Journal of Agricultural and Resource Economics 21(2):396–410

Determinants of Purebred Beef Bull Price Differentials

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Bulls are an important investment for commercial beef cattle producers since, over time, bulls introduce most of the new genetic attributes into typical beef cow herds. Therefore, heritable bull traits determine bull prices. Bulls possess a large number of traits to consider in pricing. In recent years, new measures of bull qualities have been introduced in the form of expected progeny differences (EPDs). This study estimates market values associated with specific bull attributes, recently introduced EPDs, and bull sale marketing efforts. Important bull price determinants include bull color, polled, conformation, muscling, disposition, age, birth weight, weaning weight, milk EPD, birth and weaning weight EPDs, sale location, order bull was sold, whether the bull had a picture in the sale catalog, and whether a percentage of semen rights were retained by the seller.

Key words: bull marketing, bull prices, hedonic models

Introduction

Bulls have a major impact on economic returns for commercial beef cattle producers. The value of a bull is determined by its expected value in production. Bulls represent 50% of the genetic makeup of any year's calf crop and, for producers who retain their own heifers, 90% of cowherd genetic change (Wagner et al.). Differences in heritable traits of beef bulls determine bull market price differentials. The objective of this research is to identify determinants of beef bull prices and to estimate the marginal contribution of various bull traits to the overall value of a bull. Bull sellers and buyers need this information to make efficient production and marketing decisions.

Bull value is related to the length of time a bull is used. A U.S. Department of Agriculture (USDA) study found bull's age and factors related to age (size and number of offspring in herd) were ranked lower than physical factors (infertility, lameness, disease, and temperament) when making bull culling decisions. Offspring performance was ranked lower than bull physical factors but higher than age. This indicates producers consider a bull to be a relatively long-term investment provided the bull remains physically sound. Clary, Jordan, and Thompson concluded that the length of time a producer plans to keep a bull was an important determinant of its value. Therefore, producers should make informed decisions when purchasing bulls since substantial financial and

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Helpful comments of James Mintert, James Sartwelle III, *JARE* Editor B. Wade Brorsen, and three anonymous reviewers are gratefully acknowledged. Contribution No. 97-1-J from the Kansas Agricultural Experiment Station.

genetic risks are associated with buying poor quality bulls. Producers need to factor the value of physical and genetic characteristics of bulls into their pricing decisions.

Purebred breeders, as the principal bull suppliers, need to recognize the value of physical and genetic characteristics affecting bull prices so they can make economical decisions regarding the type of bulls they produce and offer for sale. Because genetic changes take time to make, purebred breeders must be cognizant of bull demand or risk losing their market. Additionally, purebred bull producer reputation is critical and has a significant impact on bull prices (Commer, Couvillion, and Herndon). Reputation of sellers may be important for instilling trust in information provided by sellers, customer service, business integrity, and known bull quality. Significance of seller reputation affecting bull prices indicates that physical and genetic characteristics of bulls alone do not provide adequate information to buyers.

Historically, commercial cattle producers have selected bulls predominantly based on visual appraisal (Corah, Simms, and Zoellner). Visual selection does not necessarily indicate genetic or performance potential of a bull's progeny. Factors affecting bull purchasing decisions include structural soundness, conformation, appearance, breed, temperament, price, reputation of breeder, weaning/yearling weight, birth weight, hip height/frame score, calving ease, and expected progeny differences (USDA; Simms, Geske, and Bolze). Surveys have identified factors producers consider when purchasing bulls, but they provide little information about relative economic importance of individual factors. Quantifying values of specific bull characteristics is integral to determining the economic importance of these factors.

Numerous studies have examined price determinants and demand for cattle characteristics across various segments of the beef industry. Parcell, Schroeder, and Hiner estimated hedonic price models for cow-calf pairs. Mintert et al. analyzed price differentials of cull cows. Many studies have investigated factors affecting feeder cattle prices (e.g., Bailey, Peterson, and Brorsen; Bailey and Peterson; Faminow and Gum; Sartwelle et al.; Schroeder et al.; Sullivan and Linton; Turner, Dykes, and McKissick; Turner, McKissick, and Dykes). Jones et al. and Ward examined factors affecting prices of fed cattle.

Few studies have examined factors affecting beef bull prices. Greer and Urick found over time that bull prices were responsive to calf price and cowherd inventory. Kerr found calf weaning weight, average daily gain, and calving difficulty significantly affected prices for bulls sold in auctions. He concluded that commercial cattle producers incorporated genetic potential of bulls into prices paid. Commer, Couvillion, and Herndon found performance characteristics, yearling weight ratio, frame score, and sale promotion programs were significant factors explaining sale prices of performance tested bulls. Clary, Jordan, and Thompson concluded that the genetic quality of a bull, as measured by gain in average weaning weight, had a large positive impact on the marginal bid price.

These studies provide insights about factors affecting bull prices; however, none considered expected progeny differences. EPDs predict how future progeny of a bull will perform for various traits. They are generally expressed in terms of pounds above or below the breed average. For example, a bull with a birth weight EPD of -3.5 would be expected to sire calves 3.5 pounds lighter at birth than the average bull of that breed. Schalles and Zoellner argued EPDs provide superior production information compared with other measures. EPDs for growth (weaning and yearling weights) are positively related to actual growth (Arnold et al.; Kemp and Sullivan; Mahrt et al.; Mallinckrodt et al.; Nunez-Dominguez, Van Vleck, and Cundiff). A positive relationship also exists between milk production EPDs and progeny milk production (Diaz, Notter, and Beal; Mallinckrodt et al.; Marshall and Long; Marston et al.).

Although the performance predictability of EPDs has been well documented, Green et al. concluded many cow-calf producers have limited knowledge of this concept based on a 1990 survey of beef producers in southwestern U.S. This is confirmed by surveys where producers identified EPDs as factors affecting bull purchasing decisions but listed them as less important than many other factors (USDA; Simms, Geske, and Bolze).

Pricing Model

The derived demand for bulls is a function of both expected calf prices and productive capabilities. At a point in time, the expected calf price is constant; therefore, bull price is a function of the bull's productive characteristics. Assuming bull buyers maximize profit and short-run bull supply is inelastic, the value of a bull is determined by demand for individual traits the bull possesses. Following Ladd and Martin, the price (r_i) of a bull can be specified as (see Jones et al.; Parcell, Schroeder, and Hiner; Schroeder et al. for further development of this model):

$$r_i = \sum_j T_j x_{ji}, \tag{1}$$

where i refers to a particular bull; j refers to physical, genetic, and performance characteristics of the bull; T_j is the marginal implicit price paid for the jth characteristic; x_{ji} is the quantity of characteristic j the bull possesses. Given price and characteristic data, the marginal implicit prices can be estimated using regression.

Bull characteristics are split into two categories: physical and genetic characteristics and expected performance characteristics. Expected performance characteristics refer to progeny performance, and physical and genetic characteristics refer to the bull's own traits. Adding marketing factors to (1), bull price can be specified as:

$$\text{Bull Price}_i = f(\text{Physical and Genetic Characteristics}_i, \text{Expected Performance Characteristics}_i, \text{Marketing Factors}_i). \tag{2}$$

Specific variables included in the model and their expected signs are presented in table 1.

Physical and genetic characteristics important to bull price include factors affecting expected useful life of the bull. Age and bull price are expected to be nonlinearly related. Young bulls, with lower serving capacity, likely have lower values. Older bulls, not sold previously suggesting possible problems, are also expected to have lower values. Other physical and genetic traits include factors indicating soundness of the bull that may be heritable such as structural correctness, conformation, disposition, and muscling. These attributes are expected to be positively associated with price. Whether the bull is black and whether the bull is polled are included in the physical traits. Black bulls are expected to bring premiums because of buyer perceptions of higher marbling associated with Angus-type cattle. Polled bulls are preferred to horned bulls because of difficulty handling horned cattle and price discounts for feeder calves with horns (Sartwelle et al.; Schroeder et al.). Breed is included in genetic characteristics as buyers differentiate between breeds. No specific premium or discount by breed is expected a priori.

Table 1. Definitions of Variables Used to Explain the Logarithm of Bull Sales Price

Variable	Definition	Expected Sign
Physical and genetic characteristics		
$BREED_j$	Breed binary variables = 1 if bull is that breed; otherwise = 0 *j* = *SIMMENTAL* (default), *ANGUS, CHAROLAIS, HEREFORD, RED ANGUS, GELBVIEH,* or *LIMOUSIN*	?
$BLACK_j$	Color binary variable = 1 if bull of breed *j* is black; otherwise = 0 *j* = *SIMMENTAL, GELBVIEH,* or *LIMOUSIN*	+
POLLED	Polled binary variable = 1 if bull is polled; otherwise = 0	+
CONF	Conformation score of 1, 2, . . . , 5 (1 = poorest to 5 = best)	+
MUSCLE	Muscling score of 1, 2, . . . , 5 (1 = poorest to 5 = best)	+
CORRECT	Structural correctness score of 1, 2, . . . , 5 (1 = poorest to 5 = best)	+
DISP	Disposition score of 1, 2, . . . , 5 (1 = poorest to 5 = best)	+
AGE	Age of bull in days	+
AGESQ	Age of bull in days squared	−
Performance characteristics[a]		
$BIRTH_i$	Birth weight of bull of breed *i,* if bull not breed *i,* = 0	−
$ADJWW_i$	Adjusted weaning weight of bull of breed *i,* if bull not breed *i,* = 0 all weaning weights are adjusted to 205 days of age	+
$BWEPD_i$	Expected progeny difference for birth weight of bull of breed *i,* if bull not breed *i,* = 0	−
$WWEPD_i$	Expected progeny difference for weaning weight of bull of breed *i,* if bull not breed *i,* = 0	+
$MILKEPD_i$	Expected progeny difference for milk of bull of breed *i,* if bull not breed *i,* = 0	+
Marketing factors		
$SALE_k$	Sale binary variables = 1 if bull sold at sale *k*; otherwise = 0	?
ORDER	Order bull was sold in sale times percent order bull was sold	−
ORDERSQ	Order variable squared	+
PICTURE	Picture binary variable = 1 if bull was pictured in catalog; otherwise = 0	+
PICTORD	Picture variable times percent order bull was sold	−
RETAIN	Proportion of semen rights retained	+
RETPCT	Percent of bulls in sale having semen rights retained for bulls that have semen rights retained; otherwise = 0	−

[a] The *i* refers to breed, where *i* = 1 Simmental, 2 Angus, 3 Charolais, 4 Hereford, 5 Red Angus, 6 Gelbvieh, 7 Limousin.

Expected performance characteristics indicate production potential of a bull's offspring. Birth weight is examined as actual weight and as an EPD measure. Both are related to birth weight of the bull's offspring, with generally lighter being preferred to heavier birth weights. Weaning weight (adjusted to the same number of days) and its associated EPD are measures of growth rate of the bull's offspring and are expected to be positively associated with price. Milk EPD measures expected milk production of progeny with a larger EPD value preferred. To determine the importance of the recently adopted EPD measures on bull prices, two models are estimated, one containing weights without EPDs (Model 1) and the other including weights and EPDs (Model 2). Comparison of the estimates from these models show how much additional information EPDs provide.

Bull sellers use various marketing techniques to promote specific bulls. Marketing factors expected to influence price include the order in which the bull sold. Previous studies have found that price declined in cattle auctions as sales progressed (Mintert et al.; Sartwelle et al.; Schroeder et al.; Turner, Dykes and McKissick) or that sale order had no statistically significant effect on price (Parcell, Schroeder and Hiner; Turner, Dykes and McKissick). One study found that prices increased during the sale (Bailey, Brorsen, and Thompson). Sellers typically place their highest quality bulls at the beginning of sales.[1] If bull characteristics are captured in the model, order sold would not be expected to influence bull prices unless buyers' bidding behavior is related to time of sale. Therefore, sale order-price effects reflect either bidder behavior or changing bull quality attributes not contained in other variables. To allow for a sale order effect, an order sold variable was included in the model. Order was allowed to be nonlinear by including squared sale order. Binary variables for each sale were included in the model to account for differences across sellers.

Sellers promote bulls by including pictures of individual bulls in the sale catalog. Because of the printing expense and expected return from a picture, only a few pictures are usually displayed in the catalog. If the seller incurs the expense of placing a picture in the catalog, presumably the seller is featuring the bull. Therefore, bulls with a picture in the catalog are expected to receive higher prices. To capture this effect, bulls with pictures are assigned a binary variable equal to 1. Some sellers place pictures of bulls randomly throughout the catalog, suggesting they are not using the picture to feature an early selling, higher quality bull. To capture this effect, an interaction of the picture dummy variable multiplied by the percentile order sold was included. The expected sign of this variable is negative indicating the value of a picture for bulls sold late in the sale is worth less than the value of a picture for bulls sold early in the sale.

Sellers occasionally retain a portion of semen rights on several bulls with the portion indicated in the catalog.[2] This may be a marketing technique to draw buyer attention to the bull, or it may reflect an expectation by the seller regarding future value of the bull's semen. Semen retention is expected to be positively associated with price. If a seller retains semen rights on a large percentage of bulls, this suggests the seller is retaining without consideration of special quality attributes, and the perceived value of retaining to the buyer is expected to be smaller. To capture this effect, the percentage of bulls in a sale for which semen rights were retained was included. The expected sign of this variable is negative.

Data

Sale price, physical characteristics, genetic information, and marketing factors were collected on individual animals from 26 purebred beef bull sales in Kansas during spring 1993. The data included 1,700 bulls representing seven beef breeds. Because of incomplete data only 1,650 observations were used. Breeds and percentages of bull sales on

[1] Analysis of the bull sales data used here confirmed that bull quality generally was lower at most sales the later in the sale the bull was ordered.

[2] Retention of semen rights means the buyer has full use of the bull with the buyer's cattle but must share revenue with the seller on any commercial semen sales.

Table 2. Summary Statistics of Selected Purebred Kansas Bull Sales Data, 1993

Variable	Mean	SD	Minimum	Maximum
Bull sale price ($/head)	2,306.1	1,272.9	650	20,000
Birth weight (lbs.)	85.3	11.4	40.0	128.0
Adjusted wean weight (lbs.)	651.7	77.0	444.0	961.0
Conformation	3.27	0.56	1.00	5.00
Muscling	3.25	0.68	1.00	5.00
Correctness	3.40	0.59	1.00	5.00
Disposition	3.26	0.69	1.00	5.00
Age (days)	449	118	298	1,136
Picture	0.077	0.267	0.00	1.00
Retain	0.006	0.049	0.00	0.67
Distribution of Bull Sale Prices ($/head)		(%)		
Less than or equal to 1,000		4.7		
1,000–2,500		64.1		
2,501–3,500		21.4		
3,501–5,000		8.1		
5,001–10,000		1.6		
Greater than 10,000		0.2		

which data were collected were Angus (46.5%), Charolais (12.4%), Gelbvieh (14.3%), Hereford (7.5%), Limousin (3.6%), Red Angus (4.4%), and Simmental (11.3%).

Individual bulls were evaluated at the time of sale and assigned a rank of 1 (poor) to 5 (excellent) with respect to conformation, muscling, correctness, and disposition.[3] Other information recorded at the time of sale were order sold, breed, lot, polled, color, age, and price. Sale catalogs containing physical and genetic information for each bull were obtained from each sale. Physical and genetic characteristics recorded were actual birth weight, birth weight EPD, adjusted weaning weight, weaning weight EPD, and milk EPD. Other information taken from the sale catalogs on individual bulls was retention of semen and whether the bull was pictured in the catalog.

Summary statistics of selected data are provided in table 2. The average price paid was $2,306.10 per head. Prices ranged from $650 to $20,000 per head with 93.6% of the prices in the $1,001 to $5,000 range. Average birth weight was 85 lbs. and average adjusted weaning weight was 652 lbs. The bulls averaged 449 days old with a range of 298 to 1,136 days. Approximately 8% of the bulls had a picture in a sale catalog. Roughly 1% of bulls had at least some proportion of semen rights retained by the seller.

Results and Discussion

Parameter estimates of Models 1 (excluding EPDs) and 2 (including EPDs) are reported in table 3. The models were initially estimated using ordinary least squares (OLS) regression with both actual prices and logarithmic transformed prices. A likelihood ratio test indicated rejection of the linear model in favor of the log model at the 0.05 level. Therefore, the reported models explain the logarithm of bull prices. Collinearity tests

[3] Data collection and bull evaluations were conducted in a systematic manner by Kansas State University animal scientists.

Table 3. Parameter Estimates of Kansas Purebred Bull Sale Price Determinants, 1993

Variable	Model 1 Parameter Estimate	Model 1 *t*-Statistic	Model 2 Parameter Estimate	Model 2 *t*-Statistic
Intercept	5.9080**	14.16	5.9670**	13.39
Physical and genetic characteristics				
BREED (default = *SIMMENTAL*)				
ANGUS	0.73530*	1.82	0.39196	0.89
CHAROLAIS	0.61126	1.23	0.76802	1.38
HEREFORD	−0.73143	−1.03	−0.83039	−0.94
RED ANGUS	0.44794	0.68	0.33584	0.44
GELBVIEH	0.53164	1.13	0.34404	0.70
LIMOUSIN	0.19455	0.28	0.33692	0.46
BLACK SIMMENTAL	0.49535**	7.71	0.53109**	8.55
BLACK GELBVIEH	0.12343*	1.86	0.15299**	2.31
BLACK LIMOUSIN	0.29653**	2.12	0.39854**	2.71
POLLED	0.10153**	3.30	0.10457**	3.43
CONF	7.94E−02**	4.27	6.96E−02**	3.89
MUSCLE	2.76E−02*	1.95	3.26E−02**	2.38
CORRECT	2.91E−02	1.60	2.83E−02	1.62
DISP	3.27E−02**	2.36	2.47E−02*	1.84
AGE	1.57E−03**	2.38	1.19E−03*	1.85
AGESQ	−1.08E−06*	−1.85	−7.33E−07	−1.29
Performance characteristics				
BIRTH1 — Simmental	−7.63E−03**	−2.90	−5.40E−03	−1.63
ADJWW1	1.41E−03**	3.47	9.44E−04**	2.32
BIRTH2 — Angus	−9.53E−03**	−6.81	−3.84E−03**	−1.99
ADJWW2	1.57E−03**	6.54	1.18E−03**	4.44
BIRTH3 — Charolais	−9.25E−03**	−3.58	−7.65E−03**	−2.11
ADJWW3	1.54E−03**	3.83	1.18E−03**	2.82
BIRTH4 — Hereford	−3.12E−03	−0.51	−4.18E−04	−0.05
ADJWW4	2.74E−03**	3.53	2.21E−03**	2.56
BIRTH5 — Red Angus	−6.09E−03	−1.21	−8.03E−03	−0.94
ADJWW5	1.39E−03*	1.66	1.43E−03	1.61
BIRTH6 — Gelbvieh	−6.25E−03**	−2.61	−2.66E−03	−0.95
ADJWW6	1.50E−03**	4.23	1.41E−03**	4.09
BIRTH7 — Limousin	−8.86E−04	−0.18	2.79E−03	0.44
ADJWW7	5.75E−04	0.77	−3.63E−04	−0.45
Expected progeny differences				
BWEPD1 (Simmental)			−4.37E−02**	−1.98
WWEPD1 (Simmental)			1.43E−02**	3.23
MILKEPD1 (Simmental)			2.77E−02**	3.87
BWEPD2 (Angus)			−4.43E−02**	−4.20
WWEPD2 (Angus)			7.96E−03**	2.92
MILKEPD2 (Angus)			7.63E−03**	2.45
BWEPD3 (Charolais)			−1.11E−02	−0.63
WWEPD3 (Charolais)			4.51E−03	1.51
MILKEPD3 (Charolais)			6.13E−03	1.54
BWEPD4 (Hereford)			−2.58E−02	−0.70
WWEPD4 (Hereford)			1.23E−02*	1.93
MILKEPD4 (Hereford)			−3.28E−03	−0.48

Table 3. Continued

Variable		Model 1 Parameter Estimate	Model 1 *t*-Statistic	Model 2 Parameter Estimate	Model 2 *t*-Statistic
BWEPD5	Red Angus			1.11E−02	0.27
WWEPD5	Red Angus			5.83E−03	1.00
MILKEPD5	Red Angus			2.40E−02**	2.19
BWEPD6	Gelbvieh			−4.62E−02**	−2.65
WWEPD6	Gelbvieh			1.01E−02**	2.53
MILKEPD6	Gelbvieh			9.45E−03	1.35
BWEPD7	Limousin			−2.71E−02	−0.52
WWEPD7	Limousin			3.34E−02**	2.28
MILKEPD7	Limousin			−5.70E−03	−0.36
Marketing factors					
SALE1		−0.31587**	−4.39	−0.23282**	−3.16
SALE2		−0.28983**	−4.61	−0.22239**	−3.41
SALE3		−0.32426**	−4.95	−0.28611**	−4.33
SALE4		−0.29457**	−4.42	−0.30504**	−4.78
SALE5		−0.34139**	−5.01	−0.38230**	−5.65
SALE6		0.46318**	7.76	0.44744**	6.80
SALE7		−0.15986**	−2.20	−0.13612*	−1.93
SALE8		−0.10061	−1.56	−0.01181	−0.18
SALE9		−0.54797**	−7.32	−0.38351**	−4.82
SALE10		−0.13048**	−2.18	−0.06475	−1.00
SALE11		−0.42547**	−6.01	−0.33051**	−4.55
SALE12		−0.38674**	−4.31	−0.41765**	−4.65
SALE13		0.05069	0.25	−0.01072	−0.05
SALE14		−0.66795**	−6.20	−0.72566**	−6.95
SALE15		−0.19956**	−2.61	−0.13786*	−1.82
SALE16		−0.65109**	−6.42	−0.56933**	−5.53
SALE17		−0.79756**	−4.86	−0.81442**	−4.85
SALE18		−0.60004**	−4.81	−0.46641**	−3.40
SALE19		0.25241**	3.64	0.18955**	2.68
SALE20		−0.10312	−1.03	−0.16323*	−1.65
SALE21		−0.56577**	−6.13	−0.53114**	−5.94
SALE22		−0.44269**	−7.99	−0.51371**	−8.75
ORDER		−5.75E−05**	−6.74	−5.59E−05**	−6.78
ORDERSQ		1.68E−09**	2.17	1.78E−09**	2.39
PICTURE		2.78E−01**	5.23	2.65E−01**	5.18
PICTORD		−2.20E−03	−1.53	−2.16E−03	−1.56
RETAIN		1.99260**	3.25	1.87450**	3.15
RETPCT		−4.17910*	−1.77	−4.47680*	−1.92
R^2		0.699		0.726	
RMSE		0.061		0.057	
Observations		1,650		1,650	

Note: Two asterisks and one asterisk denote coefficients which are significantly different from zero at the 0.05 and 0.10 levels, respectively.

were conducted on the residuals and the only possibly degrading collinearity (Belsley, Kuh, and Welsch) detected was amongst the binary breed variables and the intercept. Since emphasis is on value of characteristics and not differentials associated with breeds, this was not a concern.

Residuals were tested for normality using the Jarque-Bera test (Jarque and Bera). Normality of the residuals of Models 1 and 2 was rejected at standard statistical levels. The normality rejection was primarily because of kurtosis. Several especially high-priced bulls received prices higher than the models predicted. Examination of these bulls indicated they were often sold early in the sales, usually within the first ten bulls. Attempts to explain these higher than expected prices with sums of several attributes to create a composite character of the bulls did not improve the models. To account for this nonnormality the models were reestimated using the multivariate-*t*-errors robust estimation method in SHAZAM using 3 degrees of freedom and assuming independent residuals (Judge et al.; Zellner). As the degrees of freedom value increases, the multivariate-*t* estimation approaches OLS with standard normality assumptions (a *t*-distribution with infinite degrees of freedom is a normal distribution). Smaller degrees of freedom place less restrictions on the distribution of the errors. If the errors are independent rather than just uncorrelated parameter estimates are more precise; however, if errors are assumed to be independent when they are just uncorrelated, the variances of the estimates will be underestimated (Judge et al.). The multivariate-*t* regression models explained 69.9% and 72.6% of the variability in the logarithms of bull prices. Most variables had the anticipated signs and were statistically significant.

Effects of Physical Characteristics

When EPDs were not included (Model 1), Angus bulls brought a significant premium relative to Simmental bulls, but other breeds did not significantly differ from Simmental. When EPDs were included in the model (Model 2), none of the breed effects were significantly different from zero. Black Simmental bulls brought premiums of 50 to 53% compared with Simmental bulls that were not black. Similarly, black Gelbvieh and Limousin bulls received premiums of 12 to 15% and 30 to 40%, respectively, compared with red bulls. Previous studies found Angus-type, or black, feeder cattle brought premiums over several other breeds (Sartwelle et al.) and the value of this trait is reflected in the derived demand for bulls. Polled bulls received a 10% premium. The marginal premium paid on conformation was two to three times greater than for muscling, correctness, or disposition with premiums of 8 and 7% for Models 1 and 2, respectively, for each incremental increase in conformation score.

Historically, bulls have often been sold as two-year olds, but the beef industry now uses more yearling bulls (Gossey). This is confirmed by the fact that 79% of the bulls sold were less than 18 months old. Age had a nonlinear effect on bull prices indicating buyers paid a premium for older bulls but at a decreasing rate (fig. 1). Two-year-old and older bulls brought premiums compared with younger bulls but probably not large enough premiums to offset the added expense of raising the bulls.

Performance Factors

Birth weight, adjusted weaning weight, and EPD variables were estimated separately by breed because of differences in standards across breeds. Birth weight had a negative impact

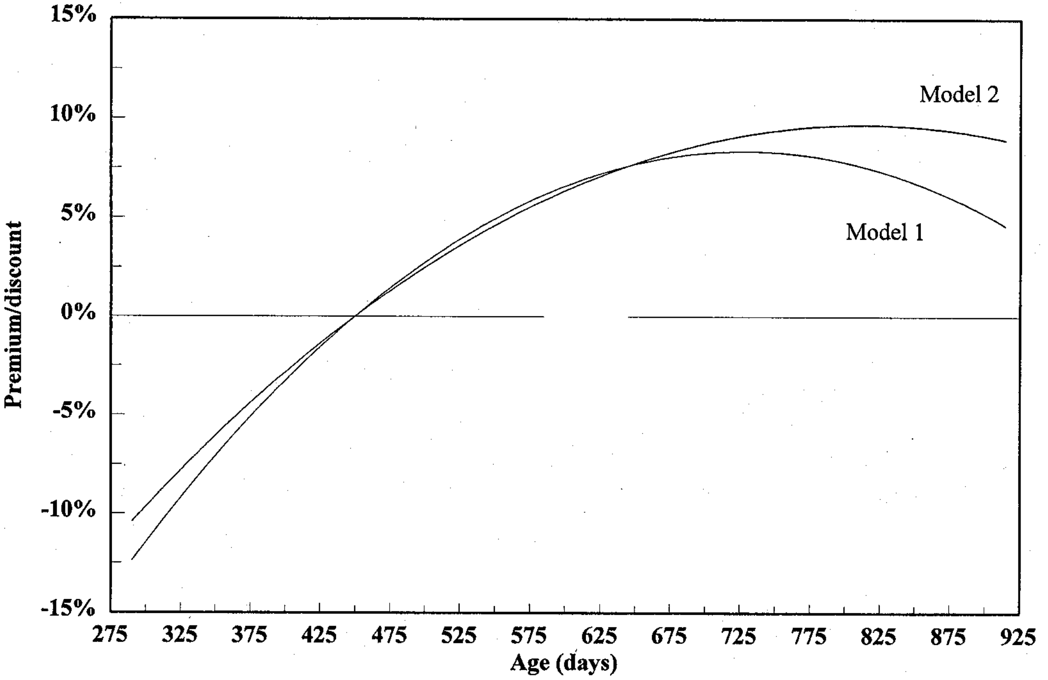

Figure 1. Effect of bull age on bull price, base age is 450 days

on bull prices indicating bulls with higher birth weights sold at a discount to bulls with lower birth weights. When EPDs were not included (Model 1), birth weight was significant for four of seven breeds and the discounts ranged from 0.6 to 1.0% for each additional pound of birth weight. When EPDs were included (Model 2) actual birth weight was statistically significant for only two of the seven breeds. In general, the birth weight discount decreased when birth weight EPD was included in the model. Birth weight EPDs had significant impacts on prices for three of the seven breeds and ranged from a discount of 4.4 to 4.6% for each incremental increase in EPD. Birth weight EPDs were negative for six of the seven breeds indicating producers discount bulls with relatively high birth weight calves.

Adjusted weaning weight was significant for six of the seven breeds and was positive as expected in both models. The premium ranged from approximately 0.1 to 0.3% for each additional pound of weaned weight when EPDs were not included in the model. When weaning weight EPDs were included in the model, premiums associated with actual weaning weight decreased slightly. Weaning weight EPDs had a significant impact on the price of bulls for five of the seven breeds and ranged from 0.8 to 3.4% for each incremental increase in EPD.

Milk EPDs were significant for three of the seven breeds. The premium on milk EPDs ranged from about 0.8 to 2.8% for each incremental increase in milk EPD.

Table 4 reports the statistical significance of groups of performance factors for Models 1 and 2. Adjusted weaning weight, birth weight EPD, weaning weight EPD, and milk EPD are all highly statistically significant in Model 2 and birth weight is significant at the 10% level. This indicates buyers use both physical measures and EPD values in determining prices to pay for bulls; however, actual birth weights and birth weight EPDs may be providing buyers similar information. Individually, all three EPD variables were

Table 4. Statistical Significance of Performance Characteristics in Explaining Bull Prices

	Model 1		Model 2	
Variable Group	*F*-Statistic	Significance	*F*-Statistic	Significance
Birth weight	10.78	0.0000	1.86	0.0716
Weaning weight	13.96	0.0000	8.19	0.0000
Birth weight EPD			4.26	0.0001
Weaning weight EPD			5.32	0.0000
Milk EPD			4.31	0.0001

significant for the Simmental and Angus breeds. Two of the three EPD variables were significant for Gelbvieh. The number of significant EPD variables for the other four breeds was either one or none. This indicates the use of EPDs varies considerably across breeds and for some breeds they are not being used in pricing bulls.

Marketing Factors

Numerous binary variables for sales were significant indicating a sale effect was present. This could reflect seller reputation (Commer, Couvillion, and Herndon; Turner, McKissick, and Dykes), location, or marketing factors not measured here. Because sales were separated by breed (even if they occurred at the same location on the same day), complete use of all breed and sale dummy variables in the model was not possible due to perfect collinearity. Therefore, sale dummy variables have a default sale associated with each breed.

The order a bull was sold significantly affected price. Prices declined at a decreasing rate the later in the sale a bull was sold. Figure 2 shows the price discount received for two different sizes of sales with sale order on a relative basis. The discount decreases at a slower rate for sales with fewer bulls compared with those offering more bulls. A discount of 20% occurred slightly over halfway through the sale when 120 bulls were sold. That same discount was reached after over 80% of bulls were sold at sales with 60 bulls.

Bulls featured in the sale catalog with pictures received premiums of roughly 27 to 28% compared with bulls without pictures. However, the value of a picture declined as the bull was sold later in the sale. Whether the presence of the picture in the catalog influenced sale price or the bulls with pictures were considered to be of superior quality (for which the individual attributes in the pricing model estimated did not adequately capture) is not discernable since causality cannot be established. Bulls that had a portion of semen rights retained by the sellers received large premiums; however, the premiums decreased rapidly as the percentage of bulls with semen rights retained increased.

One interesting aspect of these bull sales is that some bulls brought considerably higher prices than the sum of the marginal predicted values of their quality differences (contributing to nonnormal residuals). Attempts to model this by combining several traits into composite quality variables failed to improve the models. This phenomenon is similar to what Frank and Cook labeled "the winner take all."[4] In a winner-take-all market the highest valued performers receive more than their marginal differences would predict. To examine this

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[4] We are indebted to an anonymous journal reviewer for bringing this concept to our attention.

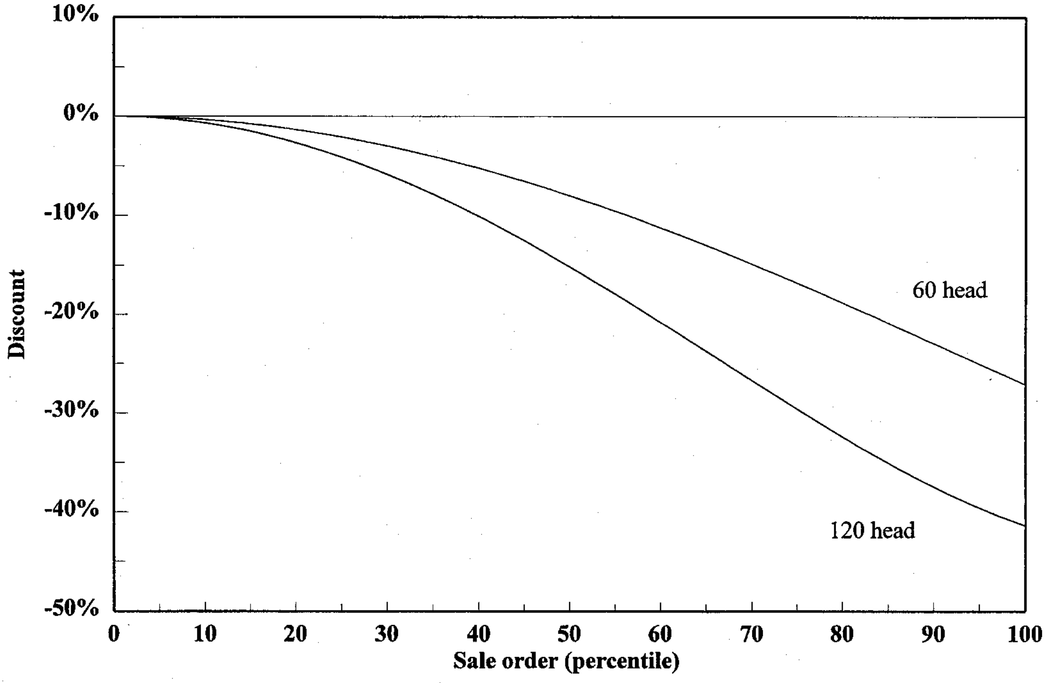

Figure 2. Effect of sale order on bull price by size of sale (Model 2)

phenomenon more closely, the predicted prices were plotted against the actual prices (fig. 3). Bulls receiving the highest actual prices had predicted prices that were less than they actually received. The top 10% highest priced bulls had an average residual of 16 to 18%, suggesting prices for these bulls were underpredicted on average. Why these bulls brought such high prices is difficult to determine. Some of these bulls could have been purchased by purebred breeders; however, we were unable to obtain data to confirm this. This suggests the possibility of a separate market for these higher priced bulls.

Conclusions

Bull prices are determined by genetic, physical, and expected performance characteristics of the bull and by marketing techniques not necessarily related to the quality of the bull. While absolute price levels varied by breed, after quality characteristics are accounted for, generally breed had no effect on price. Buyers paid premiums for black Simmental, Gelbvieh, and Limousin bulls. Polled bulls received premiums. Premiums were paid for bulls receiving higher subjective ratings for conformation, muscling, and disposition indicating buyers incorporate visual appraisal of bulls into their pricing decisions. Price was nonlinearly related to age indicating producers paid a premium for older bulls, but the premium decreased as age increased.

Expected performance variables were important in explaining price variability for most breeds. Bull prices were negatively correlated with birth weight for all breeds except Limousin. Price was also negatively correlated with birth weight EPDs for most breeds; however, birth weight EPDs were only statistically significant for three of the breeds. Birth weight EPDs did not provide buyers new information compared with actual birth weights for most

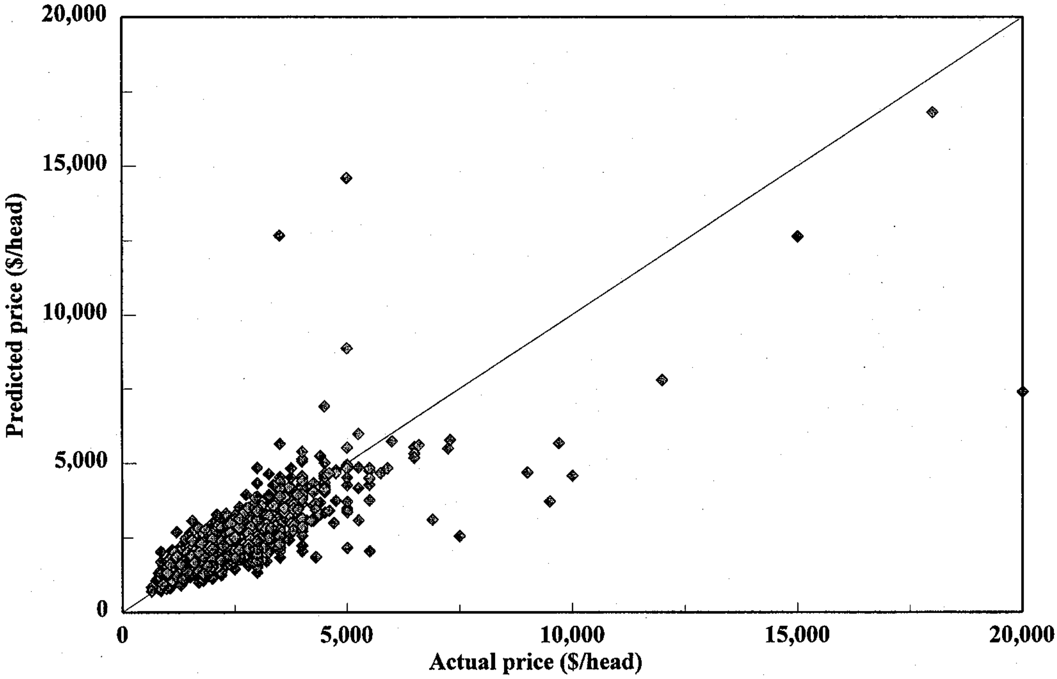

Figure 3. Comparison of actual and predicted bull prices (Model 2)

breeds. Bull prices were positively correlated with adjusted weaning weight and significantly different from zero for most breeds. Prices were positively correlated with weaning weight EPDs for all breeds and statistically significant for all breeds except Charolais and Red Angus. Milk production EPD significantly affected bull prices in three of the breeds and was positively correlated with price. Buyers use expected performance measures in their purchasing decisions; however, the information used varies by breed. EPDs were statistically significant in explaining the price of Angus, Gelbvieh, and Simmental breeds but were less significant in other breeds. Performance variables were not significant in explaining the price of Limousin bulls indicating buyers differentiated these bulls based on other factors.

Bull prices varied considerably between sales indicating seller reputation, location, and marketing factors not included in this analysis significantly impact price. Bull prices declined as sales progressed. If sellers featured a bull by including its picture in the sale catalog, they received a premium for that bull. However, the premium decreased if the pictured bull was sold late in the sale. If sellers retained a portion of the semen rights on a bull, they received a premium for that bull. However, the premium decreased rapidly as the number of bulls with semen rights retained increased. Finally, some bulls brought prices considerably higher than the models predicted suggesting the possibility of a separate market for these bulls.

[*Received January 1996; final version received July 1996.*]

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