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Carcass Quality and Genetic Selection in the Beef Industry

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A lack of high-quality beef has been cited as one of the primary factors for the 50% decline in beef demand from the mid-1970s to the late 1990s. Cattle producers argue that appropriate price premiums are not sufficient to encourage the production of high-quality cattle. Although some improvement in carcass quality can be made by the cattle feeding and processing sectors, substantial improvements in quality must include genetic progress. A hedonic analysis of four major U.S. beef seedstock producers indicates that bull purchasers place relatively high values on a bull's ability to produce progeny with improved carcass-quality traits.

Key words: beef quality, expected progeny differences, hedonic model

Introduction

A lack of high-quality beef has been cited as one of the primary factors for the 50% decline in beef demand that occurred between the mid-1970s and the late 1990s (Smith et al., 2000). In response, the National Cattlemen's Beef Association argued for increased value-based marketing as a means for improving beef quality (Value-Based Marketing Task Force, 1990). A value-based system measures the quality of fed cattle carcasses and then establishes individual cattle sales prices based upon these measures. Although many value-based cattle pricing methods have been implemented, Johnson and Ward (2005) note that value-based pricing has, on average, only weakly influenced fed cattle quality.

This paradoxical result begs the following question: If consumers truly demand higher quality beef, why are market prices unable to transfer this information to fed and feeder cattle producers? It could be that transactions costs of measuring, managing, and transferring such price information simply do not exceed the benefits of doing so. Or, it could be that fed cattle producers are limited in their ability to improve fed cattle carcass quality because of a lack of high-quality feeder cattle. That is, while cattle feeding practices can influence fed cattle carcass quality, feeder cattle genetics are a limiting factor in the production of high-quality fed cattle (Corah and McCully, 2006). Alternatively, it may be that such information is actually being transmitted along the marketing chain, but appropriate data are not available to adequately research the issue.

Indeed, feeder cattle producers often argue that appropriate price premiums are either unavailable or insufficient to encourage the production of high-quality feeder cattle. However, it is virtually impossible to directly determine the soundness of this argument

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for a number of reasons. First, the evaluation of feeder cattle quality is fraught with measurement error and signal extraction problems. Second, approximately 37 million head of feeder cattle are produced each year in the United States [Livestock Marketing Information Center (LMIC), 2008a]. Given that the average beef cattle operation maintains a breeding cow herd numbering less than 50 head, the costs of measuring feeder cattle quality are large (LMIC, 2008b). Third, the eventual end-use quality of any single feeder calf is ultimately a combination of genetics, feeding strategies, weather conditions, animal health, and processing activities.

If the marketing chain is not clearly signaling consumer demands for higher quality beef cuts (i.e., more tender, consistent, and flavorful) to feeder cattle producers, then fed cattle carcass quality would not be substantially improved by value-based pricing methods. Furthermore, feeder cattle (i.e., cow-calf) producers would be expected to ignore the potential for higher fed cattle carcass quality when purchasing bull seedstock. Cow-calf producers select bull seedstock based on expectations of a bull's ability to transfer various characteristics to its offspring. Expected progeny differences (EPDs) are quantitative measures of heritable traits that may be transmitted to a bull's offspring (e.g., birth weight, weaning weight, yearling weight, etc.). Measures of a young bull's own physical characteristics and those of its relatives are used to calculate EPDs. The direct measurement of a young bull's offspring is not possible at the time of purchase because such bulls have not reached breeding maturity. Thus, they have yet to produce any offspring. EPDs serve as proxies for the expected characteristics of a bull's progeny.

Over the past few years, several U.S. purebred cattle seedstock producers have included in sale catalogs two new EPD measures related to expected carcass quality of a bull's progeny—intramuscular fat and ribeye area (Shafer, 2008). Bulls that are expected to transfer higher levels of these two characteristics to their offspring should be worth more to cow-calf producers if they are rewarded for producing feeder cattle with higher carcass-quality characteristics. If cow-calf producers place positive values on EPD carcass-quality characteristics of young bulls, then we can conclude that consumer demands for higher quality beef are being transmitted to at least some feeder cattle producers.

Background

Cow-calf producers purchase or raise breeding stock for the purpose of producing calves. Most calves are born in the spring of each year, and then weaned (separated from their mothers) in the fall. Feeder calves are eventually placed in feedlots where they are "finished" or "fed" using high-protein feed rations. Finished cattle are slaughtered and processed into beef and various slaughter by-products. Thus, cattle and beef production usually involves several ownership transfers. Across these transfers, the end-use quality of live cattle is difficult to determine. If end-use quality were accurately measurable throughout the marketing chain, price signals should readily transmit consumer demands to the cow-calf sector.

Many producers, especially cow-calf producers, assert they do not receive such price signals. Prior to the mid-1990s, most fed cattle were sold in pen-sized lots of 100–300 head. Each animal in a pen received the same per unit price regardless of potential differences in end-use value (Feuz, 1999). This pricing mechanism is referred to as "pricing-on-the-average." Industry participants were concerned that while pricing-on-the-average may reduce transactions costs, the mechanism may fail to send appropriate quality signals through the marketing channel. Nonetheless, at least one-half of the 25 million head of fed cattle slaughtered annually continue to be priced "on-the-average."

Beef quality is influenced by a number of factors including genetic selection, feed management, animal health, carcass aging, and food preparation methods. If appropriate quality signals are not transmitted to feeder cattle producers, end-use quality will suffer. The growth of cattle/beef alliances between cattle producers and beef processors/ retailers has evolved from this concern (Balut and Lawrence, 2007; Gillespie et al., 2006). Strategic alliances are often formed to reduce transactions costs and improve price signals and coordination among vertically related production sectors. A value-based beef marketing system determines prices for individual animals in accordance with that animal's end-use quality. In general, grids are established that reward or discount animal carcasses based upon yield and quality grades.

In the early 1990s, only a handful of alliances existed. However, by 2002, Cattle-Fax (2002) estimated that more than 60 alliances were in operation. According to the *2007 National Meat Case Study*, 51% of beef is now sold in branded forms at retail meat counters compared to 42% in 2004 (Cattlemen's Beef Board, 2008).

Schroeder and Kovanda (2003) note that several issues have influenced the growth of alliances in the beef industry, including needs for: (*a*) improved price signals, (*b*) increased value-based pricing, (*c*) organized producer groups to directly supply consumers, (*d*) reduced transactions costs, (*e*) improved end-use quality, and (*f*) improved vertical coordination for producing branded beef products. Furthermore, they report that while only 8% of fed cattle were marketed by an alliance in 1996, the market share of alliances increased to 27% by 2001. Surveys reveal 39% of fed cattle were likely marketed through an alliance in 2006. Nonetheless, Johnson and Ward (2005) conclude that although grid pricing has somewhat altered carcass quality, price signals are only being weakly transmitted to fed cattle producers. In addition, Feuz (1999) argues that grid pricing transmits some price information to fed cattle producers, but lumpiness in quality categories causes substantial signaling problems.

At yearling bull sales, buyers are usually provided with bull performance measures called expected progeny differences (EPDs). As noted above, EPDs are measures of heritable characteristics a bull may transmit to its offspring. These measures have been developed for most cattle breeds using statistical procedures, and are updated each year to reflect new information (Henderson, 1976). Simple performance measurements (e.g., a bull's own birth weight, weaning weight, and rate of gain) are combined with similar information regarding a bull's ancestors and their offspring. EPDs regarding expected birth weight, weaning weight, and yearling weight of a bull's future offspring are routinely reported for individual bulls at bull sales. For example, a bull with a birth weight EPD of 4.0 would be expected to sire calves with birth weights 4.0 pounds heavier than calves sired by the average bull of that breed. As a number of researchers have found, buyers consider EPDs and the needs of their own cow herds and ranch management systems when selecting beef genetics (Chvosta, Rucker, and Watts, 2001; Dhuyvetter et al., 1996; Walburger, 2002).

Recently, several large purebred bull producers in the United States have started including in sales catalogs two additional EPD measures—intramuscular fat and ribeye area—of the expected end-use quality of a bull's progeny. Higher levels of both attributes are correlated with higher quality beef products. Both traits have been shown to

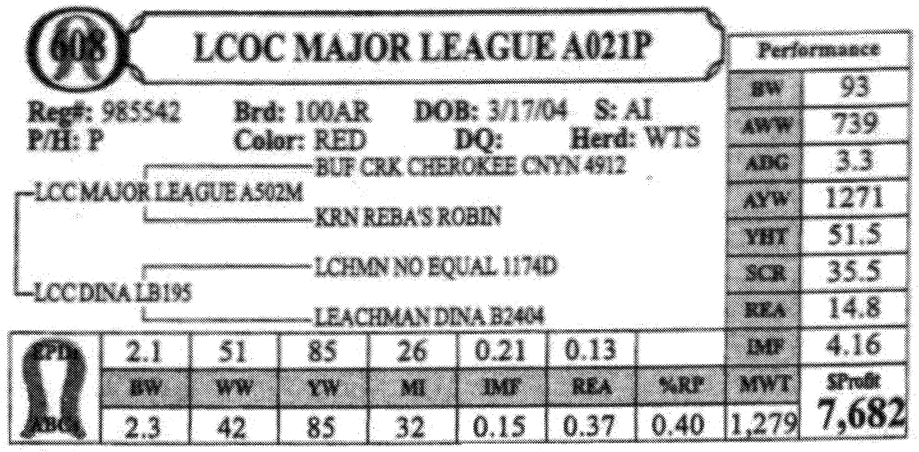

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Figure 1. Sample bull sale catalog advertisement

be as heritable as birth weight (Association for the Advancement of Animal Breeding and Genetics, 2008). Seedstock producers use ultrasound technologies to obtain measures of intramuscular fat and ribeye area of yearling bulls. Ultrasound technology is used because direct measurement of both characteristics can be obtained only after an animal is slaughtered. The production of calves requires the breeding services of bulls. Hence, bulls are not slaughtered until their breeding potential is exhausted. Ultrasound measures of an individual bull's carcass characteristics are coupled with similar ultrasound measures and, when available, observed post-slaughter carcass characteristics of a bull's relatives to develop carcass-quality EPD metrics.

Although seedstock producers use unique promotion formats to market bulls, the informational content provided by sale advertisements is similar across producers. An illustration of a seedstock producer's catalog sales information advertisement is presented in figure 1. In addition to EPDs, this seedstock producer identifies a bull's family tree, date of birth, conception method, and simple performance measures. Simple performance measures are actual measurements of a bull's traits and are presented in the right-hand column of figure 1. For example, this bull had an observed birth weight of 93 pounds and an average daily gain since birth of 3.3 pounds. EPDs are reported at the bottom of the advertisement. The top row reports the EPDs of this Red Angus bull with respect to the Red Angus breed. The bottom row reports EPDs for Across-Breed Comparisons (ABCs) of this bull with respect to all breeds of cattle for which EPDs are available. Standard EPD production measures include birth weight (BW), weaning weight (WW), yearling weight (YW), and milking index (MI), which is an indicator of the expected maternal characteristics a bull may pass to its female offspring.

The EPD for intramuscular fat (IMF) indicates this bull is expected to produce offspring that will have 0.21 percentage points more intramuscular fat than the offspring of an average Red Angus bull, and 0.15 percentage points more intramuscular fat than the offspring of an average bull across all breeds. In addition, this bull is expected to produce offspring having 0.13 more square inches of ribeye area (REA) than the offspring of an average Red Angus bull, and 0.37 more square inches of ribeye area than the offspring of an average bull across all breeds.

Hedonic Model

A hedonic model is used to estimate the implicit value of heritable traits (EPDs) on bull sale prices. The hedonic model specification generally follows that of Becker (1965), Ladd and Martin (1976), Lancaster (1966), Palmquist (1989), and Rosen (1974). The model is used to estimate the implicit values of both production and carcass-quality EPDs.

Hedonic Model Using Nonstandardized Data

The price of a bull is assumed to be a function of heritable and nonheritable bull traits:

$$p_i^r = \sum_j T_j^r x_{ji}^r + \sum_k F_k^r z_{ki}^r, \tag{1}$$

where for the rth ranch, p_i is the price of the ith bull; T_j is the marginal value of the jth heritable trait; x_{ji} is the quantity of heritable trait j possessed by bull i; F_k is the marginal value of the kth nonheritable trait; and z_{ki} is the quantity of nonheritable trait k associated with bull i. Each of the four ranches in our data set prepares promotional material that appears to target different bull purchasers. Thus, the hedonic model's general form is specified as:

$$\begin{aligned} PRICE = {} & \beta_1 * BWEPD + \beta_2 * WWEPD + \beta_3 * YWEPD + \beta_4 * REAEPD \\ & + \beta_5 * IMFEPD + \beta_6 * AGE + \beta_7 * LOGNUM + \beta_8 * DUM_{2005} \\ & + \beta_9 * DUM_{2006} + \varepsilon, \end{aligned} \tag{2}$$

where *PRICE* is the auction sale price of a bull, *BWEPD* is the birth weight EPD, *WWEPD* is the weaning weight EPD, *YWEPD* is the yearling weight EPD, *REAEPD* is the ribeye area EPD, *IMFEPD* is the intramuscular fat EPD, *AGE* is the age of a bull (in days) at the time of sale, *LOGNUM* is the log of the lot number (which represents the sale order of each bull), and DUM_i represent year-specific binary variables. Because binary variables are included for each year, the usual constant term must be excluded.

Cow-calf producers generally sell weaned calves and yearlings by the pound. Calves that are heavier at birth are also likely to be heavier at weaning. Heavier birth weights, however, may lead to increased calf and cow mortality during the birthing process and decreased profitability (Chvosta, Rucker, and Watts, 2001). Hence, the marginal effect of birth weight (*BWEPD*) on the price of bulls is expected to be negative. The ability of calves to quickly gain weight increases ranch profitability. Ceteris paribus, heavier animals generate more revenue, and usually more profit. Therefore, bulls with higher weaning weight (*WWEPD*) and yearling weight (*YWEPD*) EPDs are expected to sell for higher prices.

In general, value-based fed cattle marketing systems provide premiums for animals possessing higher levels of intramuscular fat and ribeye area. Thus, the marginal effects of *IMFEPD* and *REAEPD* are expected to be positive.

Older bulls are expected to be more mature and possess more breeding capacity relative to younger bulls. Therefore, the marginal effect of *AGE* is expected to be positive. Traditionally, bulls presented for sale during the earlier portions of bull sales (earlier lots in an auction) have been pre-sorted based on the seller's opinion of quality. In addition, the order in which each bull is presented in auction sales catalogs matches the order in which each bull is presented at auction. The first few bulls are expected to sell at much higher prices than those that follow. It seems reasonable to assume the effect of lot number on bull prices declines at a decreasing rate. Hence, the natural logarithm of the lot number (*LOGNUM*) is included in the specification, and its marginal effect is expected to be negative. Binary variables (DUM_i) are used to account for fixed effects specific to annual time periods for each seedstock producer.

Our data represent an unbalanced cross-section. Equation (2) could be estimated as four separate equations (one for each of the four ranches in our data set). However, tests of parameter equality across such equations would be cumbersome. To facilitate such tests, the data were arranged as a block matrix and then estimated as a single equation (Zellner, 1962; Parks, 1967).

Thus, the data are stacked as:

$$(3)\qquad \begin{bmatrix} \mathbf{P}^1 \\ \mathbf{P}^2 \\ \mathbf{P}^3 \\ \mathbf{P}^4 \end{bmatrix} = \begin{bmatrix} \mathbf{X}^1 & 0 & 0 & 0 \\ 0 & \mathbf{X}^2 & 0 & 0 \\ 0 & 0 & \mathbf{X}^3 & 0 \\ 0 & 0 & 0 & \mathbf{X}^4 \end{bmatrix} \times \begin{bmatrix} \mathbf{B}^1 \\ \mathbf{B}^2 \\ \mathbf{B}^3 \\ \mathbf{B}^4 \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}^1 \\ \boldsymbol{\varepsilon}^2 \\ \boldsymbol{\varepsilon}^3 \\ \boldsymbol{\varepsilon}^4 \end{bmatrix},$$

where for each ranch r, $\mathbf{P}^r$ is a vector of sales prices and $\mathbf{X}^r$ is a matrix of heritable traits and nonheritable traits. For example, $\mathbf{P}^1$ represents bull sale prices for Ranch 1, and $\mathbf{X}^1$ represents the explanatory variables for Ranch 1 including data on birth weight EPDs, birth-to-yearling gain EPDs, intramuscular fat EPDs, ribeye area EPDs, age, the natural logarithm of lot number, a 2005 binary variable, and a 2006 binary variable. $\mathbf{B}^r$ represents ranch-specific vectors of estimated coefficients of the hedonic model, and $\boldsymbol{\varepsilon}^r$ is a vector of errors.

Equation (3) can be estimated with ordinary least squares (OLS) if the error structure is homoskedastic, or with weighted least squares (WLS) if it is not. The right-hand side of equation (3) includes a full complement of binary variables. Thus, the equation must be estimated without a constant term to avoid singularity. Nonetheless, the procedure does not invalidate goodness-of-fit statistics because the regression line is not being forced through the origin given that all binary variables are included in the specification. Parks' (1967) approach to organizing the data is more user-friendly—i.e., all of the parameter estimates and standard errors are produced directly by any regression package, and testing the equality of estimated coefficients across ranches is accomplished through common F-tests.

Hedonic Model Using Standardized Data

The estimated coefficients of equation (3) represent the marginal value of a one-unit increase in each right-hand-side variable on the dependent variable. However, the explanatory variables specified in equation (3) have widely differing variances. Consequently, the estimated coefficients do not provide an evaluation of the relative importance of each trait in explaining bull prices. In such cases, Pindyck and Rubinfeld (1998) suggest standardizing data based on each respective standard deviation such that:

> Standardized coefficients describe the relative importance of the independent variables in a multiple regression context.... A standardized coefficient of .7 means that a change of 1 standard deviation in the independent variable will lead to a change of .7 standard deviation in the dependent variable (pp. 98–99).

The absolute value of estimated coefficients obtained from a hedonic model using standardized data can then be ranked in terms of their ability to explain bull prices. Therefore, the hedonic model is also estimated with all variables (except the binary variables) standardized by subtracting the mean of each from its observed value, and dividing the result by each variable's standard deviation.

Data

Cross-sectional data were collected from four registered U.S. Red and Black Angus producers. Each producer is among the largest in the United States, and each has a strong reputation for producing high-quality bulls. The performance data were published in catalogs and available to prospective buyers at each bull sale. Auction sales prices for each bull were obtained from each bull producer. Sales data for the years 2005 and 2006 were collected, which provided 2,576 initial observations. Bull prices exceeding $40,000 (three in total) were deleted for estimation purposes. These bulls were purchased by other purebred bull producers rather than by commercial cattle producers. In each case, a limited number of potential buyers of these high-value bulls are furnished with more information than the standard details provided in sale catalogs or to typical bull purchasers. Consequently, such sales are not representative of commercial producer purchases. Furthermore, these three outliers were between 5 and 23 standard deviations above the means of the data. Therefore, 2,573 usable observations remained for estimation purposes.

Table 1 lists descriptive statistics of the variables used in the regression analysis. The average bull price was $3,915 with a standard deviation of $2,028. The birth weight EPD for the four ranches (*BWEPD*) ranged from −4.00 to 8.60 with a standard deviation of 1.60. On average, the bulls in this study are expected to sire calves that are 1.78 pounds heavier at birth relative to the average of all Angus bulls.

The EPDs for birth weight (*BWEPD*), weaning weight (*WWEPD*), and yearling weight (*YWEPD*) were collinear. Consequently, *WWEPD* and *YWEPD* were replaced with a birth-to-yearling gain EPD (*BYGEPD*), constructed by subtracting birth weight EPDs from yearling weight EPDs. On average, the birth-to-yearling EPD on these bulls indicates their progeny are expected to produce 79.4 pounds more gain between birth and yearling ages than the progeny of an average Angus bull, with a standard deviation of 11.6. On average, both of the carcass EPD variables reveal that the bulls in this study have higher carcass-quality attributes than an average Angus bull. Specifically, these bulls are expected to produce offspring with 0.21 percentage points more intramuscular fat and 0.29 square inches more ribeye area than an average Angus bull. The average age of the bulls from all four ranches was 505 days.

Ranch Descriptions

Each of the four ranches disseminates promotion and marketing literature to potential bull purchasers prior to their respective bull auctions. These materials clearly indicate

Table 1. Summary Statistics for Four Purebred Seedstock Producers (2005–06)

Variable	All Ranches	Ranch 1	Ranch 2	Ranch 3	Ranch 4
Price (*PRICE*):					
Mean (dollars)	3,914.70	5,230.55	2,854.35	3,597.76	3,212.73
Standard Deviation	2,028.02	2,360.62	1,784.36	1,359.04	1,683.36
Minimum	392.00	2,000.00	392.00	1,550.00	1,500.00
Maximum	30,000.00	30,000.00	27,500.00	29,000.00	15,500.00
Birth Weight EPD (*BWEPD*):					
Mean (pounds)	1.78	1.84	1.07	2.10	1.49
Standard Deviation	1.60	1.33	1.70	1.72	1.16
Minimum	−4.00	−2.60	−4.00	−3.70	−1.90
Maximum	8.60	7.40	7.10	8.60	5.40
Birth-to-Yearling Gain EPD (*BYGEPD*):					
Mean (pounds)	79.41	86.72	75.35	78.11	70.68
Standard Deviation	11.63	7.04	14.11	10.67	9.73
Minimum	35.90	60.10	36.20	35.90	38.10
Maximum	122.60	110.20	122.60	110.80	99.30
Intramuscular Fat EPD (*IMFEPD*):					
Mean (percentage)	0.21	0.31	0.16	0.21	0.04
Standard Deviation	0.17	0.15	0.20	0.14	0.13
Minimum	−0.29	−0.12	−0.29	−0.17	−0.24
Maximum	0.85	0.85	0.84	0.69	0.47
Ribeye Area EPD (*REAEPD*):					
Mean (square inches)	0.29	0.40	0.37	0.22	0.10
Standard Deviation	0.24	0.21	0.24	0.21	0.18
Minimum	−0.38	−0.16	−0.34	−0.38	−0.34
Maximum	1.16	1.16	1.05	0.94	0.65
Age (*AGE*):					
Mean (days)	505.28	582.74	417.39	514.28	398.15
Standard Deviation	118.75	15.82	64.91	145.65	14.01
Minimum	363	511	365	392	363
Maximum	839	617	760	839	432
No. of Observations	2,573	771	454	1,073	275

that the ranches have differing competitive strategies regarding the production of bulls for specific target markets.

Ranch 1 provided 771 usable observations from its spring 2005 and 2006 production sales. This ranch sells registered Black Angus bulls averaging 19 months of age (i.e., bull calves that are born in the fall rather than the spring). The average bull sale price for this ranch was $5,231. Ranch 1 has a reputation for being the leader of genetic improvements in the Angus breed. Its target market may include other purebred producers who are attempting to improve their own genetics.

Ranches 2, 3, and 4 primarily produce bulls for the commercial production of feeder cattle. Ranch 2 provided 454 usable observations on Red and Black Angus bulls. Although the ranch is a leader in Red Angus genetics, it also sells Black Angus bulls. Many buyers are predisposed to purchasing one breed or the other. Therefore, a binary variable (*REDDUM*) is added to the specification. The binary variable has a value of 1 for Red Angus bulls, and 0 for Black Angus bulls. Both Red and Black Angus bulls are born each spring and sold as yearlings in the following spring production sale. The ranch's average selling price of bulls was $2,854. Ranch 2's competitive advantage centers on producing bulls with low birth weight EPDs.

Ranch 3 provided 1,073 usable observations. These observations include bulls produced by two separate, but related, herds. Bull buyers at this sale recognize that differences exist between the two herds. Hence, a herd-specific binary variable (*HERDUM*) is added to the specification to account for this delineation. The average selling price of these bulls was $3,598.

Ranches 1, 2, and 3 target both U.S. and international bull buyers. In contrast, Ranch 4 primarily targets local or regional cow-calf producers who desire bulls that are able to traverse rough terrain and produce low birth weight calves with high birth-to-yearling gain potential. This ranch provided usable data on the sale of 275 Black Angus bulls from its 2005 and 2006 spring sales, with an average bull sale price of $3,213.

Empirical Results

Equation (3) was estimated twice—once using nonstandardized data (data in levels or, in the case of lot number, natural logarithms) and once using standardized data. Both models were initially estimated using OLS in *STATA 9.2* (Statacorp, 1984–2007). However, White's test rejected the null hypothesis of no heteroskedasticity. Consequently, WLS parameter estimates are reported along with White's robust standard errors.

Hedonic Model Regression Results Using Nonstandardized Data

The WLS estimates of the ranch-specific hedonic model using nonstandardized data are presented in table 2. The estimated parameters have expected signs and are generally statistically significant.

A one-unit increase in birth weight EPD (i.e., a one-pound increase in the expected birth weight of the sire's offspring relative to the average of all Angus bulls) is associated with a $98/head decrease in the price of bulls sold by Ranch 3, and a decrease of $287/head for Ranch 4. Bulls sold by Ranches 1 and 2 have discounts of $278/head and $183/head, respectively, for every one-unit increase in *BWEPD*.

The parameter estimates for birth-to-yearling gain are positive and statistically significant for each ranch. A one-unit increase in *BYGEPD* results in a minimum increase (Ranch 2) of $16/head, and a maximum increase (Ranch 4) of $56/head.

The binary variable for the Red Angus breed (*REDDUM*) is positive and statistically significant for Ranch 2. The coefficient indicates Red Angus bulls are worth $1,083/head more than Black Angus bulls at this particular bull sale. For Ranch 3, the coefficient estimate on *HERDUM* shows that bull purchasers differentiate between bulls being offered for sale from the two different herds.

The parameter estimates for carcass-quality EPDs must be carefully evaluated because of their scale. That is, the standard deviations of *IMFEPD* and *REAEPD* are 0.17 and 0.24, respectively, and are very close to their means (see table 1). Therefore, a one-unit increase in either of these variables represents a five-standard-deviation change. Within this context, the parameter estimates reported in table 2 for these traits appear reasonable. For example, a one-unit increase in *IMFEPD* causes a $600/head increase in the price of bulls sold by Ranch 3, an $822/head increase for Ranch 2, and

Table 2. Hedonic Model Regression Results Using Nonstandardized Data

Independent Variable	Ranch 1	Ranch 2	Ranch 3	Ranch 4
Birth Weight EPD	−277.99**	−182.68**	−97.79**	−286.63**
(*BWEPD*)	(−5.33)	(−3.08)	(−4.72)	(−3.43)
Birth-to-Yearling Gain EPD	27.61**	16.18**	35.79**	56.03**
(*BYGEPD*)	(2.72)	(2.24)	(6.66)	(5.41)
Intramuscular Fat EPD	3,292.46**	822.02*	600.19**	504.48
(*IMFEPD*)	(6.31)	(1.81)	(2.19)	(0.47)
Ribeye Area EPD	2,160.36**	1,515.44**	822.27**	2,083.17**
(*REAEPD*)	(5.64)	(5.32)	(6.70)	(2.85)
Age	−2.99	−0.30	−0.05	13.33**
(*AGE*)	(−0.70)	(−0.30)	(−0.13)	(2.59)
Log Lot Number	−1,271.23**	−486.65**	−430.00**	−458.90**
(*LOGNUM*)	(−9.88)	(−3.16)	(−11.81)	(−2.54)
2005 Binary Variables	10,685.77**	2,836.13**	3,586.79**	−3,814.71*
(DUM^r_{2005})	(4.09)	(4.67)	(6.65)	(−1.62)
2006 Binary Variables	9,084.09**	3,570.48**	3,204.97**	−4,226.53*
(DUM^r_{2006})	(3.46)	(6.22)	(6.09)	(−1.76)
Red Angus Binary Variable		1,082.94**		
(*REDDUM*)		(3.76)		
Ranch 3 Binary Variable			−196.84**	
(*HERDUM*)			(−2.83)	
No. of Observations = 2,573				
Degrees of Freedom = 2,539				
Adjusted R^2 = 0.51				

Notes: Single and double asterisks (*) denote statistical significance at α = 0.10 and 0.05 levels, respectively. Values in parentheses are t-statistics.

a $3,292/head increase in the price of bulls sold by Ranch 1. For Ranch 4, the parameter estimate is not statistically different from zero. The parameter estimates for *REAEPD* are positive and statistically significant for all four ranches; for a one-unit increase, the minimum bull price increase is $822/head (Ranch 3) and the maximum is $2,160/head (Ranch 1).

The estimated coefficient for *AGE* is statistically significant only for Ranch 4. A single-day increase in age causes a $13/head increase in bull prices for this ranch. Clearly, the clientele served by this ranch place a premium on older yearling bulls, while age is not important to the clientele served by Ranches 1, 2, and 3. The order of sale for bulls (*LOGNUM*) is negative and statistically significant for all ranches—i.e., sale prices are lower for bulls that are sold later at each bull auction.

Table 3 presents F-test results of the null hypotheses that the estimated coefficients are equal across ranches. The F-tests reject the null hypotheses at the 5% level for each EPD measure. Consequently, bull purchasers attending each ranch auction value EPDs differently, confirming each ranch caters to different target markets.

Hedonic Model Regression Results Using Standardized Data

Equation (3) was also estimated after standardizing the data using each variable's standard deviation. The results are reported in table 4. A one-standard-deviation increase in

Table 3. *F*-Test Results of the Equality of EPD Parameter Estimates Across the Four Ranches Using Nonstandardized Data

Variable	*F*-Statistic	*p*-Value	Variable	*F*-Statistic	*p*-Value
Birth Weight EPD (*BWEPD*)	4.81	0.0024	Intramuscular Fat EPD (*IMFEPD*)	7.22	0.0001
Birth-to-Yearling Gain EPD (*BYGEPD*)	3.62	0.0126	Ribeye Area EPD (*REAEPD*)	5.50	0.0009

No. of Restrictions = 3
Degrees of Freedom = 2,539
Critical Value 5% Level = 2.60

Table 4. Hedonic Model Regression Results Using Standardized Data

Independent Variable	Ranch 1	Ranch 2	Ranch 3	Ranch 4
Birth Weight EPD	−0.05**	−0.17**	−0.13**	−0.20**
(*BWEPD*)	(−5.33)	(−3.08)	(−4.77)	(−3.43)
Birth-to-Yearling Gain EPD	0.03**	0.13**	0.29**	0.32**
(*BYGEPD*)	(2.72)	(2.24)	(6.66)	(5.41)
Intramuscular Fat EPD	0.06**	0.09*	0.06**	0.04
(*IMFEPD*)	(6.31)	(1.81)	(2.19)	(0.47)
Ribeye Area EPD	0.06**	0.20**	0.13**	0.23**
(*REAEPD*)	(5.64)	(5.31)	(6.70)	(2.85)
Age	−0.01	−0.01**	−0.01	0.11**
(*AGE*)	(−0.70)	(−0.70)	(−0.13)	(2.59)
Log Lot Number	−0.17**	−0.28**	−0.37**	−0.26**
(*LOGNUM*)	(−9.88)	(−3.16)	(−11.81)	(−2.54)
2005 Binary Variables	0.08**	−0.38**	0.19**	0.13*
(DUM^i_{2005})	(6.31)	(−6.98)	(3.44)	(1.87)
2006 Binary Variables	−0.14**	0.03	−0.09**	−0.12*
(DUM^i_{2006})	(−12.19)	(0.57)	(−2.04)	(−1.87)
Red Angus Binary Variable		0.61**		
(*REDDUM*)		(3.76)		
Ranch 3 Binary Variable			−0.14**	
(*HERDUM*)			(−2.83)	

No. of Observations = 2,573
Degrees of Freedom = 2,539
Adjusted R^2 = 0.30

Notes: Single and double asterisks (*) denote statistical significance at $\alpha = 0.10$ and 0.05 levels, respectively. Values in parentheses are *t*-statistics.

birth weight EPD (*BWEPD*) decreases bull price by between 0.05 (Ranch 1) and 0.20 (Ranch 4) standard deviations. A one-standard-deviation increase in birth-to-yearling gain EPD (*BYGEPD*) increases the standard deviation of bull price from 0.03 to 0.32 across the ranches. The standard deviation of intramuscular fat EPD (*IMFEPD*) is statistically different from zero for Ranch 1 (0.06), Ranch 2 (0.09), and Ranch 3 (0.06). The parameter estimates for ribeye area EPD (*REAEPD*) range from 0.06 for Ranch 1 to 0.23 for Ranch 4.

Table 5. *F*-Test Results of the Equality of EPD Parameter Estimates Across the Four Ranches Using Standardized Data

Variable	*F*-Statistic	*p*-Value	Variable	*F*-Statistic	*p*-Value
Birth Weight EPD (*BWEPD*)	5.86	0.0006	Intramuscular Fat EPD (*IMFEPD*)	0.16	0.9250
Birth-to-Yearling Gain EPD (*BYGEPD*)	19.95	0.0000	Ribeye Area EPD (*REAEPD*)	7.47	0.0001

No. of Restrictions = 3
Degrees of Freedom = 2,539
Critical Value 5% Level = 2.60

Table 6. *F*-Test Results of the Equality of EPD Parameter Estimates Within Each Ranch Using Standardized Data

	Degrees of Freedom				
Ranch	Numerator	Denominator	*F*-Statistic	5% Critical Value	*p*-Value
Ranch 1	3	763	34.86	2.60	0.000
Ranch 2	3	445	12.02	2.60	0.000
Ranch 3	3	1,064	21.79	2.60	0.000
Ranch 4	3	267	13.05	2.60	0.000

Table 7. Ranking of Heritable Traits Within Each Ranch

Variable	Ranch 1	Ranch 2	Ranch 3	Ranch 4
Birth Weight EPD (*BWEPD*)	3	2	3	3
Birth-to-Yearling Gain EPD (*BYGEPD*)	4	3	1	1
Intramuscular Fat EPD (*IMFEPD*)	1	4	4	4
Ribeye Area EPD (*REAEPD*)	2	1	2	2

Note: The numerical rank is an ordinal ranking of the absolute value of the estimated EPD regression coefficients within each ranch, as presented in table 4.

F-test results of the null hypotheses that the EPD parameter estimates obtained from standardized data across ranches are equal are presented in table 5. The null hypothesis for intramuscular fat (*IMFEPD*) cannot be rejected. However, the null hypotheses for each of the remaining variables are rejected, indicating the relative explanatory value of birth weight, birth-to-yearling gain, and ribeye area differs among the ranches.

Table 6 reports *F*-test results of the null hypotheses that the standardized EPD parameter estimates are equal within each ranch. The *F*-tests clearly reject the null hypothesis in each case. Hence, the absolute values of the EPD parameter estimates presented in table 4 can be used to ordinally rank the importance of each heritable trait within each ranch in explaining bull prices. As shown by the rankings presented in table 7, each ranch caters to buyers with somewhat different demands. For Ranch 1, the most important trait is intramuscular fat, followed by ribeye area. For Ranch 2, the most important trait is ribeye area. Ranches 3 and 4 have identical trait rankings, with birth-to-yearling gain considered the most important, followed by ribeye area.

While differences exist across ranches, the common theme is that one or more carcass-quality traits rank as either the first or second most important heritable trait desired by bull purchasers.

Summary and Implications

Johnson and Ward (2005) note that the fed cattle market provides little evidence to indicate value-based cattle marketing has improved beef quality. However, such research is inherently difficult to conduct because beef quality can be determined only after an animal is slaughtered, and even then, errors in measurement occur. In addition, value-based marketing primarily focuses on the pricing of fed cattle. To the extent that genetics are an important contributor to improving fed cattle quality, price signals must also be transmitted to feeder cattle producers because most genetic progress in the beef industry occurs through seedstock selection. Bulls are selected for commercial breeding purposes based upon expectations of both paternal and maternal heritable characteristics that will be manifest in their progeny. If consumers demand higher quality beef, this signal should be sent through the marketing chain to producers of feeder cattle. However, many producers argue they do not get paid for producing feeder cattle with higher carcass-quality potential. It is difficult (and perhaps impossible) to determine if this argument is sound. Yet, if the argument is valid, cow-calf producers would not place any value on expected carcass-quality heritable traits when purchasing bulls.

Our hedonic analysis of four major U.S. beef seedstock producers suggests bull purchasers place relatively high values on the expectation of a bull's ability to produce progeny with improved carcass-quality traits. Based on ranch-specific regression results, ribeye area is the first or second most important heritable trait sought by bull purchasers. Evidently, cow-calf producers are responsive to consumer preferences for higher quality beef because, ceteris paribus, they are paying higher prices for bulls that are expected to produce progeny with higher carcass quality. Cow-calf producers must be receiving enough compensation for producing higher quality calves to offset the higher costs of acquiring this heritable characteristic when purchasing seedstock. Although the mechanism may not be clear, our analysis confirms that consumer preferences for higher quality beef are being transmitted to cow-calf producers.

Finally, if demands for higher quality beef are being transmitted to feeder cattle producers, why does previous research suggest that value-based (grid) pricing methods have not substantially improved fed cattle carcass quality? As Johnson and Ward (2005) note, it may be that only a minority of feeder cattle producers are responding to these incentives—i.e., over 50% of feeder cattle are produced by operations maintaining cow herds of less than 50 head. Clearly, these are not commercial operations in the sense that such managers could not possibly derive the majority of their income from feeder cattle production. Furthermore, the growth of alliances suggests commercial producers (i.e., those who rely on feeder cattle production for a majority of their income) are likely on the leading edge of technological advancement. In addition, they are more likely to be purchasing bulls at formal bull auctions and more likely to be involved in strategic cattle marketing alliances. Feeder cattle produced by these operations may circumvent publicly available grid pricing opportunities. Hence, it may be that a segment of the beef industry is concentrating on improving carcass quality, but these improvements may not be manifest in non-alliance, value-based marketing programs.

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