.

Weight is an important factor in the sale price of a calf. Schroeder et al. (1988) observed the expected trend in price as weight increases. This trend is nonlinear, and generally decreases as weight increases. This pattern has also been noted in past research (Faminow and Gum, 1986; Dhuyvetter and Schroeder, 2000; Barham and Troxel, 2005; Dhuyvetter et al., 2009; Williams et al., 2012). Dhuyvetter and Schroeder (2000) saw this trend, but noted that the price-weight slide varied by sex. As the weight of yearling heifers increased, price has been documented to increase as well (Schroeder et al., 1988). This is likely due to some of these heifers entering into breeding herds.

Breed types of calves are typically based on industry perception by buyers at the auctions (Barham and Troxel, 2007). Hide color is often used as indicator of breed. The effect of breed type has shown a $33.28/cwt difference between the highest priced and lowest priced cattle in Arkansas sales (Barham and Troxel, 2007). Russell et al. (2015) noted that past research has consistently indicated that Brahman influenced feeder calves receive a discount. This is likely due to their overall lack of marbling ability when compared to other breeds. Barham and Troxel (2007) also found the trends that Russell et al. (2015) referred to. Cattle with any degree of Brahman influence, from one-fourth to purebred Brahman, sold for $4.75/cwt to $14.42/cwt less than the highest selling breed type (Hereford X Charolais) (Barham and Troxel, 2007). Ervin et. al (2006) also found that British/Continential breed types brought premiums of $2.25/cwt compared to purebred British breeds. Ervin et al. (2006) stated that the market prefers cattle that are black or black baldy. As for cattle with *Bos indicus* influence, those were discounted $7.31/cwt compared to purebred British breeds (Barham and Troxel, 2007). In 2009, Leupp et al. noted that black cattle received statistically greater prices than other colors of cattle.

An additional area for possible premiums or discounts is the degree of muscling an animal expresses. Degree of muscling is an indicator of the expected total amount of red meat yield from an animal at time of harvest. Feeder cattle are classified using a range of USDA muscling scores from 1 to 4 (USDA, 2000). An animal classified as a 1 is heavy muscled whereas an animal that is classified as a 4 is extremely light muscled; animals that are double-muscled are deemed “unthrifty” and receive a large discount. The average selling price for cattle with a muscle score of 1 was $120.45/cwt and the average selling price for muscle score 4 cattle was $82.21/cwt. USDA muscle scores 1, 2, 3, and 4 all had significantly different prices associated with each (Barham and Troxel, 2007).

Presence of horns can also lead to discounts in feeder cattle. Horns that are small or even tipped (cut shorter) can cause injury or damage to carcass quality due to bruising other cattle during life in a yard pen or handling such as loading onto or unloading from trucks. Polled cattle sold for significantly higher prices of $118.57/cwt, whereas horned cattle sold for $114.87/cwt (Barham and Troxel, 2007). Dhuyvetter et al. (2009) and Schroeder et al. (1988) also noticed a discount due to horns.

Frame score is also an important factor when purchasing cattle. Cattle ultimately end up as meat products, so their sheer carcass size needs to meet the specifications demanded by processing plants. USDA classification of feeder calf frame scores are small, medium, or large and estimate finished weights of animals when obtaining 0.5

inches of 12th rib fat thickness (USDA, 2000). Dhuyvetter et al. (2009) found that small framed cattle received a discount of $5.98/cwt whereas large framed cattle were given a small premium of $0.75/cwt. To add to this point, Barham and Troxel (2007) also noted that the price paid for large framed cattle and medium framed cattle were not significantly different. However, small framed cattle brought $95.43/cwt when large and medium framed cattle brought $118.27/cwt and $118.15/cwt, respectively. However, Schroeder et al. (1988) found that small framed heifers were not discounted more than their steer counterparts, due to some of the heifers being purchased for breeding stock.

Next, the amount of condition that an animal carries is an important consideration. Dhuyvetter et al. (2009) found cattle that were extremely thin or extremely fat both received discounts. If an animal is too thin, there are health concerns and morbidity and mortality risks associated with buying this type of cattle. Barham and Troxel (2007) discovered that average conditioned cattle ($118.14/cwt) brought significantly more per hundred-weight than the slightly thin cattle ($116.80/cwt). Ervin et. al (2006) noted that slightly thin cattle (BCS 3) received a discount of $33.95/cwt. Those that were slightly over conditioned demanded a premium of $1.52/cwt.

Typically, feeder cattle buyers will pay more for slightly thinner cattle in anticipation of capitalizing on compensatory gain. For feedyards, it is cheaper to add weight to animals rather than to buy heavier animals that have already added condition. Alternatively, the more condition a breeding animal is carrying, the better indication that this animal is able to maintain body condition score with lower nutritional inputs.

There are other descriptive factors that also affect the sale price of feeder calves. For example, many of these are health related and grouped accordingly. Descriptions such as sick, lame, bad eye, crooked nose, short tail, dead hair, healthy, or preconditioned are used. Some of these physical attributes are unappealing, but others are highly rewarded. Schroeder et al. (1988) noted that health had the most profound influence on price. Sick cattle received discounts exceeding 20% of the average price given to healthy cattle (Schroeder et al., 1988). Barham and Troxel (2007) found that sale prices were statistically lower on sick and physically lame cattle ($80.22/cwt and $84.74/cwt) compared to cattle that were healthy ($118.21/cwt). They also noted that preconditioned cattle sold at statistically higher prices ($122.36/cwt) than healthy cattle ($118.21/cwt). Dhuyvetter et al. (2009) also found that non-healthy cattle were heavily discounted ($6.31/cwt) compared to healthy cattle. It was also noted by King and Seeger (2004) that calves who are enrolled in preconditioned programs will receive a higher price than unweaned, unvaccinated calves by $4.84/cwt and $5.33/cwt depending on the program.

Death loss in a stocker or feedyard operation is a major concern financially so procuring healthy cattle that are low risk is very important. Preconditioned cattle are given premiums because most of the risk due to death loss is removed by teaching them how to survive without their dams and training them how to eat grain from a bunk. Additionally, it is thought that preconditioned cattle have stronger immune systems going into the stocker operation or feedlot due to them already surviving one of the most stressful times in their lives.

Bulut and Lawrence (2006) examined the differences in premiums given to preconditioned cattle with and without third-party certification. They concluded that the third-party certification premium was $2.75/cwt greater than the premium for no certification and third-party verification premium was $6.15/cwt compared to calves with no preconditioning. This difference exceeded the cost of third-party certification, which was $1/cwt (Bulut and Lawrence, 2006). Williams et al. (2012) studied cattle that were enrolled in an Oklahoma value-added third-party verification program. This report showed an average $6/cwt premium over non-certified cattle. According to the National Animal Health Monitoring System (USDA, 2008), 35.2% of operations conveyed herd health practices to potential buyers. Of the 35.2% of operations, 58.1% did so by oral communication and 40.2% with some form of written documentation (USDA, 2008).

Lot size is also a consideration, although minor, that still affects selling price (Kuehn, 1979; Ervin et al., 2006; Barham and Troxel, 2007). Faminow and Gum (1986) found that the relationship between lot size and price was quadratic. Likewise, Dhuyvetter et al. (2009) found that the highest prices were paid for cattle in lots that approached truck load sizes. Faminow and Gum (1986) reported that there was a quadratic relationship between price received and lot size, where at approximately 32,000 pounds selling price is maximized. This result was unexpected due to truck capacity being 40,000 pounds. It was also concluded that within larger lot sizes the chance of mixed cattle decreases thereby decreasing health risks that coincide with comingling cattle (Dhuyvetter et al., 2009). Barham and Troxel (2007) reported that cattle sold in groups brought more than singles. Groups of 2 to 5 head brought

$120.12/cwt and groups of 6 head or more brought $122.61/cwt (Barham and Troxel, 2007). Leupp et al. (2009) also found trends that align with prices found by Barham and Troxel (2007).

Lastly, Barham and Troxel (2007) concluded that when selling lighter calves, breed type and color were the two most important factors in predicting performance. The heavier the cattle were the more the buyers evaluated the physical characteristics that were already present such as muscle and frame score (Barham and Troxel, 2007). Most of the aforementioned factors that influence selling price can either be controlled through genetic selection or management practices. In order to increase revenue, it is recommended to know not only the production environment and what thrives but to also have an understanding of the factors that lead to premiums and discounts in the desired market.

The physical attributes that an animal expresses may influence price in the short run. When thinking over the long run, the price of an animal is determined by the supply or inventory of cattle and demand factors. According to Schroeder et al. (1988), prices are a function of the expected cost of gain and expected fed cattle prices. Market force factors could include expected prices for inputs, output prices, and other variables such as interest rate (Schroeder et al., 1988).

One non-animal factor that could influence price is the location of the sale as well as how cattle were sold. As reported by Schmitz et al. (2003), the majority (60.8%) of the United States calf crop is sold through local livestock auctions. In a survey of cattle producers by Fausti et al. (2006), it was reported that producers in the Dakotas strongly prefer to sell their cattle through local livestock auctions rather than private treaty. A driver of local auctions use may be the comfort of producers with the accuracy of local market information. In the Dakotas, producers believe that local sources are more reliable for gathering price information. This trend was also found previously by Lawrence et al. (1996) in a survey of Iowa producers. There are many relationships between all the factors that determine price and price reporting within the beef cattle industry.

More recently, the 2007-2008 National Animal Health Monitoring System survey was conducted across 24 states with 2,872 cow calf operations participating (USDA, 2008). One section of this report focuses on what production practices were used to market the calves that were produced. It was reported that 62.8% of operations market their calves as conventional beef with a smaller percentage (13.6%) of producers using a breed-influenced program. The South Central region, comprised of Texas and Oklahoma, had similar marketing trends as the national average. The percentage of operations that used the conventional marketing channel and the breed-influenced program were 57.7% and 11.5%, respectively. Similar to reports by Fausti et al., (2006), producers chose local sources to gather information on a variety of topics. When asked about where producers received general beef cattle information from, 53.1% of operations choose veterinarians followed by 23.7% seeking council from other producers (USDA, 2008). Veterinarians and fellow producers are also the most used sources for breeding and genetics information with 45.2% and 22.4%, respectively (USDA, 2008). These 2 sources were overwhelmingly more popular than others sources such as the extension service or universities, beef magazines or print publications, company representatives, and internet. However, 31.7% of operations choose to rely on feed salespersons or retailers for animal nutrition information. Veterinarians and other producers are the next most used sources with 27.3% and 15%, respectively. Lastly, producers were asked which factor was the most important for determining when calves are ready to be weaned from the cow herds. Over half of the operations surveyed (53.8%) choose to wean calves based on their age or weight. 11.9% of operations wean calves based on tradition, because that is the way that it has always been done. This could be specific ranch tradition or tradition based on their area of production. Other common reasons for weaning calves were physical condition of the cow (9.3%) and forage availability (8.1%).

Factors that influence the price of herd bulls

The aforementioned most common factors discussed are all important in determining the values of feeder calves, which have been widely reported (Sullivan and Linton, 1981; Schroeder et al., 1988; Bailey et al., 1991; Bailey and Peterson, 1991; Turner et al., 1991; Turner et al., 1993; Sartwelle et al., 1996; Ervin et al., 2006; Barham and Troxel, 2007). However, much fewer studies have examined prices or values of herd bulls, with the majority of these studies on British and Continental European bulls.

Stevens (2015) investigated the attributes that buyers placed on Angus herd bulls that were sold through the Oklahoma Panhandle State University (OPSU) bull test sale. The majority of the bulls sold at the OPSU bull sales over a six-year time frame (2008 – 2013) were Angus, and other breeds were not included in analyses. In order to analyze these bulls, multiple hedonic models were created using different forms of data. Throughout all models, more information was added such as values that came from the feeding trial, performance and maternal EPDs, and lastly, carcass EPDs. The OPSU study employed these models to analyze bull prices. In model 1, the bulls actual birth weight, final test weight, and average daily gain were all significant factors in determining price ($P < 0.01$). The coefficient for birth weight suggests that for each pound of birth weight the price will decrease by \$19.82. For final test weight, results suggest that for each pound of weight associated with the bull, the price will increase by \$2.08. For each pound of average daily gain, the price will increase by \$478.00. Results for model 2 indicated that actual birth weight, average daily gain, final test weight, and calving ease direct EPD were significant ($P < 0.05$). As in the first model, the coefficient for birth weight was negative while the coefficients for final test weight and average daily gain were positive. The calving ease direct EPD coefficient was positive suggesting that for each unit increase in EPD, the price will increase by \$49.85. The third model specifications found that birth weight and average daily gain were the most significant in determining bull price ($P < 0.01$). The birth weight coefficient was -\$24.18 and the average daily gain coefficient was \$555.01. The coefficients for final test weight and ribeye area EPD were \$1.72/lb and \$665.58/sq in, respectively ($P < 0.10$). The three factors that remained statistically significant ($P < 0.10$) across all model specifications were actual birth weight, average daily gain, and test weight. This suggests that bull buyers place most of their emphasis on performance and growth measures rather than EPD's. EPD's are used to predict the performance of an animals' future progeny for a specific trait. These measures are useful, but also related to the actual performance of the animal. The use of and value of EPD’s have been reported in few studies (Arnold et al., 1991; Nunez-Dominguez et al., 1993; Kemp and Sullivan, 1995).

Additionally, Dhuyvetter et al. (1996) studied the determinants of beef bull prices at many purebred auctions across Kansas. In this study, data were collected on British and Continental breed bulls (Angus, Charolais, Gelbvieh, Hereford, Limousin, Red Angus, and Simmental). Physical and genetic characteristics were collected along with market conditions. Rather than combining all EPD’s and individual performance measures, Dhuyvetter et al. (1996) separated each breed along with their EPD’s and individual performance data from one another in order to understand which factors were significant in price determination for each breed. None of the breed effects were significantly different from zero. However, they concluded that premiums were paid for bulls with black hide color due to the expected superior carcass quality associated with Angus-type cattle. Premiums were paid for black Simmental (50 to 53%), Gelbvieh (12 to 15%), and Limousin (30 to 40%) compared to red bulls. Subjective ratings were also given to bulls for the categories of conformation, muscling, and disposition. Premiums were given to bulls that ranked higher for desirable physical attributes.

When looking at expected progeny performance variables such as birth weight EPD, weaning weight EPD, and milk production EPD, all significantly affected the price that was paid for several breeds of bulls (Dhuyvetter et al., 1996). High birth weight EPD’s were discounted 4.4 to 4.6%/lb for three breeds ($P < 0.05$). Weaning weight EPD premiums ranged from 0.8 to 3.4%/lb for five of the seven breeds ($P < 0.05$). Premiums for Milk EPD ranged from 0.8 to 2.8%/lb for three breeds ($P < 0.05$). Depending on the breed of bull, some factors explained differences in price better than others. For example, performance characteristics and EPD's were significant when determining price for Simmental bulls, but not significant for Red Angus bulls.

Marston et al. (2002) also concluded that buying habits and emphasis of traits differed between the different breeds of bulls marketed between 1997 and 2000 in the Kansas Bull Test sales. This could possibly be due to what each breed association is emphasizing or the buyers' involvement with the association. Lastly, Dhuyvetter et al. (1996) noted there were marketing factors that were not included in their analysis such as seller (breeder) reputation and location that could impact the selling price further.

Walburger (2002) found that purebred bull producers in Alberta, Canada were selecting for attributes that were directly tied to payment criteria. At the time of this study, packers had started to realize that consumers were demanding more consistency, quality, and palatability from the beef industry. Although consumers were willing to pay, producers were lagging. Even though there were some beginning signs of purebred associations stepping up to fill the need, there was a need for industry developed selection tools with financial incentives. Certified Angus Beef was started in 1978; by 1995, Certified Angus Beef had sold 1 million pounds of beef and was gaining in popularity as a branded beef program that offered financial incentives for cattle that met strict specifications (Certified Angus Beef, 2018).

Determinants of cow prices

As with all other classes of cattle, there are specific factors that are most influential in determining price and value of female breeding cattle. Mintert et al. (1990) concluded that, in general, cow buyers were looking for cows that were healthy. If an animal was deemed "unhealthy" or having defects such as bad eyes, signs of hardware disease, or visible knots, they were heavily discounted up to $8.97/cwt (Mintert et al., 1990). This sends a clear signal to producers to cull and sell cattle before they become severe health risks. Lot size was also a significant factor in determining the value of cows. Lots that consisted of 2 to 20 animals were given a premium over cattle that were sold as singles. However, groups of 5 head or more captured over half of the $1.25/cwt premium given to lots of 11 to 15 cattle (Mintert et al., 1990). At the time that productivity, health, or other parameters are measured to identify cull animals, producers should plan to market those animal at the same time. This will allow them the potential to take advantage of large group premiums. Similar to these results, Barham and Troxel (2007) also found results that aligned with this trend when marketing feeder calves.

Mintert et al. (1990) also found that the breed effect was significant in determining price of cows sold in Kansas cattle auctions. When using Hereford as the base breed, Exotic crosses that included Simmental, Charolais, Gelbvieh, and Maine-Anjou demanded a premium of $1.27/cwt. It is hypothesized that these premiums were due to expectations of higher meat yields. Cattle that were judged as being more than ¼ Brahman received premiums of $1.77/cwt more than Hereford cattle. This was thought to be due to the higher dressed weights in Brahmans. However, due to the small percentage of Brahman influenced cows in the sale, these premiums might be due to a buyer wanting them specifically for other uses (breeding) rather than slaughter.

Greer and Urick (1988) studied bull prices of Line 1 Hereford from Miles City, Montana as effected by calf prices and herd inventories in years 1978 and 1979. It was concluded that if there was a 10% increase in cow inventory, it would cause a 25% increase in bull price. However, a 10% increase in heifer inventory only caused an 11.7% increase in bull price. Cow herd inventory is thought to have a greater effect on bull price due to the biological relation between cow age and pounds of calf produced (Greer and Urick, 1988). These older cows have an established record and are likely to be bred to reputation bulls.

Value of Brahman genetics when used as breeding animals

Many studies have explored the values of Brahman influenced feeder cattle and their performance in the feedyard. However, there have been very few studies conducted to look at the value of Brahman genetics when used as breeding animals. This is where the Brahman breed appears to be the most valuable. In South Texas and in many parts of Central and South America, Brahman influenced cattle thrive better than any purebred British and Continental breed types by being able to tolerate heat and humidity and resist parasites. Brahmans are best known for their ability to be used in crossbreeding systems. By crossbreeding Brahmans with *Bos taurus* breeds, one can increase the amount of hybrid vigor in their herd.

Russell et al. (2015) examined the effects of Brahman influence on sale prices of females at a special sale in South Texas. The percentage of Brahman was broken down into 5 groups (0%, 25%, 50%, 75%, and 100%). Each type of cattle that contained a percentage of Brahman influence commanded prices that were significantly higher than cattle with no Brahman influence. One specific factor that was studied that would not be studied in any feeder cattle study was breeding status. Russell et al. (2015) noted that animals that were exposed to a bull brought statistically significantly higher prices than those that were sold as open. None of the heifers sold as exposed were verified as bred. A potential explanation for the increased price demand was due to a trust factor or the possibility that they could be bred. The highest premiums that are associated with breeding status were the pairs followed by the heifers that were bred (Russell et al., 2015).

It is believed that the value of a cow-calf pair is increased due to the apparent value of a calf that can be sold as immediate income and the already proven maternal ability of the cow. The cow has already been bred, given birth to a calf, and is in the process of raising the calf successfully. This eliminates some of the risk that is associated with purchasing bred heifers. Russell et al. (2015) also found that similar to feeder calf data, frame score is important in determining price. In this study, medium framed animals were worth more to the buyer when compared to small framed heifers. One benefit of smaller animals could be that they will require less nutritional resources to maintain body condition. However, lower prices could be attributed to the fear that smaller framed heifers might have dystocia related problems when they are ready to calve. The smaller framed cows will also have a lower salvage value at the point that they are no longer useful as breeding stock. Although Brahman influenced feeder calves are heavily discounted, this study showed that producers are willing to pay premiums for Brahman or Brahman influenced females to be used in their herds. These animals are great assets to an operation in terms of increasing the amount of heterosis.

Summary of Literature Review and research objectives

Depending on what kind of cattle producers are trying to market, many different animal as well as non-animal factors are involved. When marketing feeder calves, weight, muscle score, frame, breed type, color are the driving animal factors of price. Many fewer studies have evaluated price determinants of breeding cattle. When marketing breeding animals, it is important to keep in mind what factors are the most important from a physical and economic standpoint. It is easy to focus on one aspect only, but both of these standpoints determine the revenue received. Producers may place more evaluation emphasis on income than profit (using income as a proxy for profit). However, each operation is unique in that they could have vast differences in expenses which will determine the overall profitability and sustainability of the operation. Reports of bull price determinants have been made in several British and Continental breeds. More precise information regarding breeding bull prices in American breeds need to be determined. This thesis evaluated five years of bull sale data from a Beefmaster seedstock producer in central Texas with the following objectives:

1. Determine the animal and non-animal factors influencing price of purebred Beefmaster herd bulls.
2. Develop hedonic pricing models that describe purebred Beefmaster bull values when targeted toward commercial and seedstock (purebred) bull buyers.

MATERIALS AND METHODS

Animal data and background information

Data were collected from a purebred Beefmaster ranch in central Texas. Five consecutive years (2012-2016, n = 521) of data from an annual bull production sale were analyzed. According to each sale catalog, cattle were performance tested before the sale. The bulls were subjected to a gain test for 300+ days. Every year the test was started in early January and ran through the end of November with the last portion of the test running up to sale day. Testing is forage-based where bulls start on winter oat pasture and end with a supplement test on summer Bermuda grass pasture. At the beginning and end of each test, bulls were weighed to measure average daily gain and weight per day of age. They were also ultrasound scanned to estimate carcass merit. Additionally, all bulls were visually evaluated by a set of professional cattlemen on conformation, disposition, and fleshing ability. All bulls were sold in the order that they were ranked according to their performance test data.

Prior to the sale, catalogs were available upon request from sale management. These catalogs were also available the day before the sale and on sale day to buyers who were viewing the bulls at the sale location. All data that were used for this project were collected from these printed materials, except for pedigree information, phenotype scores and underline scores, which were provided by the Beefmaster Breeders United office based in Boerne, TX.

Data were entered into a spreadsheet from paper copies of sale catalogs that were provided to potential buyers. Descriptive and identifying information that was available to buyers on each bull consisted of the following: the consignor, the individual's registration number, brand, date of birth, color, and horned/polled status. All bulls were put through performance testing and the following ratios were collected: spring test average daily gain (ADG) ratio, spring test weight per day of age (WDA) ratio, ultra sound ratio, summer test ADG ratio, summer test WDA ratio, visual ratio, and a total ratio. Next, each bull was compared to their contemporaries and the following data was recorded: birth weight (BW) ratio, number of contemporaries for BW, adjusted BW, weaning weight (WW) ratio, number of contemporaries for WW, adjusted WW, yearling weight (YW) ratio, number of contemporaries for YW, adjusted YW, adjusted scrotal circumference, ribeye area (REA) ratio, number of contemporaries for REA, adjusted REA, percent intramuscular fat (%IMF) ratio, number of contemporaries for %IMF, adjusted %IMF, rib fat ratio, number of contemporaries for rib fat, adjusted rib fat, rump fat ratio, number of contemporaries for rump fat, and adjusted rump fat. Each bull has a set of EPDs listed with their respective accuracies.

The following EPDs and their accuracies were listed: Birth Weight (BW), Weaning Weight (WW), Yearling Weight (YW), Milk, Total Maternal (TM) (EPD only), and Scrotal Circumference (SC). Some bulls throughout the five years also had the following carcass trait EPDs and accuracies: REA, %IMF, Rib Fat, and Rump Fat. Terminal Index ($T) and Maternal Index ($M) were only recorded for bulls sold in 2016. Therefore, the Terminal Index and Maternal Index were not investigated. Additionally, each bulls' pedigree up to three previous generations was printed in the catalog. Lastly, overall conformation scores and underline scores were given to each bull by a Beefmaster Breeders United representative on sale day. Conformation scores range from 1 (ideal) to 4 (undesirable) (BBU Standard of Excellence, 2016). There are numerous variations within each score.

Beefmaster Breeders United (BBU) Standards of Excellence (2016) is a list of guidelines that outline the ideal Beefmaster bull along with discriminations to be determined by the field representative who is scoring the bulls, and have the following descriptions. Male head characteristics are to be masculine, alert, and proportionate to the animal, full muzzle with nostrils wide and open, and good width between the eyes. Conformation score will be altered due to a long and narrow head that is not proportionate to the body or one that is short and dished. Neck standards indicate the neck must be medium in length, muscular with smooth attachment with moderate crest, hump, and clean dewlap development. Discriminations will be given to bulls that have thin necks or excessive crests. Exceptional bulls need to have well-muscled and masculine shoulders and forearms. Those that exhibit coarse, bold shoulders or excessive width or open shoulders will be deemed less than ideal, and bulls must have a full and wide chest floor with a full heart girth with ample capacity. Bulls with protruding and/or heavy briskets, pinched or narrow heart girths, or narrow chest floor will be ranked accordingly by the field representative. Back and rib guidelines state that bulls must have an abundance of natural thickness down their top and ribs must be well sprung from the backbone. Discriminations are given to bulls with a short middle, tight ribs and middle giving the appearance of a barrel belly, or flat ribs with no outward curve. Additionally, bulls with a weak top or a hump back will also be docked. Standards suggest that the tail heads must be smoothly attached and the rump must be long, level, and square from hooks to pins. Muscling must be thick and deep meeting well down to the hocks with a well-developed stifle and muscle extending into the flank. Undesirable scores will be given to bulls with sloped rump or narrowing from the hooks to the pins, extremely rounded hindquarters, or shallow round and twist lacking natural muscle.

Bulls that would be assigned a conformation score of 4 were culled before the time of sale, and no conformation scores of 4 were reported in these sale data. Underline scores are ranked from 1 (ideal) to 5 (undesirable) (BBU Standards of Excellence, 2016). Standards of Excellence define sheaths to be of moderate size, with discriminations given for long pendulous sheaths or lack of sheath. Additionally, testicles must be well developed or proportionate in size. Underline score will be docked for testicles that are underdeveloped. Bulls that would be assigned underline scores of 5 were culled throughout the 300+ day test period, and no underline scores of 5 were reported in these sale data.

After the sales were made, each bull was noted by the sale organizer whether the buyer was going to use the bull in a commercial herd or a seedstock (denoted as purebred) herd. Consequently, separate analyses were performed on each set of animals (commercial buyers vs. purebred buyers) to estimate potential differences in buyer preferences.

Statistical analyses and model development

The statistical software package R was used to perform regression and general linear model analysis on all models (R Core Team, 2017). The packages of Companion to Applied Regression, Estimated Marginal Means (Least Squares Means), and Various R Programming Tools were used for analyses. Type I error rates of $P < 0.10$ and $P < 0.05$ were thresholds to identify statistical trends and significance, respectively, for all analyses.

Hedonic modeling methods were used to analyze data. By definition, hedonic modeling is valuing goods based on the summation of the goods' factors and their relationships with each other rather than defining an explicit value (Stevens, 2015). Hedonic models can be influenced by market signals throughout sectors of the beef industry. For instance, if packers are continually pushing for heavier carcass weights, a producer may place more value on growth traits such as weaning weights and yearling weights and their respective EPDs. Likewise, breeders are able to use these signals to make more informed breeding decisions based on what the buyers are emphasizing. It is not advised for producers to select bulls based on a single trait, but to select sires that are well balanced for many production measures. Thus, the price of Beefmaster bulls is thought to depend on several physical attributes and other explanatory variables.

Some data entries were questionable based on their values as outliers. Before any data were dropped from the analyses, sale averages were calculated for each of the five years, and ranges were evaluated for all animal traits. Some animals that were listed in the catalogs were listed as “not sold”. These animals were removed from further analysis.

Commercial buyer models

The dependent variable investigated was sale price of Beefmaster bulls sold at the host production sale (measured in $ per animal). Due to many different variables recorded on each bull, three separate models were made as to group similar types of continuous traits together where models included (1) adjusted traits of the animals, (2) trait ratios of the animals, or (3) EPDs of animals. At the completion of these three models, one “final” model was constructed to compare significant factors from each previous model. All models included categorical variables of year, lot number, season, consignor, sire ID, maternal grandsire ID, and conformation score. A total of 342 bulls were included for commercial buyer analyses.

Adjusted Trait Model

This model included factors that were derived from the bulls’ individual performance as well as the categorical variables listed above. The basis for including performance traits is that buyers are viewing the animals visually before and during the sale. These traits could be physically evaluated by size and weight of the bulls. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, relative to January 1

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (BBU Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

BW adj. = Individual birth weight adjusted for age of dam (lb)

WW adj. = Individual weaning weight adjusted to 205-days (lb)

YW adj. = Individual yearling weight adjusted to 365-days (lb)

Scrotal adj. = Scrotal circumference (cm)

REA adj. = Individual ribeye area adjusted for sex, age of dam, and age at scanning (sq in)

% IMF adj. = Individual percent intramuscular fat adjusted for sex, age of dam, and age at scanning (%)

Rib Fat adj. = Individual rib fat adjusted for sex, age of dam, and age at scanning (in)

Rump Fat adj. = Individual rump fat adjusted for sex, age of dam, and age at scanning (in)

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

EPD Model

This model includes factors that could be used by buyers to predict performance of future offspring as well as the categorical variables listed above. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, relative to January 1

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (BBU Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

BW EPD = Birth Weight EPD

WW EPD = Weaning Weight EPD

YW EPD = Yearling Weight EPD

Milk EPD = Maternal Milk EPD

TM EPD = Total Maternal EPD

SC EPD = Scrotal Circumference EPD

REA EPD = Rib Eye Area EPD

% IMF EPD = Percent Intramuscular Fat EPD

Rib Fat EPD = Rib Fat EPD

Rump Fat EPD = Rump Fat EPD

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

Ratio Model

This model includes factors that are used to rank bulls against others in the same contemporary group as well as the categorical variables listed above. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, relative to January 1

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (BBU Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

SpT ADG ratio = Average daily gain ratio of individual during the spring test period

SpT WDA ratio = Weight per day of age ratio of individual during the spring test period

SmT ADG ratio = Average daily gain ratio of individual during the summer test period

SmT WDA ratio = Weight per day of age ratio of individual during the summer test period

BW ratio = ratio of individual's birth weight compared to average of contemporary group

WW ratio = ratio of individual's weaning weight compared to average of contemporary group

YW ratio = ratio of individual's yearling weight compared to average of contemporary group

REA ratio = ratio of individual's rib eye area size compared to average of contemporary group

% IMF ratio = ratio of individual's amount of intramuscular fat compared to average of contemporary group

Rib Fat ratio = ratio of individual's amount of rib fat compared to average of contemporary group

Rump Fat ratio = ratio of individual's amount of rump fat compared to average of contemporary group

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

Final Commercial Buyer Model

This model includes factors that were deemed statistically significant in each of the three previous models. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, identified bulls as long yearlings or 2-year-olds

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

WW adj. = Individual weaning weight adjusted to 205-days (lb)

Scrotal adj. = Scrotal circumference (cm)

REA adj. = Individual ribeye area adjusted for sex, age of dam, and age at scanning (sq in)

Rib Fat adj.^{2} = Individual rib fat squared adjusted for sex, age of dam, and age at scanning (in)

BW EPD = Birth Weight EPD

WW EPD = Weaning Weight EPD

WW EPD^2 = Weaning Weight EPD squared

BW ratio^2 = ratio of individual's birth weight compared to average of contemporary group squared

YW ratio^2 = ratio of individual's yearling weight compared to average of contemporary group squared

REA ratio = ratio of individual's rib eye area size compared to average of contemporary group

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

Purebred buyer models

The dependent variable investigated was sale price of Beefmaster bulls sold at the host production sale (measured in $ per animal). Due to many different variables recorded on each bull, three separate models were made as to group similar types of continuous traits together where models included (1) adjusted traits of the animals, (2) trait ratios of the animals, or (3) EPDs of animals. At the completion of these three models, one "final" model was constructed to compare significant factors from each previous model. All models included categorical variables of year, lot number, season, consignor, sire ID, maternal grandsire ID, and conformation score. A total of 179 bulls were included for purebred buyer analyses.

Adjusted Trait Model

This model included factors that were derived from the bulls' individual performance as well as the categorical variables listed above. The basis for including performance traits is that buyers are viewing the animals visually before and during the sale. These traits could be physically evaluated by size and weight of the bulls. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, identified bulls as long yearlings or 2-year-olds

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

BW adj. = Individual birth weight adjusted adjusted for age of the dam (lb)

WW adj. = Individual weaning weight adjusted to 205-days (lb)

YW adj. = Individual yearling weight adjusted to 365-days (lb)

Scrotal adj. = Scrotal circumference (cm)

REA adj. = Individual ribeye area adjusted for sex, age of dam, and age at scanning (sq in)

% IMF adj. = Individual percent intramuscular fat adjusted for sex, age of dam, and age at scanning (%)

Rib Fat adj. = Individual rib fat adjusted for sex, age of dam, and age at scanning (in)

Rump Fat adj. = Individual rump fat adjusted for sex, age of dam, and age at scanning (in)

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

EPD Model

This model includes factors that could be used by buyers to predict performance of future offspring as well as the categorical variables listed above. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, identified bulls as long yearlings or 2-year-olds

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

BW EPD = Birth Weight EPD

WW EPD = Weaning Weight EPD

YW EPD = Yearling Weight EPD

Milk EPD = Maternal Milk EPD

TM EPD = Total Maternal EPD

SC EPD = Scrotal Circumference EPD

REA EPD = Rib Eye Area EPD

% IMF EPD = Percent Intramuscular Fat EPD

Rib Fat EPD = Rib Fat EPD

Rump Fat EPD = Rump Fat EPD

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

Ratio Model

This model includes factors that are used to rank bulls against others in the same contemporary group as well as the categorical variables listed above. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, identified bulls as long yearlings or 2-year-olds

Consignor = A, if host ranch or B, if other than host ranch

Conformation Score = 1 or 2 (Standards of Excellence, 2016)

Sire ID = Sire identification number

DS ID = Sire of the dam identification number

SpT ADG ratio = Average daily gain ratio of individual during the spring test period

SpT WDA ratio = Weight per day of age ratio of individual during the spring test period

SmT ADG ratio = Average daily gain ratio of individual during the summer test period

SmT WDA ratio = Weight per day of age ratio of individual during the summer test period

BW ratio = ratio of individual's birth weight compared to average of contemporary group

WW ratio = ratio of individual's weaning weight compared to average of contemporary group

YW ratio = ratio of individual's yearling weight compared to average of contemporary group

REA ratio = ratio of individual's rib eye area size compared to average of contemporary group

% IMF ratio = ratio of individual's amount of intramuscular fat compared to average of contemporary group

Rib Fat ratio = ratio of individual's amount of rib fat compared to average of contemporary group

Rump Fat ratio = ratio of individual's amount of rump fat compared to average of contemporary group

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

Final Purebred Model

This model includes factors that were deemed statistically significant ($P < 0.05$) in each of the three previous models. The independent variables investigated in this model included:

Int = Intercept

Year = 2012, 2013, 2014, 2015, or 2016

Lot number (within year) = Sale order as listed in each sale catalog

Season = Fall or Spring born, identified bulls as long yearlings or 2-year-olds

Consignor = A, if host ranch or B, if other than host ranch

Sire ID = Sire identification number

BW EPD = Birth Weight EPD

WW EPD = Weaning Weight EPD

YW EPD^2 = Yearling Weight EPD squared

Rib Fat EPD^2 = Rib Fat EPD squared (in)

WW ratio = ratio of individual's weaning weight compared to average of contemporary group

Some traits were dropped before reaching the model of best fit due to extremely high *P*-values and high correlations.

RESULTS AND DISCUSSION

General summary and description of datasets

Information regarding sale price and sale catalog data were obtained from a single registered Beefmaster operation in central Texas. Summary statistics for the available traits of interest for commercial buyers are provided in Table 1, and traits of interest for seedstock (purebred) buyers are provided in Table 2. Frequency distributions for commercial buyers are provided in Table 3 and purebred buyers are provided in Table 4.

Several statistical models were used to investigate sale price of bulls, and type of buyer (commercial vs. purebred) was investigated through separate analyses, which is unique to other reports found in the literature. Mixed model analyses were performed in R where alternate continuous variables were evaluated as: (1) animals' performance trait values, (2) animals' ratio values, or (3) animals' EPD values. The components for each model are discussed as they relate to the dependent variable, price.

Table 1. Summary statistics for bulls sold to commercial buyers

Trait	n	Raw mean	Standard deviation	CV	Min	Max
Price	342	5924	2730	0.46	2500	30000
Spring test ADG ratio	342	107.01	23.99	0.22	10.35	209.51
Spring test WDA ratio	342	98.18	11.00	0.11	63.10	137.27
Ultrasound ratio	342	102.44	12.25	0.12	56.74	149.59
Summer test ADG ratio	342	103.18	16.73	0.16	46.71	156.00
Summer test WDA ratio	342	100.93	8.57	0.08	8.94	122.48
Visual ratio	342	101.20	4.96	0.05	80.01	114.00
Total ratio	342	101.83	4.79	0.05	88.99	116.82
Birth weight ratio	258	101	6	0.06	86	128
Birth weight contemporary	258	9	8	0.94	1	31
Birth weight adjusted	259	78.56	33.55	0.43	53.00	106.00
Weaning weight ratio	335	101	8	0.08	78	144
Weaning weight contemporary	334	11	11	1.08	1	50
Weaning weight adjusted	336	625.56	63.64	0.10	476.00	811.00
Yearling weight ratio	339	100	5	0.05	85	112
Yearling weight contemporary	340	6	6	1.03	1	27
Yearling weight adjusted	339	835.32	81.15	0.10	554.00	1104.00
Scrotal adjusted	335	36.24	3.74	0.10	19.87	48.00
Ribeye area ratio	339	100	8	0.08	80	125
Ribeye area contemporary	339	6	6	1.05	1	27
Ribeye area adjusted	339	10.36	1.40	0.13	6.18	16.99
Percent intramuscular fat ratio	339	101	26	0.26	32	218
Percent intramuscular fat contemporary	339	6	6	1.05	1	27
Percent intramuscular fat adjusted	339	2.05	0.79	0.39	0.51	3.81
Rib fat ratio	339	98	19	0.19	14	160
Rib fat contemporary	339	6	6	1.05	1	27
Rib fat adjusted	339	0.17	0.05	0.28	0.06	0.33
Rump fat ratio	339	100	19	0.20	48	172

Table 1. Continued.

Trait	n	Raw mean	Standard deviation	CV	Min	Max
Rump fat contemporary	339	6	6	1.05	1	27
Rump fat adjusted	339	0.22	0.07	0.31	0.08	0.52
Birth weight EPD	335	0.97	1.13	1.16	-3.40	3.60
Birth weight EPD accuracy	335	0.42	0.12	0.28	0.14	0.59
Weaning weight EPD	335	13	8	0.59	-6	36
Weaning weight EPD accuracy	335	0.45	0.08	0.17	0.19	0.60
Yearling weight EPD	335	20	13	0.65	-5	64
Yearling weight EPD accuracy	335	0.41	0.08	0.20	0.19	0.59
Milk EPD	335	3	4	1.28	-6	14
Milk EPD accuracy	335	0.18	0.07	0.38	0.06	0.37
Total maternal EPD	335	10	7	0.73	-6	30
Scrotal circumference EPD	335	0.18	0.27	1.48	-0.70	1.20
Scrotal circumference EPD accuracy	335	0.29	0.12	0.40	0.10	0.55
Ribeye area EPD	217	-0.08	0.14	-1.71	-0.48	0.36
Percent intramuscular fat EPD	217	0.01	0.13	8.84	-0.40	0.30
Rib fat EPD	217	-0.01	0.04	-2.65	-0.14	0.10
Rump fat EPD	123	0.03	0.07	1.91	-0.18	0.18
$ Terminal EPD	94	61.26	14.43	0.24	14.17	108.19
$ Maternal EPD	94	13.82	6.85	0.50	-1.54	34.95

Table 2. Summary statistics for bulls sold to purebred buyers

Trait	n	Raw mean	Standard deviation	CV	Min	Max
Price	179	9561	5207	0.54	2400	32000
Spring test ADG ratio	179	110.89	24.38	0.22	69.01	203.61
Spring test WDA ratio	179	100.33	11.27	0.11	77.38	127.78
Ultrasound ratio	179	100.51	11.55	0.11	58.00	141.78
Summer test ADG ratio	179	107.72	16.99	0.16	69.13	153.00
Summer test WDA ratio	179	103.60	7.87	0.08	86.97	125.50
Visual ratio	179	103.47	5.46	0.05	88.37	116.64
Total ratio	179	104.03	5.48	0.05	91.52	117.08
Birth weight ratio	159	100	7	0.07	78	124
Birth weight contemporary	159	11	9	0.81	1	31
Birth weight adjusted	159	76.50	7.27	0.10	59.00	101.00
Weaning weight ratio	175	103	8	0.08	82	135
Weaning weight contemporary	175	14	13	0.93	1	50
Weaning weight adjusted	175	638.37	63.47	0.10	496.00	818.00
Yearling weight ratio	177	101	7	0.06	86	124
Yearling weight contemporary	177	8	8	0.93	1	27
Yearling weight adjusted	177	848.97	90.87	0.11	632.00	1233.00
Scrotal adjusted	174	36.90	3.59	0.10	26.53	45.00
Ribeye area ratio	177	102	10	0.10	76	142
Ribeye area contemporary	177	8	8	0.93	1	27
Ribeye area adjusted	177	10.49	1.58	0.15	7.45	15.77
Percent intramuscular fat ratio	177	102	27	0.27	26	211
Percent intramuscular fat contemporary	177	8	8	0.93	1	27
Percent intramuscular fat adjusted	177	2.01	0.75	0.37	0.41	3.72
Rib fat ratio	176	100	18	0.18	27	148
Rib fat contemporary	176	8	8	0.93	1	27
Rib fat adjusted	176	0.17	0.05	0.27	0.06	0.35
Rump fat ratio	177	102	20	0.20	58	170

Table 2. Continued.

Trait	n	Raw mean	Standard deviation	CV	Min	Max
Rump fat contemporary	177	8	8	0.93	1	27
Rump fat adjusted	177	0.23	0.07	0.31	0.09	0.53
Birth weight EPD	177	0.91	1.30	1.43	-2.80	3.10
Birth weight EPD accuracy	177	0.47	0.10	0.22	0.15	0.59
Weaning weight EPD	177	14	8	0.60	-9	44
Weaning weight EPD accuracy	177	0.47	0.08	0.16	0.26	0.60
Yearling weight EPD	177	20	12	0.63	-10	66
Yearling weight EPD accuracy	177	0.43	0.08	0.19	0.24	0.58
Milk EPD	176	3	4	1.57	-6	13
Milk EPD accuracy	176	0.20	0.07	0.33	0.06	0.34
Total maternal EPD	177	10	8	0.79	-5	44
Scrotal circumference EPD	177	0.20	0.25	1.22	-0.30	1.10
Scrotal circumference EPD accuracy	177	0.31	0.11	0.36	0.14	0.55
Ribeye area EPD	121	-0.11	0.15	-1.35	-0.54	0.37
Percent intramuscular fat EPD	121	0.02	0.13	5.92	-0.40	0.40
Rib fat EPD	121	-0.01	0.04	-3.46	-0.11	0.10
Rump fat EPD	83	0.04	0.06	1.65	-0.11	0.18
$ Terminal EPD	38	62.58	18.00	0.29	19.45	113.10
$ Maternal EPD	38	16.80	7.32	0.44	5.67	41.75

Table 3. Frequency table of categorical variables for commercial buyers

Variable	Frequency
Commercial buyers	342
2012	53
2013	66
2014	60
2015	73
2016	95
Fall	111
Spring	231
Consignor A	145
Consignor B (not consignor A)	197
0 (non-repeat customers)	112
1 (repeat customers)	230
Brown mottle underline	1
Dark red	37
Dark red mottle underline	11
Dark red star face	1
Dark red star face mottle underline	1
Dun	4
Light red	21
Light red mottle underline	3
Light red star face white underline	1
Red	200
Red mottle underline	2
Red mottle face mottle underline	2
Red mottle underline	42
Red star face	4
Red star face mottle underline	4
Red star face white underline	1
Red white underline	7
Horns	269
Polled	14

Table 3. Continued.

Variable	Frequency
Scurs	6
Number of sires	96
Number of dams	294
Number of maternal grandsires	149
Conformation score 1	65
Conformation score 2	267
Underline score 1	18
Underline score 2	190
Underline score 3	123
Underline score 4	1

Table 4. Frequency table of categorical variables for purebred buyers

Variable	Frequency
Purebred buyers	179
2012	28
2013	31
2014	38
2015	48
2016	39
Fall	52
Spring	127
Consignor A	121
Consignor B (not consignor A)	58
0 (non-repeat customers)	41
1 (repeat customers)	138
Brindle	3
Dark red	15
Dark red mottle underline	9
Dark red white underline	2
Dun	4
Dun mottle underline	1
Light red	11
Light red mottle underline	3
Red	100
Red mottle face	1
Red mottle face mottle underline	1
Red mottle underline	17
Red star face	3
Red star face mottle underline	3
Red white underline	5
White	1
Horns	136
Polled	13
Scurs	3

Table 4. Continued.

Variable	Frequency
Number of sires	53
Number of dams	150
Number of maternal grandsires	73
Conformation score 1	72
Conformation score 2	104
Underline score 1	15
Underline score 2	118
Underline score 3	43

Commercial buyer models

Among commercial buyers, repeat customer status, horned/polled status, and consignor did not influence sale price. Traits such as bull color pattern, $T, and $M were not evaluated due to imbalanced data. $T and $M were introduced in 2016, so in prior years these measures were not available. All bulls sold in these sales were similar in color pattern with most bulls being a variation of red in color. Underline score was also not investigated due to its high correlation with conformation score. All commercial buyer models included year, season (age category), consignor, sire, maternal grandsire, and BBU conformation score as categorical traits and the regression on sale order within year. However, alternative pricing models evaluating different types of continuous variables regarding the bulls' (1) performance trait actual values, (2) performance trait ratios, and (3) performance trait EPDs were used. An overall, final pricing model was also evaluated. These trait models accounted for 81 to 85% of the variation in price paid by commercial buyers for Beefmaster bulls in central Texas, with the final model accounting for 85%. The results for these commercial buyer models regarding estimates and significance levels are shown in Table 5. Table 6 shows the sale price least squares means for commercial buyer models.

Table 5. Summary of commercial buyer models

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
Intercept	1323.29 ± 3721.406	7114 ± 3609.000	6714.82 ± 2812.166	5321.39 ± 4039.630
	P = 0.723	*P* = 0.052	*P* = 0.019	*P* = 0.191
Year				
2012	Base	Base	Base	Base
2013	3195 ± 1358.9	4381 ± 1169.0	4710 ± 1169.1	4137 ± 1329.4
	P = 0.021	*P* < 0.001	*P* < 0.001	*P* = 0.003
2014	3174 ± 1228.3	3396 ± 1227.0	3929 ± 1134.1	3864 ± 1200.8
	P = 0.011	*P* = 0.007	*P* = 0.001	*P* = 0.002
2015	3607 ± 1249.9	4282 ± 1147.0	5061 ± 1163.2	4333 ± 1220.5
	P = 0.005	*P* < 0.001	*P* < 0.001	*P* = 0.001
2016	783 ± 1212.9	1705 ± 1175.0	900 ± 1180.7	1105 ± 1231.6
	P = 0.520	*P* = 0.151	*P* = 0.448	*P* = 0.372
Lot number				
2012	-15.77 ± 16.455	-34.80 ± 17.030	-14.29 ± 16.472	-10.88 ± 16.327
	P = 0.341	*P* = 0.044	*P* = 0.388	*P* = 0.507
2013	-55.90 ± 12.956	-67.60 ± 12.160	-59.33 ± 10.077	-58.98 ± 12.864
	P < 0.001	*P* < 0.001	*P* < 0.001	*P* < 0.001
2014	-37.38 ± 10.497	-33.64 ± 11.800	-29.64 ± 9.410	-36.18 ± 10.031
	P = 0.001	*P* = 0.006	*P* = 0.002	*P* = 0.001

Table 5. Continued

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
2015	-17.36 ± 9.236	-25.44 ± 9.570	-22.02 ± 9.059	-20.51 ± 9.250
	P = 0.063	*P* = 0.010	*P* = 0.017	*P* = 0.029
2016	-23.90 ± 7.814	-37.39 ± 8.300	-23.28 ± 7.564	-23.78 ± 7.985
	P = 0.003	*P* < 0.001	*P* = 0.003	*P* = 0.004
Season				
Fall	Base	Base	Base	Base
Spring	1252.48 ± 560.205	1840.00 ± 570.000	1096.58 ± 488.722	883.30 ± 540.285
	P = 0.028	*P* = 0.002	*P* = 0.027	*P* = 0.106
Conformation Score				
Score 1	Base	Base	Base	Base
Score 2	-910.94 ± 351.101	-1079. 00 ± 365.400	-910.77 ± 343.827	-934.55 ± 347.528
	P = 0.011	*P* = 0.004	*P* = 0.009	*P* = 0.009
Consignor				
A	Base	--	--	--
B	-415.20 ± 320.362	--	--	--
	P = 0.198			
Sire ID	*P* < 0.001	*P* = 0.010	*P* < 0.001	*P* < 0.001
Maternal grandsire ID	*P* = 0.001	*P* = 0.086	*P* = 0.002	*P* = 0.001
WW adj.	4.06 ± 2.114	--	--	4.97 ± 2.705
	P = 0.058			*P* = 0.070

Table 5. Continued

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
Scrotal adj.	108.11 ± 55.099 *P* = 0.053	--	--	78.54 ± 53.467 *P* = 0.146
REA adj.	-258.73 ± 104.908 *P* = 0.016	--	--	--
Rib Fat² adj.	22341.7 ± 7218.307 *P* = 0.003	--	--	--
BW ratio²	--	0.2 ± .100 *P* = 0.040	--	--
YW ratio²	--	0.25 ± .140 *P* = 0.072	--	--
REA ratio	--	-46.39 ± 15.510 *P* = 0.004	--	-40.64 ± 14.667 *P* = 0.007
SpT ADG ratio	--	-11.09 ± 7.830 *P* = 0.161	--	--
SpT WDA ratio	--	19.26 ± 14.660 *P* = 0.193	--	--
BW EPD	--	--	-389.26 ± 211.800 *P* = 0.069	-343.59 ± 214.098 *P* = 0.112
WW EPD	--	--	-83.19 ± 47.513 *P* = 0.083	-117.81 ± 51.671 *P* = 0.025

Table 5. Continued

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
WW EPD^2	--	--	4.72 ± 1.784 *P* = 0.009	4.86 ± 1.770 *P* = 0.007
Adjusted R^2	0.85	0.81	0.84	0.85

Table 6. Sale price least squares means from commercial buyer models

Variable names	n	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
Year					
2012	52	4861.72 ± 643.348^{bc}	3461.64 ± 676.775^{d}	4152.30 ± 543.271^{a}	4611.59 ± 630.989^{c}
2013	65	5607.08 ± 464.504^{bc}	5718.98 ± 452.752^{bc}	6124.29 ± 394.761^{b}	5818.22 ± 451.248^{bc}
2014	59	6716.39 ± 377.362^{b}	6932.70 ± 410.815^{ab}	7149.00 ± 354.527^{b}	6934.37 ± 376.546^{b}
2015	72	8371.33 ± 342.836^{a}	8349.82 ± 326.930^{a}	8743.83 ± 342.024^{c}	8358.36 ± 355.038^{a}
2016	94	5148.41 ± 369.983^{c}	4999.22 ± 359.703^{cd}	4506.27 ± 390.613^{a}	4930.40 ± 427.216^{c}
Season of birth[1]					
Fall	111	5514.75 ± 472.364^{a}	4972.27 ± 491.551^{a}	5586.85 ± 421.417^{a}	--
Spring	231	6767.23 ± 243.327^{b}	6812.68 ± 256.643^{b}	6683.43 ± 214.174^{b}	--
Conformation score[2]					
Score 1	65	6596.45 ± 388.159^{a}	6431.74 ± 406.738^{a}	6590.52 ± 359.478^{a}	6597.87 ± 371.346^{a}
Score 2	267	5685.52 ± 190.760^{b}	5353.21 ± 215.275^{b}	5679.75 ± 184.180^{b}	5663.31 ± 185.327^{b}

[1]Fall = born before January 1, Spring = born after January 1

[2]1 to 4 scale where 1 = most ideal phenotype and 4 = least ideal phenotype (BBU Standard of Excellence, 2016)

Year of the sale was a statistically significant factor across all commercial buyer models. Bulls sold in 2012 had the lowest price. Bulls sold in 2015 brought $3607 to $5061 more than bulls sold in 2012 depending upon which model was utilized. The 2016 year was consistently the closest to 2012 across all models bringing $783 to $1705 more than bulls sold in 2012. The trends seen here with 2012 being the lowest performing year and 2015 being the greatest performing year are also seen when looking at the simple means for each year. Simple means are shown in Figure 1. Additionally, these trends in bull price across these 5 years is also similar to the trends seen in the US feeder calf market across the same 5 years (USDA-ERS, 2018).

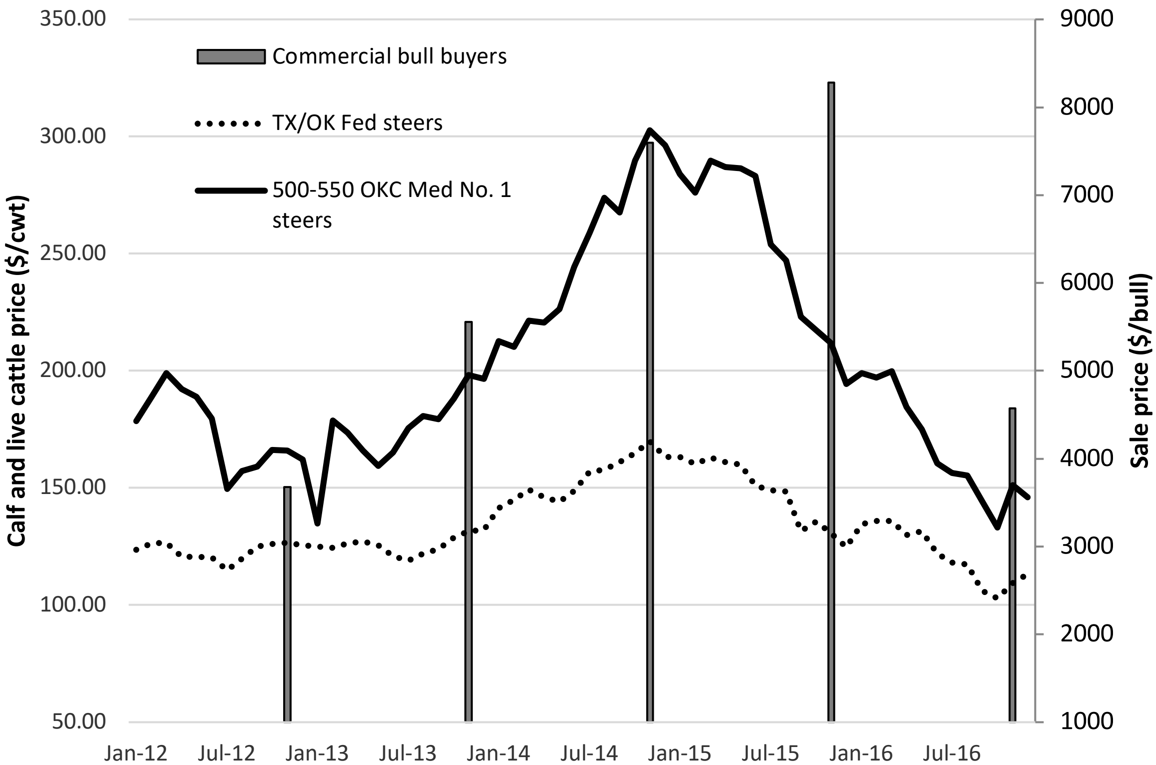

Figure 1. Simple means of sale price per year paid by commercial buyers with average monthly prices of TX/OK fed steers and 500-550 lb Oklahoma City Medium No. 1 steers (USDA-ERS, 2018).

Sale order as noted by lot number was also a statistically significant factor determining bull price. The sign on all of these coefficients were negative, which indicates that as lot number increased the sale price decreased. Across these five years, the regression of sale price on sale order was lowest in 2013 (-67.60 ± 12.160) and highest in 2012 (-10.88 ± 16.327). Sale order was also evaluated by Mintert et al. (1990) on cows sold in seven weekly auctions across Kansas. Breed composition was evaluated by data collectors based on visual appraisal. Over half of the cows were classified as Hereford, Angus, or mixed lots, and Brahman, Exotic crosses, Longhorn crosses, and dairy type cows made up small percentages relative to the total amount of cows. Mintert et al. (1990) found that market cows sold in the last quarter of the auction received a statistically significant discount of $1.76/cwt. Dhuyvetter et al. (1996) also found sale order to have a negative coefficient from 26 purebred beef bull sales in Kansas. The breeds represented were Angus, Charolais, Gelbvieh, Hereford, Limousin, Red Angus, and Simmental (Dhuyvetter et al., 1996). One major differences between this study and studies that evaluate sale order in auction barns was that sale order is not pre-determined by any performance measure, rather it is based largely on how they are penned upon arrival which is related to the order they were received.

The bulls' season of birth (age category) also affected sale price ($P < 0.05$) in the three trait models. Bulls born during the spring calving season (born after January 1, between 19 and 23 months of age at time of sale) brought more per head than fall bulls (born before January 1, between 23 and 27 months of age at time of sale). However, in the overall model, season was not statistically significant ($P = 0.106$). This could be due to commercial buyers not having a preference on the age of the bull. Within each age category the bulls were all within 5 months of age of each other. When comparing all other valuable traits of the bull together, age of the bull is not that important any longer unless they're not old enough to breed cows.

Conformation score was important as bulls that were assigned a conformation score of 2 brought $1079.00 to $910.77 less ($P < 0.05$) than bulls that were given a score of 1, depending upon which model was evaluated. Conformation score of 1 refers to an animal that best fits the ideal phenotypic standards of the Beefmaster breed, whereas a conformation score of 2 refers to a bull that is less than ideal in phenotypic quality (BBU Standards of Excellence, 2016). Dhuyvetter et al. (1996) also noted that higher prices were given to Simmental, Angus, Charolais, Red Angus, Hereford, Gelbvieh, and Limousin bulls for each incremental increase in conformation score on a scale of 1 (poorest) to 5 (best).

Consignor was not significant in any of the commercial buyer models. This means that buyers paid no premium for bulls that were bred by the ranch that hosts the production sale, consignor A, over bulls that were not bred by the host ranch, consignor B. Although in the adjusted trait model, consignor approached significance ($P = 0.198$) whereas in the following models it was removed early in analysis. However, according to Commer et al. (1990) purebred bull producer reputation had a significant impact on bull prices. The more promotional activity that a producer employed the more their bulls excelled in performance characteristics. In this data set, consignor was broken into 2 groups, not a function of how active their promotional programs were. Commercial buyers were not concerned with who raised the bulls. All bulls had similar pedigrees, were performance tested in the same manner, and performed well enough to make the sale. Emphasis was placed on other bull attributes. Walburger (2002) reported that in a multibreed purebred bull sale in Alberta, Canada that commercial bull buyer preferences may relate to heterosis considerations relative to their cow herds.

Sire pedigree information was important in all models ($P < 0.05$). The least squares mean estimates ranged from $14247 to $2653 across sires. Maternal grandsire pedigree information was important in the adjusted trait model, trait EPD, and overall models ($P < 0.05$). Estimates for least squares means across maternal grandsires were highest at $9095 and lowest at $2600. Some sires and maternal grandsires were non estimable due to a small number of progeny and confounding with other factors.

A trend for adjusted weaning weight was important ($P < 0.10$) for sale price with positive coefficients between $4.06 ± 2.114/lb to $4.97 ± 2.705/lb. Producers are able to use weight to predict calf performance. When an animal has a higher weight, producers might expect that these individuals are higher performing and that their progeny would have higher growth potential. The financial impact of weaning weight is important since most commercial producers sell their calves at weaning and are paid according to weight. Chvosta et al. (2001) also found bull weaning weight to positively influence price among Northern Plains Angus bull buyers.

The adjusted scrotal circumference is related to bull fertility and daughters' age at puberty. In the adjusted trait model, buyers were willing to pay $108.11 ± 2.114 ($P <$ 0.053) more for each additional centimeter of scrotal circumference. Walburger (2002) studied buying trends in Alberta Canada. Bulls were all British and Continental breed types with the most popular breed being Simmental (n = 256). Data were broken up into time periods of 1989 and 1993, 1996-1997, and 1998-2000. Depending on which time frame was studied, buyers were willing to pay between $62.34 and $216.71 more per additional centimeter of scrotal circumference (Walburger, 2002). There could be negative consequences for scrotal circumferences that are too large such as injury.

The adjusted ribeye area ratio was a statistically significant ($P = 0.007$) factor in the overall model for determining bull price among commercial buyers. The regression coefficient was negative, which was not expected. This means that as the ribeye area ratio increased the sale price decreased. This could be due to packers declaring that carcass weights and cut sizes are becoming too large to meet facility and customer specifications. However, most of the bull buyers are not retaining ownership of these calves through the feedlot, so they are not feeling the direct discounts given to carcasses outside the acceptable range for carcass traits. Additionally, these bulls average 1.24 square inches of ribeye area per hundred pounds of live weight. According to Griffin and Boleman (2004), animals with 1.1 sq. in. per 100 lb. live weight are considered average muscled. By these standards, these Beefmaster bulls would be above average muscled. Although this study found ribeye area ratio to have a negative coefficient, Walburger (2002) found Canadian bull buyers were willing to pay $12.39 more per additional square centimeter of ribeye area. At this time in the late 1990's, Walburger (2002) noticed that cattle producers were hesitant to make genetic changes even though consumers were willing to pay for consistency, quality, and palatability.

In the overall commercial buyer model, the quadratic of weaning weight EPD affected ($P = 0.007$) sale price. This means that premiums were given to increased weaning weight EPD's where lower weaning weights were considered undesirable. Chvosta et al. (2001) also found a quadratic effect in Angus bulls for weaning weight, and weaning weight EPD. Dhuyvetter et al. (1996) noted that performance EPD's like birth weight and weaning weight were significant drivers of bull price. Birth weight EPD was significant for prices paid among Simmental, Angus, and Gelbvieh bulls. Weaning weaning was significant for prices paid among Simmental, Angus, Gelbvieh, and

Limousin bulls. Although birth weight EPD was not statistically significant in this study (P = 0.112) it approached significance compared to other EPD's that were dropped from the model. Chvosta et al. (2001) observed variable influence of bull birth weight on sale price among Angus bulls across different regional sales.

Purebred buyer models

Among purebred buyers, repeat customer status, horned/polled status, conformation score, and maternal grandsire did not influence sale price. Bull color pattern, $T, and $M were not evaluated due to imbalanced data. Additionally, underline score was not investigated due to the high correlation with conformation score. All purebred buyer models included year, season (age category), consignor, sire, maternal grandsire, and BBU conformation score as categorical traits and the regression on sale order within year. However, alternative pricing models were used for evaluating different types of continuous variables regarding the bulls' (1) performance trait actual values, (2) performance trait ratios, and (3) performance trait EPDs. An overall, final pricing model was also evaluated. These trait models accounted for 34 to 54% of the variation in price (model R-square values) paid by commercial buyers for Beefmaster bulls in central Texas, with the final model accounting for 44%. These models were not as accurate at predicting the prices of bulls sold to purebred buyers as those sold to commercial buyers, indicating important factors besides those that were modeled. However, these R-square values are similar to those reported by Chvosta et al. (2001) for Northern Great Plains Angus bulls (40%) and by Walburger (2002) for Canadian British and Continental bulls (32% to 49%). The results for these purebred buyer models regarding estimates and significance levels are shown in Table 7. Table 8 shows the sale price least squares means for purebred buyer models.

Table 7. Summary of purebred buyer models

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
Intercept	2887.03 ± 3878.353	65330 ± 45590.000	-3279.00. ± 6370.000	5346.51 ± 4632.929
	P = 0.458	*P* = 0.155	*P* = 0.610	*P* = 0.251
Year				
2012	Base	Base	Base	Base
2013	5853 ± 2215.2	4797 ± 2746.0	-818 ± 4352.0	4693 ± 2491.594
	P = 0.009	*P* = 0.084	*P* = 0.849	*P* = 0.062
2014	4469 ± 2289.6	4151 ± 2664.0	2636 ± 4222.0	5332 ± 2431.709
	P = 0.053	*P* = 0.122	*P* = 0.555	*P* = 0.030
2015	9135 ± 2076.5	7434 ± 2390.0	10880 ± 3666.0	7373 ± 2212.652
	P < 0.001	*P* = 0.002	*P* = 0.005	*P* = 0.001
2016	5271 ± 2168.6	2282 ± 2476.0	-7819 ± 4108.0	-2051 ± 2488.253
	P = 0.016	*P* = 0.359	*P* = 0.065	*P* = 0.411
Lot number				
2012	-96.88 ± 32.988	-79.13 ± 39.310	51.72 ± 55.960	-60.94 ± 36.721
	P = 0.004	*P* = 0.047	*P* = 0.361	*P* = 0.100
2013	-138.61 ± 29.998	-106.80 ± 40.250	17.89 ± 44.370	-101.52 ± 35.906
	P < 0.001	*P* = 0.009	*P* = 0.689	*P* = 0.006
2014	-86.57 ± 25.731	-73.41 ± 32.440	24.11 ± 54.520	-71.26 ± 27.845
	P = 0.001	*P* = 0.026	*P* = 0.661	*P* = 0.012

Table 7. Continued.

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
2015	-124.89 ± 21.477	-100.30 ± 25.770	-92.05 ± 30.120	-86.26 ± 23.348
	P < 0.001	*P* < 0.001	*P* = 0.004	*P* < 0.001
2016	-93.93 ± 19.590	-65.58 ± 24.500	-15.67 ± 19.700	-46.92 ± 22.430
	P < 0.001	*P* = 0.009	*P* = 0.431	*P* = 0.039
Season				
Fall	Base	Base	--	Base
Spring	4810.73 ± 1249.910	4763.00 ± 1592.000	--	3349.07 ± 1422.354
	P < 0.001	*P* = 0.003		*P* = 0.020
Consignor				
A	Base	--	--	Base
B	-2201.45 ± 729.276	--	--	-2669.66 ± 972.941
	P = 0.003			*P* = 0.007
Sire ID	--	*P* = 0.239	*P* = 0.006	*P* = 0.063
Maternal grandsire ID	--	--	*P* = 0.128	--
WW adj.	7.28 ± 5.373	--	--	--
	P = 0.177			
WW ratio	--	-1371.00 ± 883.000	--	--
		P = 0.123		
WW ratio^2	--	7.22 ± 4.220	--	--
		P = 0.090		

Table 7. Continued.

Variable names	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
YW ratio²	--	0.531 ± .381 $P = 0.166$	--	--
BW EPD	--	--	-2793.00 ± 1020.000 $P = 0.009$	-983.06 ± 492.458 $P = 0.048$
WW EPD	--	--	506.80 ± 26.440 $P = 0.063$	--
YW EPD²	--	--	8.13 ± 2.320 $P = 0.001$	10.47 ± 1.989 $P < 0.001$
TM EPD²	--	--	-12.94 ± 10.350 $P = 0.219$	--
SC EPD²	--	--	-8834.00 ± 5669.000 $P = 0.127$	--
Rib Fat EPD	--	--	31860.00 ± 22280.000 $P = 0.161$	--
Rib Fat EPD²	--	--	-687000.00 ± 362800.000 $P = 0.066$	--
Adjusted R^2	0.34	0.35	0.54	0.44

Table 8. Least squares means for purebred buyer models

Variable names	n	Adjusted trait model	Trait ratio model	Trait EPD model	Overall model
Year					
2012	27	3341.23 ± 1015.903^{c}	4080.56 ± 1306.358^{b}	$12856.97 \pm 1966.036^{a}$	5437.62 ± 1250.430^{b}
2013	30	6826.78 ± 910.053^{b}	$7171.17 \pm 1192.523^{ab}$	9886.46 ± 1678.221^{a}	$7830.40 \pm 1071.364^{ab}$
2014	37	8395.37 ± 819.370^{ab}	8612.64 ± 1032.970^{a}	$13736.00 \pm 1587.682^{a}$	$10184.38 \pm 1022.529^{a}$
2015	47	10886.86 ± 644.455^{a}	9904.76 ± 913.621^{a}	$14584.40 \pm 1467.666^{a}$	11375.09 ± 867.211^{a}
2016	38	8779.38 ± 774.614^{a}	$6844.85 \pm 1009.570^{ab}$	748.82 ± 2165.196^{b}	4180.96 ± 1174.650^{b}
Season[1]					
Fall	52	5240.56 ± 984.955^{a}	5964.95 ± 1065.672^{a}	--	6127.16 ± 1138.037^{a}
Spring	127	10051.29 ± 506.261^{b}	10384.43 ± 494.938^{b}	--	9476.22 ± 626.907^{b}
Consignor[2]					
A	121	8746.65 ± 506.988^{a}	--	--	9136.52 ± 738.576^{a}
B	58	6545.20 ± 673.931^{b}	--	--	6466.86 ± 777.437^{b}

[1]Fall = born before January 1, Spring = born after January 1

[2]Consignor A = sale host, B = other consignors.

Year of the sale was a statistically significant factor across all purebred buyer models. Bulls sold in 2012 had the lowest price. Bulls sold in 2015 brought $10,880 to $7373 more than bulls sold in 2012 depending upon which model was utilized. One of the highest priced bulls ($32,000) sold in 2015. However, another $32,000 bull sold in 2016. The trends seen here with 2015 being the highest performing year are also seen when looking at the simple means for each year. Simple means are shown in Figure 2. Additionally, these trends in bull price across these 5 years is also similar to the trends seen in the US feeder calf market across the same 5 years (USDA AMS, 2017).

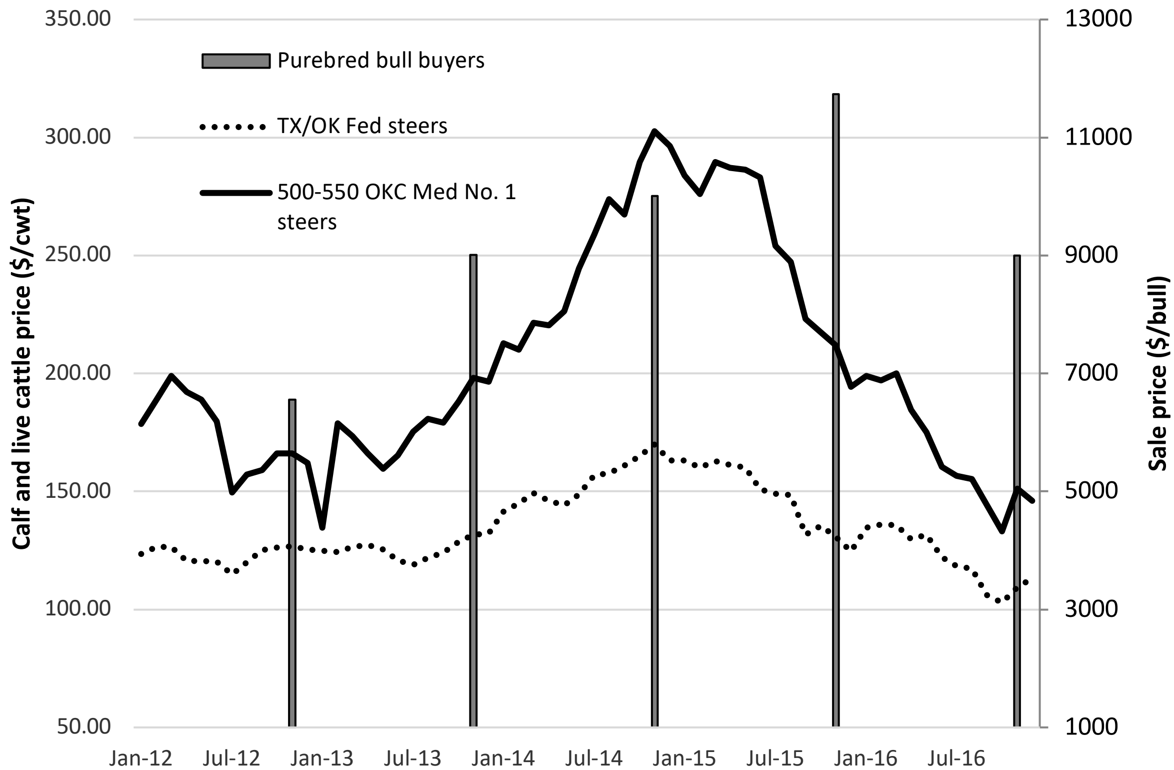

Figure 2. Simple means of sale price per year paid by purebred buyers with average prices of TX/OK fed steers and 500-550 lb Oklahoma City medium no. 1 steers.

Sale order as noted by lot number was also a statistically significant factor determining price. The sign on the majority of these coefficients were negative, which indicates that as lot number increased the sale price decreased. However, some coefficients were positive under the trait EPD model. A positive regression coefficient was not expected for this variable. Across the five years, the regression of price on sale order was lowest in 2013 (-\$138.61 ± 29.998) and highest in 2012 (\$51.72 ± 55.960). However, in the final model all coefficients were negative as expected. Minert et al.

(1990) found that cows sold in the last quarter of the auction received a statistically significant discount of $1.76/cwt. Sale order in auction barns are partially determined by the order in which they were brought to the sale barn. Additionally, Dhuyvetter et al. (1996) found sale order to have a negative coefficient. Negative coefficients were also found in the commercial buyer models of this study.

The bulls' season of birth (age category) also affected sale price ($P < 0.05$) in the adjusted trait, trait ratio, and overall models. Bulls born during the spring calving season (after January 1, between 19 and 23 months of age at time of the sale) brought between $3349.07 and $4810.73 more per head, depending on the model, than fall bulls (born before January 1, between 23 and 27 months of age at the time of sale). However, in the EPD model, season was not statistically significant. Age category of the bulls was not a significant factor for commercial bull buyers. This could be due to the differences in frequency distribution.

Conformation score was not a significant factor in determining price for purebred buyers. Purebred buyers paid no more for bulls that were given a conformation score of 1 (best) over bulls that were given a conformation score of 2 (slightly less than ideal) (Standards of Excellence, 2016). Dhuyvetter et al. (1996) noted that higher prices were given to bulls for each incremental increase in conformation score s from 1 (poorest) to 5 (best). However, this trend was not seen by purebred buyers in this study. Non-significance could be due to the differences in frequency distributions. It is not surprising that purebred buyers, unlike commercial buyers, did not find conformation score to be an important value. Typically, purebred buyers have a greater opportunity to market offspring based on performance data and EPDs when compared to commercial buyers who market the majority of their calves based on phenotype alone at local livestock markets.

Consignor was an important factor ($P < 0.05$) for determining price in the purebred buyer models, which was a different result than among commercial buyers. Purebred buyers paid a premium for bulls that were bred by the host ranch, consignor A, over bulls that were not bred by the host ranch (consignor B). Bulls sold by consignor B brought $2669.66 to $2201.45, depending on the model, less than bulls sold by consignor A. Both of the highest selling bulls ($32,000) recorded in this data set were from the host ranch. Purebred buyers may be valuing consignor due to the possibility of registering, promoting, and/or selling high valued progeny out of these bulls. These buyers might be paying more for the ranch prefix as a marketing tool rather than the fundamental breeding philosophy that these bulls were bred to satisfy. According to Commer et al. (1990), purebred bull producer reputation had a significant impact on bull prices based solely on the promotional activity of each seller, and that reputation of the seller may be important for instilling trust in the information provided by the seller and the physical and genetic characteristics of the bulls does not provide adequate information to the buyers. However, Chvosta et al. (2001) studied the presale information on Angus bulls raised by Montana, Nebraska, and South Dakota breeders. They found there to be no statistical differences in price paid for bulls across commercial and purebred buyer groups in the Montana sale data from one specific operation. However, their data suggested that there was an effect based on reputation and climate variables. The breeder effect could also be attributed to the annual changes in performance measures of the herd where the bulls come from (Chvosta et al., 2001). Data collected from Nebraska and South Dakota came from 11 different operations where no known buyer information was collected.

Purebred buyers did not value ($P > 0.05$) sire pedigree (n = 53) information to the extent of commercial buyers in these data. In the overall purebred buyers model, sire pedigree approached significance ($P = 0.063$), and it was important ($P = 0.006$) in the adjusted trait model. The estimates for least squares means per sire ranged from $38,349 to -$10,576. Due to a small number of progeny recorded on some sires and due to confounding factors, some sires had non-estimable least squares means. Maternal grandsire pedigree (n = 73) information was not statistically significant. In the trait EPD model, it approached significance ($P = 0.128$), but was removed early in analysis in all other models. Both types of pedigree information were statistically significant among commercial buyers. This is a surprising result due to the higher probability of purebred buyers reporting progeny information back to the breed association to increase the EPD accuracies of these bulls rather than commercial buyers.

In the adjusted trait model, the only continuous variable that came close to significance was the adjusted weaning weight ($P = 0.177$), and it also did not have any significance in the overall model. Buyers can use weight to predict future growth and performance of progeny, and this trait was significant to commercial buyers, probably because many commercial cattlemen market their calves through a local livestock market where they are paid on the weaning weight of their calves. Dhuyvetter et al.

(1996) found that for six of the seven breeds studied in Kansas bull auctions, adjusted weaning weight was significant with a premium paid for increased weaning weight. However, seedstock producers who are raising purebred calves might have alternative marketing methods where weight is not a major driving factor of price. These producers could be selling their calves via private treaty based on EPD's or other traits, developing replacement heifers and herd bulls to be sold at an older age, or a variety of other options where weaning weight is not as important.

Quadratic weaning weight ratio and quadratic yearling weight ratio neared significance in the trait ratio model at $P = 0.090$ and $P = 0.166$, respectively, but neither of these measures showed significance and remained in the overall model. However, Commer et al. (1990) found that physical characteristics such as yearling weight ratio had a significant impact on price paid for performance tested *Bos taurus* bulls. This study found marketing and promotional activity of breeders to influence price, with high correlations reported between promotional activity and "excellent" phenotypic characteristics (Commer et al., 1990). Chvosta et al. (2001) found quadratic effects of weaning weight and yearling weight ratios to affect Angus bull prices.

Birth weight EPD affected ($P < 0.05$) sale price in both the trait EPD model and the overall model among purebred buyers. In the overall model, buyers gave a discount of \$983.06 ± 492.458 for each 1-lb increase in birth weight EPD. The negative coefficient was expected due to the negative stigma associated with larger birth weights. As typical of herd bull sales, all of the bulls here were young (24 months or younger) with low EPD accuracies. For purebred buyers in this study, the birth weight EPD was a more important factor than the adjusted birth weight of the bull itself. Regardless, birth weight is an important factor to consider when making herd sire purchasing decisions. Relative to the producers' cow herd, large birth weights could lead to calf or cow death due to dystocia. Death loss affects the amount of income that an operation could receive, which could lead to decreased profits. Dhuyvetter et al. (1996) also noted that performance EPDs like birth weight were significant drivers of bull price in 26 purebred bull sales across Kansas. Walburger (2002) found that due to the moderate to high heritability of birth weight, buyers paid less (\$38.03 - \$68.05 per pound) for each 1% increase in birth weight across British and Continental bulls. Chvosta et al. (2001) also documented an influential birth weight EPD effect on Angus bull prices.

In both the trait EPD model and the overall model, quadratic yearling weight EPD affected ($P < 0.05$) sale price of bulls among purebred buyers. This means that premiums were given to increased yearling weight EPDs up to a certain threshold where large yearling weights were then considered undesirable or did not matter to buyers. Premiums ranged from \$8.13 to \$10.47 per lb of yearling weight EPD, depending on which model was utilized. Due to the quadratic trend, this could mean that buyers are realizing the effects of market signals that excessive growth is not ideal. Chvosta et al. (2001) documented a quadratic yearling weight EPD effect in Northern Plains Angus bulls.

SUMMARY

When marketing any breed of cattle, it is important for the seller to identify the target consumer. By understanding the buyers, sellers are able to tailor their marketing strategy to fit the demands of the customers. This is true in selling feeder cattle, commercial replacement females, and seedstock. In this study, a Beefmaster bull sale host classified bull customers as (1) commercial or (2) seedstock/purebred; all bulls were purebred and able to be registered by Beefmaster Breeders United. Although both types of buyers were buying from the same group of bulls, they had different valuation priorities. Commercial buyers placed more emphasis on the physical traits modeled as conformation score, sire and maternal grandsire pedigree information, ribeye area ratio, and the quadratic form of weaning weight EPD. Depending on the model, discounts ranging from \$1079.00 to \$910.77 for conformation score 2 bulls compared to conformation score 1 (4-point scale where 1 is most desirable). Sire and maternal grandsire were significant ($P = 0.001$). Discounts for ribeye area ratio ranged from \$46.39 to \$40.64 per 1% unit increase depending on the model used, which was unexpected. Premiums for increased weaning weight EPD ranged from \$4.72 to \$4.86 per 1-lb increase, depending on the model. Conversely, purebred (seedstock) buyers placed their emphasis on the season (age category) in which bulls were born, consignor or owner of the animal, birth weight EPD, and quadratic yearling weight EPD. Depending on which model was used, buyers paid between \$3349.07 and \$4810.73 more for spring-born (born after January 1 annually) rather than fall-born bulls (born before

January 1 annually). Bulls provided by consignors other than the host ranch were discounted between $2669.66 and $2201.45 depending on the model as compared to bulls produced by the host ranch. Birth weight discounts ranged from $2793.00 to $983.06 for each 1-lb increase in birth weight EPD, depending on which model was used. The quadratic form of yearling weight EPD had premiums between $8.13 and $10.47, depending on the model. The final commercial buyer model had an R^2 value of 85%, but the final purebred buyer model had an R^2 value of 44%, indicating that bull price predictions explained substantially more variation among commercial bull buyers.

Results from this study show that Beefmaster seedstock producers and/or managers have potential to make better-informed decisions about what their bull customers are valuing. How much of these results hold true across other Beefmaster bull sales remains unknown, but should be investigated in future analyses across multiple locations and sales. Additional study about how bull temperament affects their sale price would be useful. Although this is the first report in the literature documenting buyer attributes among Beefmaster bulls, results here regarding valuation of individual bull traits correspond to similar results reported in British and Continental European breeds. It is never suggested for producers to select any breeding cattle (bills or females) based on any single trait alone, but it is important to document values of individual traits. If commercial and seedstock producers can agree on the priorities of traits, they may have more potential to work together towards common goals.

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