What do buyers value when making herd sire purchases? An analysis of the premiums paid for genetic and phenotypic differences at a bull consignment auction

Jacob N. Brimlow and Stephen P. Doyle[1]

Introduction

Understanding how buyers value traits and performance measures when making sire selections is important for bull sale auctions, seedstock producers, extension agents, and other educators. Recognizing the challenge commercial bull buyers face sorting through available genetic and phenotypic information, many small- and mid-sized bull sale auctions attempt to differentiate their sales by consolidating and summarizing relevant information. Because computing summary scores and measuring bull traits is costly, auction owners and managers need to know what traits and information are most valuable to buyers to make their marketing efforts cost effective. Further, the profitability of seedstock producers depends on their ability to supply bulls that meet the needs of the commercial beef cattle industry, and the relative value placed on different traits at auction provides insight into what traits are most desired by buyers. As market conditions change and new measures of performance and performance predictions become available, the prices buyers are willing to pay for traits and performance indicators may change.

This paper uses data from a mid-size Nevada bull test station and sale to estimate how breeding bull buyers value a variety of sire selection criteria made available through a sale catalog and supplemental worksheet. Previous studies have taken similar approaches to analyzing bull sale prices, including Dhuyvetter et al., 1996, Chvosta et al., 2001, Jones et al., 2008, Vanek et al., 2008, McDonald et al., 2010, and Bekkerman et al., 2013, but none place both genetic and phenotypic measures of carcass and growth characteristics in models that include feed efficiency (measured using Residual Feed Intake (RFI)) and summary scores provided by the bull auction. This study provides further evidence of what bull buyer's value in making sire purchasing decisions and provides new evidence by including genetic measures of carcass traits in a model that includes feed efficiency, phenotypic carcass traits, and seller provided conformation summary values.

Methods

Hedonic Pricing Model

We use hedonic regression analysis to estimate the implicit prices paid by buyers at auction for perceived improvements in bull attributes, including lower RFI scores. Modeling a bull sale using the hedonic regression framework assumes that a bull's sale price is based on buyers' valuation of its attributes (Ladd and Martin, 1976). The hedonic model can be parameterized so regression estimates represent the present value of the expected future returns to attributes that provide value over time (Wallburger, 2002), a characteristic useful for breeding bulls, whose values are determined largely by the performance of their progeny.

Following previous studies (Dhuyvetter et al., 1996, Chvosta et al., 2001, Jones et al., 2008, Vanek et al., 2008, McDonald et al., 2010, and Bekkerman et al., 2013), we employ a semi-log

[1] Authors are, respectively, Assistant Professor of Agricultural Business, and Professor of Animal Science, College of Agriculture, California State University, Chico.

linear hedonic regression model, using a log transformation of Sale Price to adjust for the characteristic positive skewness of price data.[2] Our semi-log linear hedonic regression model is

$$\ln(\text{Sale Price})_i = \beta_0 + \beta_1 (\text{Total Conformation Score}_i) + \beta_2 (\text{Muscle Structure Score}_i) + \ldots$$

$$+ \beta_n (\text{Year\_2012}_i) + \varepsilon_{i,}$$

where *i* indexes individual sale records (bulls), *n* is the number of independent variables (22), the β's are the parameters to be estimated and the marginal effect of a change in each variable on ln(Sale Price), and ε_i is an error term assumed to have constant variance.

Data

Data included 426 complete records from bulls sold at a mid-sized consignment auction yard in Nevada in 2007 (n=138), 2008 (n=94), 2009 (n=78), and 2012 (n=117). Data from 2010 and 2011 were not available. Table 1 lists the explanatory variables (except dummy variables for breed and year) used in the hedonic regressions, including a definition and expected sign of the impact of an increase in each variable on bull sale price at auction.

Gelbvieh, Charolais, and Balancer bull data were deleted because of small samples, and two price outliers (Sale Price > $9000) were removed.[3] Seller provided summary scores for fertility, weaning, test gain, and ultrasound measurements were not included in the analysis because of collinearity with the EPD's and other genetic measures. As in Vanek et al. (2008), we addressed collinearity between birth, weaning, and yearling EPD's by replacing weaning and yearling EPD's with a birth-to-yearling gain measure (*BYGEPD*) calculated by subtracting each bull's birth EPD from its yearling EPD.

We did not include sale order in our regressions because of its collinearity with other measures of quality. At many bull consignment sales, higher quality bulls are auctioned first. As seen in Dhuyvetter et. al. (1996), Jones et al. (2008) and Vanek et al. (2008), this can lead to a statistically significant relationship between sale order and price that may hold even after controlling for quality characteristics, introducing problematic collinearity that is more pronounced for estimations with relatively low sample sizes. A regression of *SaleOrder* on the other explanatory variables used in our regression yielded a relatively high adjusted R-square of 0.68, and we chose to omit it from our regressions.

Summary statistics are reported in Table 2.

---

[2] Even after the log transformation, our price variable failed tests for normality (negative skewness). This issue was recognized by McDonald et. al. (2010), and Bekkerman et al. (2013) used a quantile regression approach and found statistically significant differences in estimates of the marginal effects of bull characteristics on price across price quantiles. Because of the sample size and focus of the study, we continue with a linear hedonic regression model, recognizing that our estimates may not capture variation in marginal impacts across different levels of bull prices.

[3] The residuals (scatter plots and Cook's D statistic) from regressions on an initial data set of 429 observations were analyzed to identify records with large amounts of leverage and/or influence, and 3 records containing data entry errors were identified and dropped, leaving a final set of 426 records.

Table 1: Description of independent variables used in hedonic regressions

Variable	Abbreviation	Expected Sign	Definition
Sale Year	*Year_*		Year of the sale (2007, 2008, 2009, 2012).
Spring Born	*SpringBorn*	-	Dummy variable to indicate Spring born animals (younger at time of sale).
Summary Scores*			
Total Conformation Score	*TotalConformationScore*	+	Aggregation of multiple conformation scores, including scrotal circumference given by team of judges.
Muscle Stucture Score	*MuscleStructureScore*	+	Quality of muscling as assigned by judging committee.
Individual Bull Characteristics (Phenotypic)			
Residual Feed Intake	*RFI*	-	Difference between an animal's actual feed intake and its expected feed requirements for maintenance and growth based on size, breed, etc.
Final Average Daily Gain	*FinalADG*	+	Measure of animal's average daily gain on test.
US Back Fat	*Back Fat*	-	Ultrasound measurement of back fat depth, in inches.
US Adjusted Ribeye	*USAdjRibeye*	+	Ultrasound measurement of ribeye area, in square inches, adjusted to a standard age.
US Marbling	*USMarb*	+	Ultrasound measurement of marbling percent.
Birth Weight	*BirthWt*	-	Birth weight, in pounds.
Day 205 Adjusted Weight	*D205AdjWt*	+	Weight of animal at 205 days on test, in pounds.
Final Weight	*FinalWt*	+	Weight of animal at end of test, in pounds.
Expected Progeny Differences (EPD)**			
Birth-weight EPD	*Birth EPD*	-	Predictor of the bull's ability to pass on birth weight, in pounds.
Birth to Yearling-weight EPD	*BYGEPD*	+	Difference between Yearling weight EPD and Birthweight EPD, in pounds.
Milk EPD	*MilkEPD*	+	Predictor of bull's ability to pass on mothering ability to his daughters, in pounds.
US Percent Intramuscular Fat EPD	*USPIMFEPD*	+	Predictor of the percent intramuscular fat in the ribeye muscle based on ultrasound measurements.
US Ribeye Area EPD	*USREAEPD*	+	Predictor of the difference in square inches of ribeye area based on ultrasound measurements.
US Rib Fat EPD	*USRibFatEPD*	-	Predictor of the external fat thickness at the 12th rib based on ultrasound measurements.

* Assigned by Snyder Livestock according to where animal falls in a normal distribution of scores.

**Expected differences from the progeny of other bulls.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Price				
Price	2717.02	978.86	1200	6500
Natural Log of Price	7.85	0.34	7.09	8.78
Seller Provided Summary Scores				
Total Conformation Score	12.61	1.64	7.55	17.49
Muscle Structure Score	7.96	1.78	1.5	13.5
Expected Progeny Differences				
Birth weight EPD	2.31	1.86	-4.5	7.3
Milk EPD	20.42	5.16	7	38
Birth to Yearling Gain EPD	76.29	14.91	9.3	112.1
Ultrasound Intramusc. Fat EPD	0.17	0.21	-0.33	1.07
Ultrasound Ribeye Area EPD	0.22	0.21	-0.27	0.94
Ultrasound Rib Fat EPD	0.00	0.02	-0.049	0.062
Phenotypic Indicators				
Residual Feed Intake	-0.13	1.80	-7.74	5.77
Final Average Daily Gain	3.66	0.54	1.88	5.63
Ultrasound Marbling	4.47	1.27	1.74	8.51
Ultrasound Adjusted Ribeye Area	13.74	1.42	9.68	18.2
Ultrasound Back Fat	0.31	0.08	0.11	0.52
Birth Weight	81.71	9.07	50	110
205-day Adjusted Weight	673.31	71.06	430	861
Final Weight	1131.34	98.45	860	1410
Dummy Variables				
Spring Born	0.39	0.49	0	1
Red Angus	0.14	0.35	0	1
Hereford	0.14	0.35	0	1
Year_2008	0.22	0.42	0	1
Year_2009	0.18	0.39	0	1
Year_2012	0.27	0.45	0	1

Notes: n = 426

Results

Table 3 reports coefficient estimates, robust standard errors[4] and statistical significance, and two interpretations of the estimated impact of each independent variable on bull sale price. The results of the regression largely conform to expectations, with statistically significant variables all having the expected signs. The R-square of 0.60 indicates the model has significant explanatory power.

In a semi-log linear hedonic regression model, the coefficient estimates can be interpreted as the % change in *Sale Price* associated with a one-unit increase in each independent variable using

$$\%\Delta y = 100 \cdot \left(e^{\beta 1} - 1\right),$$

where *y* is the un-logged dependent variable (*Sale Price*) and β_1 is the coefficient estimate being interpreted. For example, the coefficient estimate for *FinalADG* is 0.107, indicating that a one-unit increase in *FinalADG* is associated with an estimated 100*($e^{0.107}$) - 1) = 11% change in *Sale Price*, on average, holding all other variables in the analysis constant.

Table 3 also reports estimates as changes in price from the mean. For example, a one unit increase in *BirthWt (a one pound increase)* is associated with a $16 decrease in price, on average, holding all other variables in the analysis constant.

As expected, our results indicate that buyers value both genetic and phenotypic indicators of low birth weight, high finishing weights, rapid growth, and favorable carcass characteristics. EPD's for birth weight, birth to yearling gain, and rib eye area were all statistically significantly related to price. Ultrasound measurements indicating bulls with larger rib eye areas and increased marbling were positively related to price. Variables measuring weight and average daily gain were all statistically significant and had the expected signs. Our estimates indicate that buyers are willing to pay a small premium for more feed efficient animals as measured by *RFI*.[5]

Bulls born in the spring (younger at the time of sale) received less, on average, than those born in the fall. Red Angus bulls received less than Angus, on average, while Hereford bulls received more. Year dummy variables were included to capture differences in cattle market conditions over time (e.g., cost of feed), and show the average difference in bull sale prices for the year indicated versus the omitted year, 2007. On average, bull prices in 2008 and 2009 were lower than in 2007, but higher in 2012.

One-unit increases in each continuous independent variable may represent very small (e.g., *BYGEPD*) or very large (e.g., *FinalADG*) changes, making interpretation of the relative importance of each variable difficult. As in Vanek et al. (2008) and McDonald et al. (2010), we estimated a linear regression using independent variables that were standardized using their

---

[4]The residuals from the final regression model with 426 observations were homoscedastic but not normally distributed; a Shapiro-Wilk Test for normality of the residuals rejected the hypothesis of normally distributed residuals, and the Beusch-Pagan / Cook-Weisburg test failed to reject the hypothesis of homoscedastic residuals. To account for the non-normality of the residuals, we use a robust Huber/White/sandwich estimator to compute the standard errors.

[5] Lower (negative) RFI scores are preferred, so a negative coefficient estimate on RFI indicates buyers are willing to pay a premium for improvements in RFI.

Table 3: Hedonic Regression Coefficient Estimates and Interpretations

Variable	Coeff Est.		Std Error	% change[1]	Estimated Price Change[2]
Seller Provided Summary Scores					
Total Conformation Score	0.016	*	0.009	2%	$43.46
Muscle Structure Score	0.011		0.009	1%	$30.35
Expected Progeny Differences					
Birth weight EPD	-0.044	***	0.010	-4%	-$117.65
Milk EPD	-0.002		0.003	0%	-$5.45
Birth to Yearling Gain EPD	0.007	***	0.001	1%	$18.58
Ultrasound Intramusc. Fat EPD	-0.062		0.071	-6%	-$164.40
Ultrasound Ribeye Area EPD	0.148	*	0.078	16%	$432.23
Ultrasound Rib Fat EPD	-0.475		0.744	-38%	-$1,026.86
Phenotypic Indicators					
Residual Feed Intake	-0.022	***	0.006	-2%	-$59.49
Final Average Daily Gain	0.107	***	0.028	11%	$307.26
Ultrasound Marbling	0.032	***	0.013	3%	$87.28
Ultrasound Adjusted Ribeye Area	0.030	***	0.011	3%	$83.55
Ultrasound Back Fat	-0.125		0.173	-12%	-$318.59
Birth Weight	-0.006	***	0.002	-1%	-$16.23
205-day Adjusted Weight	0.000	**	0.000	0%	$1.20
Final Weight	0.000	***	0.000	0%	$1.11
Dummy Variables					
Spring Born	0.075	***	0.027	-7%	-$196.01
Red Angus	-0.069	**	0.043	-7%	-$179.93
Hereford	0.262	*	0.056	30%	$813.44
Year_2008	-0.238	***	0.037	-21%	-$576.49
Year_2009	-0.279	***	0.036	-24%	-$660.88
Year_2012	0.206	***	0.045	23%	$622.11

*Notes: n = 426; R-square = .6028; ***, **, and * indicate statistical significance at the 99%, 95%, and 90% level, respectively*

1 Estimated percentage change in bull sale price when the corresponding independent variable goes up by one unit.

2 Estimated impact on a bull's sale price (at the mean) of a one unit increase in the corresponding independent variable.

standard deviations.[6] Table 4 reports the standardized regression coefficients, which show the relative impact of bull characteristics on sale price, and are interpreted as the effect on price (measured in standard deviations) of a one standard deviation increase in the explanatory variable. For example, a one standard deviation increase in *BYGEPD* is associated with a 0.297 standard deviation increase in the natural log of sale price. Genetic measures of gain (*BYGEPD*) and birth weight (*BirthEPD*) topped the list of factors influencing bull sale price, while seller-provided *TotalConformationScore* was the least influential statistically significant variable.

Table 4: Ranked standardized coefficient estimates

Variable	**Coefficient**
*Birth to Yearling Gain EPD****	0.297
*Birth Weight EPD****	-0.240
*Final Average Daily Gain****	0.170
*Birth Weight****	-0.159
*US Adjusted Ribeye Area****	0.126
*US Marbling****	0.118
*Final Weight****	0.117
*Residual Feed Intake****	-0.117
*205-day Adjusted Weight***	0.091
*US Ribeye Area EPD**	0.089
*Total Conformation Score**	0.076
Muscle Structure Score	0.058
US Percent Intramuscular Fat EPD	-0.038
US Back Fat	-0.030
Milk EPD	-0.030
US Rib Fat EPD	-0.024

Notes: *,**,*** indicate statistical significance at the 90, 95, and 99% level, respectively.

Discussion and Conclusions

Our results show that bull buyers base purchase decisions on a combination of genetic and phenotypic measures, focusing primarily on weight and growth indicators. Both genetic and phenotypic measures of birth weight were highly valued, reflecting that buyers place significant emphasis on birth weights. Birth weight EPD (*BirthEPD)* received a higher premium than actual birth weight (*BirthWT)*; this may indicate buyer acceptance of *BirthEPD* as a genetic measure of value in selection programs. Similar findings were reported by Jones et al. (2008). Furthermore, Irsik et al. (2008) and McDonald et al. (2010) found similar trends in phenotypic and genetic birth weight measures, reporting bulls with lighter birth weights and EPD's received premiums. Lighter birth weight bulls produce lighter calves, reducing dystocia and the need for

[6] This procedure removes the challenge of comparing variables with different units, but interpretation and validity of the standardized coefficients is sensitive to normality of the distributions of the independent variables.

calving intervention. While birth weight was important, the birth to yearling gain EPD (*BYGEPD)* topped our list of standardized coefficients (Table 4), indicating bull buyers were willing to pay a premium for bulls with high genetic potential for growth from birth to yearling. Similar findings were reported by Irsik et al. (2008) and McDonald et al. (2010).

Phenotypic ultrasound measures of carcass quality were more highly valued than genetic measures. Ultrasound measurements for ribeye area and marbling (*USAdjRibeye* and *USMarb)* followed only genetic and phenotypic measures of gain and birth weight in importance, but the ribeye area EPD (*USREAEPD)* was at the bottom of the statistically significant list of factors, and intramuscular and rib fat EPD's (*USPIMFEPD* and *USRibFatEPD)* were not statistically significant. The preference for phenotypic measures over genetic measures of carcass quality are likely explained by two factors: 1) carcass quality characteristics tend to be highly heritable, so selecting on the phenotypic characteristic of a bull is a simple and reliable indicator of herd impact, and 2) carcass quality EPD's are perceived to be less accurate and unreliable. A similar explanation for the latter was reported for yearling weight EPD by Jones et al. (2008). Buyers may have less confidence in EPD measures for yearling bulls because pedigree estimates used to produce the EPD's have relatively low reported accuracy or are reported as interim values.

A focus on growth and carcass characteristics that ignores feed efficiency may be detrimental to beef cattle production profitability. Feed inputs account for the largest share of beef production costs (Arthur et al., 2001; Herd et al., 2003), estimated to be 50% or higher (Kennedy et al., 1993). While there is evidence to support the significant role of feed inputs on production system profitability, past and current practices in livestock genetic selection to improve beef production have primarily focused on output traits (Herd et al., 2003) such as carcass characteristics.

Advances in feeding technology and data acquisition have allowed for improved phenotypic and genetic measures of feed efficiency. A newer measure that is getting more widespread attention is Residual Feed Intake. Residual feed intake (RFI; Koch et al., 1963), or net feed efficiency (NFI), is popular because of its reported favorable or negligible phenotypic and genetic relationships with feed intake, feed conversion ratio (FCR), and body weight (Arthur et al., 2001; Hoque et al., 2006; Tedeschi et al., 2006; Nkrumah et al., 2004). However, RFI is an expensive phenotype to measure. Bull test stations face decisions of whether or not to incur the necessary costs to provide RFI scores for bulls, and this decision will depend on buyer valuation of the trait.

Ours and previous (McDonald et al., 2010) estimates that buyers pay a premium for improvements in RFI are likely explained by RFI's potential to generate increases in profit for producers by increasing how efficiently animals convert feed energy into gain. A one point improvement (decrease) in RFI indicates that an animal eats one pound less feed per day than would be expected given its size and rate of gain. Our estimates suggest a 2% premium (about $60 at the mean), on average, for a one-point improvement in RFI. Crews et al. (2006) investigated the economic value of RFI at the feedlot, developing a multiple trait selection index, including bull residual feed intake, with the objective of improving the net feedlot revenue of progeny representing bulls with bull test data. The final selection index included bull residual feed intake (kg/day), bull average daily gain (kg), and bull yearling weight (kg); the economic weight of -10.12 for bull residual feed intake (RFI, kg) indicated an increase in net feedlot revenue per unit improvement in RFI. Crews et al.'s (2006) finding that bulls with favorable RFI generate higher net revenues due to reduced feed intake in the feedlot is consistent with our estimate that buyers pay a premium for improvements in RFI at auction.

In an attempt to address the increasing amount of information buyers sort through at a sale, and to differentiate their auctions, sale managers often provide phenotypic summary evaluations to buyers. Our results provide new evidence that buyers place less emphasis on seller provided summary scores than on phenotypic and genetic measures. *Total Conformation Score*, which summarizes the conformation of a bull relative to its cohort, ranked lowest on the list of statistically significant determinants of sale price, and *Muscle Structure Score* was not statistically significant. However, if summary scores influence bull buyers' or seedstock producers' choice of sale, they may be worth providing regardless of the premium they command at the sale.

Differences in age and breed were valued by buyers. As in Vanek et al., 2008 and McDonald et al., 2010, our results indicate that long yearlings (approx. 18 months) appear to be preferred by buyers. As suggested by Vanek et al. (2008), this result is likely a function of bull buyers having the expectation that an older bull has a greater breeding capacity compared to its younger counterpart due to physiological maturity; however, Irsik et al. (2008) reported that the premium received by seedstock producers for a long yearling bull may not offset the added expenses.

Our results show that bull breed is an important consideration for bull buyers. Unlike previous studies (Dhuyvetter et al. (1996); Irsik et al. (2008)) where Angus bulls received the largest premium, Hereford bulls received a premium over Angus in our study. This result may reflect supply and demand for Hereford bulls in the West. Angus offerings outnumbered Hereford 3:1 in an average year at the sale investigated.

Results of this study indicate that western cattle producers place primary importance on phenotypic and genetic indicators of growth and birth weight when making herd sire selections. Unlike previous studies estimating the impact of improvements in residual feed intake, this study included both phenotypic and genetic predictors of carcass quality, allowing comparisons of the relative importance of each to buyers. Results suggest that phenotypic ultrasound measures were preferred over genetic predictors of carcass quality in this study, providing incentive to bull sale managers to include this information in their catalogs. Feed efficient bulls (favorable RFI) received a premium, but it is undetermined how the premium is related to cost savings. Finally, our study provides new evidence that buyers place less emphasis on auction-provided conformation summary scores relative to other information when making purchase decisions; further research is required to determine whether the cost of generating summary scores is justified by their ability to attract buyers and sellers to one auction over another.

Literature Cited

Arthur, P. F., J. A. Archer, D. J. Johnston, R. M. Herd, E. C. Richardson, and P. F. Parnell. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. J. Anim. Sci. 79:2805-2811.

Beckkerman, A., G. W. Brester, and T. J. McDonal. 2013. A semiparametric approach to analyzing. J. Agr. and Appl. Econ. 45(1):79–94.

Chvosta, J., R. R. Rucker and M. J. Watts. 2001. Transaction costs and cattle marketing: The information content of seller-provided presale data at bull auctions. American J. Agr. Econ. 83(2):286-301.

Crews, D. H. , Jr., G. E Carstens, and P. A. Lancaster. 2006. Case study: A multiple trait selection index including feed efficiency. The Professional Animal Scientist. 22: 65-70.

Dhuyvetter, K. C., T. C. Schroeder, D. D. Simms, R. P. Bolze, J r. , an d J. Geske, 1996. Determinants of purebred beef bull price differentials. J. Agr. and Resour. Econ. 21:396-410.

Herd, R. M., J. A. Archer, and P. F. Arthur. 2003. Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci. 81:E9-E17.

Hoque, M. A., P. F. Arthur, K. Hiramoto, and T. Oikawa. 2006. Genetic relationship between different measures of feed efficiency and its component traits in Japanese Black (Wagyu) bulls. Livestock Science 99:111-118.

Irsik, M., A. House, M. Shuffitt, and J. Shearer. 2008. Factors affecting the sale price of bulls consigned to a graded sale. Bovine Practitioner 42(1):10-16.

Jones, R., T. Turner, K. C. Dhuyvetter, and T. L. Marsh, 2008. Estimating the economic value of specific characteristics associated with Angus bulls sold at auction. J. Agr. and Appl. Econ. 40(1):315–333.

Kennedy, B. W., J. H. J. van der Werf, and T. H. E. Meuwissen. 1993. Genetic and statistical properties of residual feed intake. J. Anim. Sci. 71:3239-3250.

Koch, R. M., L. A. Swiger, D. Chambers, and K. E. Gregory 1963. Efficiency of feed use in beef cattle. J. Anim. Sci. 22:486-494.

McDonald, T. J., G. W. Brester, A. Bekkerman, and J. A. Paterson. 2010. Case study: Searching for the ultimate cow: The economic value of residual feed intake at bull sales. Prof. Anim. Sci. 26:655-660.

Nkrumah, J. D., J. A. Basarab, M. A. Price, E. K. Okine, A. Ammoura, S. Guercio, C. Hansen, C. Li, B. Benkel, B. Murdoch, and S. S. Moore. 2004. Different measures of energetic efficiency and their phenotypic relationships with growth, feed intake, and ultrasound and carcass merit in hybrid cattle. J. Anim. Sci. 82:2451-2459.

Tedeschi, L. O., D. G. Fox, M. J. Baker, and D. P. Kirschten. 2006. Identifying differences in feed efficiency among group-fed cattle. J. Anim. Sci. 84:767-776.

Vanek, J., M. J. Watts, and G.W. Brester, 2008. Carcass quality and genetic selection in the beef industry. J. Agr. and Resource Econ. 33(3):349-363.

Wallburger, A. M. 2002. Estimating the implicit prices of beef cattle attributes: A case from Alberta. Can. J. Agr. Econ. 50:135.