SEARCHING FOR THE ULTIMATE COW: THE ECONOMIC

VALUE OF RFI AT BULL SALES

by

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ABSTRACT

Selecting cattle that consume less feed without production losses can increase the profitability of cow/calf producers by reducing input costs. However, genetic selection based on historical measures of feed efficiency or feed to gain ratios (F:G) is unable to improve this trait because of correlations between feed efficiencies and gain traits. Residual feed intake (RFI) is an alternative measure of feed efficiency that is independent of body weight (BW) and growth traits. RFI is the difference between an animal's actual feed intake and expected feed intake. For example, an animal that consumes 3 pounds less feed than expected would be assigned a RFI of -3 and is considered more feed efficient than those with larger RFI measures.

Seed stock producers sell bulls to cow/calf producers. Cow/calf producers select bulls that are perceived to have the greatest potential to improve the genetics of breeding cows and/or their offspring. Bull sales often provide sale catalogs to potential buyers that contain various performance measures including expected progeny differences (EPDs) and simple performance measures (SPMs). These measures provide information to purchasers so that rational decisions regarding genetic improvements can be made.

Midland Bull Test (MBT) in Columbus, MT conducts bull performance tests on 1,200 bulls annually for bull producers throughout the Unites States. In 2008 and 2009, MBT used a new technology (GrowSafe) to record individual feed intake which allows for the calculation of RFI. These measures, along with performance EPDs, provide the basis for a linear hedonic price model to determine if bull purchasers value RFI.

Regression results indicate buyers are willing to pay additional amounts for bulls that are RFI efficient. However, buyers appear to be valuing RFI below its theoretical contribution to cost reductions because of risk and uncertainty. Purchasers at the MBT bull sales valued gain traits, birth weight, and age more highly than RFI. If this behavior is consistent in other markets and buyers continue to value RFI, it would be reasonable to expect an RFI EPD to be developed in the future.

CHAPTER 1

INTRODUCTION

The cattle industry in the United States continues to develop new cost-reducing technologies. Early adopters of new technologies obtain competitive advantages in commodity markets. For example, new pharmaceutical technologies have improved the performance of feedlot cattle and increased the health and performance of cow herds. However, new technologies have uncertain payoffs and may fail.

The technology adoption literature explains different stages in the adoption process. Beale and Bolen (1955) were some of the first researchers to conclude that awareness of the technology is the critical first stage. Awareness is defined as the point where individuals learn the technology is available, but possess little knowledge about it. Kromm and White (1991) explained that media (radio, TV) has been the instrument that helps individuals become aware of new technologies. Carlson and Dillman (1986) reported that particular sources of information are important at different stages of adoption. Kromm and White (1991) also noted that personal experience and input provided by neighbors, consultants, and agriculture professionals are critical during the adoption process.

Most potential adopters of new technology use a number of informational sources, and the type of source used changes throughout the stages of adoption (Rollins, 1993). Additionally, Longo (1990) noted information is delivered in two main fashions; mass media and personal communication. The mass media is responsible for providing

the initial awareness of the new technology, while personal communication (face-to-face talk) and "how to" demonstrations seem to be responsible for the final adoption stage.

Examples of new technologies include sexed semen, which was specifically used by the dairy industry to increase the percentage of females born. This technology became commercially available in 2005, but has existed for the past 2 decades (Herbst et al. 2009). The authors concluded that sexed semen will have a positive effect on the profitability of Southern dairies even though a widespread industry adoption is lacking at this time.

Finally, precision farming technologies have been developed to adjust or prevent overlapping of input use. The technology has been available since the early 1990's. McBride and Daberkow (2003) reported that the private sector is the driving force behind precision farming adoption because of their comparative advantage in technical expertise.

<u>Statement of Problem</u>

Recently, cattle genetic selection has concentrated on growth and carcass trait attributes. This focus on output factors has led to a significant increase in mature cow and fed cattle weights (Table 1.1). Increased cattle weights have generated increased feed consumption per animal.

Table 1.1. Average live weight of fed steers, fed heifers, cows, and bulls.

	1975	2005	Difference	% change
Steers	1068	1297	+229	21.4
Heifers	869	1172	+303	34.9
Cows	1047	1350	+303	28.9
Bulls	1340	1769	+429	32.0

Several events have increased livestock feed prices. The Energy Policy Act of 2005 established a renewable fuels standard which required the use of 4 billion gallons of renewable fuel in 2006 and 12.5 billion gallons by 2012 (Yacobucci, 2007). Additionally, the Energy Independence and Security Act of 2007 focused on the continued development of biofuels by raising renewable fuel standards to 9 billion gallons by 2008 and 36 billion gallons by 2022 (Sissine, 2007). Renewable fuel production is generally based on corn ethanol, and this increased demand has raised the price of corn to historical highs (Figure 1.1). Because corn is a staple in the diets of feedlot cattle, these higher feed prices have made it more difficult to maintain profit margins.
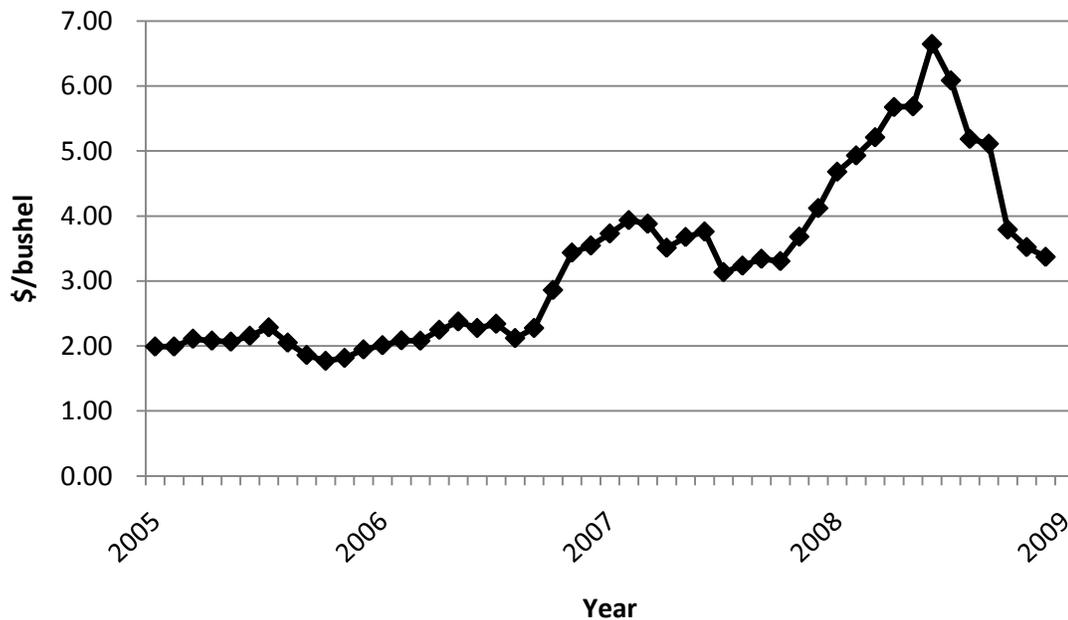
Figure 1.1. Corn prices for the United States, 2005-2008
Source: Livestock Marketing Information Center (2009)

Historically, as corn prices have increased, prices of other feeds such as hay and grazing leases have increased (Figure 1.2). Feed requirements to maintain mature cows represent 70-75% of cow/calf producers' total feed requirements. The remaining 25-30% is used for growth, gestation, and lactation (Ferrell and Jenkins, 1985). Feed costs account for 56-71% of total production costs for cow/calf producers (Basarab et al. 2007). Because this is the largest single expense of most commercial beef production operations, reducing feed usage while maintaining performance levels could substantially improve a ranch's profitability (Arthur et al. 2001). Additionally, feedlots could also benefit from lower cost of gains (cost of feed per one pound of gain).
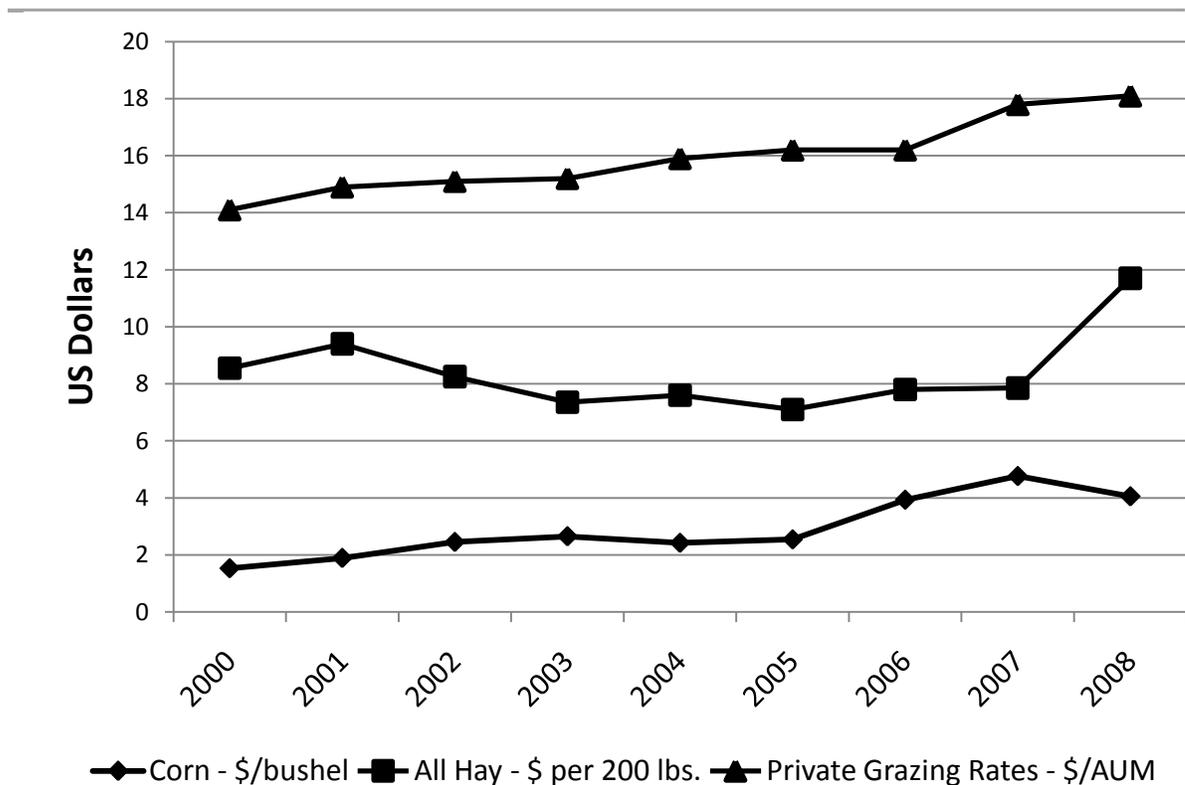
Figure 1.2. Montana corn, hay, and grazing lease prices (2000-2008).
Source: National Agricultural Statistics Service (2010)

Feed efficiency (FE), feed conversion ratio (FCR), and feed/gain ratio (F:G) are each defined as the amount of feed required by an animal to gain one pound of weight. In feedlot cattle on high concentrate grain diets (> 80% concentrate), F:G ratios average 6.5. F:G ratios have improved over time through the use of feed additives (ionophores) such as monensin and tylosin which restrict feedlot cattle intakes of high-grain diets thereby allowing cattle to grow at similar rates to cattle fed roughage-based diets (Loerch, 1990; Sip and Pritchard, 1991). By restricting intakes, feed additives can prevent feed-related metabolic disorders such as acidosis, founder, and bloat which are caused by an overconsumption of the high-grain diet (Montgomery et al. 2003). However, further improvements in F:G ratios have been hampered by the expense of obtaining feed efficiency measures for single animals. Additionally, genetic selection for F:G traits have not been pursued because F:G is embodied in growth traits. Therefore, a selection for improved F:G ratios indirectly selects for faster gaining, larger animals (Archer et al. 1999; Crews 2005).

Beginning in 1990, a Canadian company (GrowSafe®) started developing systems using radio frequency identification (RFID) to monitor and record individual animal feed intakes. The system uses wireless readers on feed bunks. By allowing only one animal to eat at a time, the technology identifies an animal when it places its head in a feed bunk and simultaneously records the initial weight of feed in the bunk. When an animal removes its head from the bunk, the ending bunk feed weight is recorded thereby allowing for measures of individual feed intakes (GrowSafe, 2009).

Research has shown there is considerable difference in feed intakes within breeds regardless of size or growth rate (Herd et al. 2003). First proposed by Koch et al. (1963), residual feed intake (RFI) is an alternative measure of feed efficiency and is independent of growth traits. RFI is calculated as the difference between an animal's actual feed intake and its *expected* feed intake necessary to meet requirements for maintenance plus growth or production based on body size and average daily gain (ADG).

Actual feed intake is recorded by the GrowSafe system whereas expected feed intake is calculated from structured regression analyses. Expected feed intake could be calculated from the National Research Council (NRC) which is the authority on nutrient requirements of livestock in the United States. However, nutrient requirements are based on many factors including body weight (BW) and ADG (NRC, 1996). Therefore, the correlation of RFI to ADG and BW is not zero. By using regression analyses, RFI is forced to be independent of ADG and BW (i.e., the correlation on a phenotypic basis is zero).

The calculation of RFI is performed with the following steps:

A.   Initial BW and ADG are predicted from a series of actual body weight measurements recorded every 2 weeks during a total test period of 70 days (Archer et al. 1997).

   1) **Regression model:** BW = f (animalID, day*animalID) (no intercept is used). The coefficient on animalID represents the predicted initial BW, and the coefficient on day*animalID represents the predicted ADG.

B.   Metabolic body weight (MBW) is then computed by the following: (1) predicted initial BW is multiplied by the predicted ADG and number of days on feed to estimate an ending weight; (2) a mid-test weight (MTW) is calculated as the average of the predicted initial and ending weight; and (3) MBW is calculated as the MTW to the three-quarter power.

1) **Model:** Predicted end weight = predicted BW * predicted ADG * days on feed

2) **Model:** MTW = AVG (predicted initial BW + predicted end BW)

3) **Model:** MBW = $MTW^{0.75}$

C.   RFI is then calculated by a phenotypic regression of actual intake or dry matter intake (DMI) on MBW and predicted ADG (Crews et al. 2006).

1) **Regression model:** DMI = f (MBW, predicted ADG) (no intercept is used). The output is given by 3 columns; the observed DMI, the predicted DMI, and the residual (difference between observed DMI and predicted DMI). The residual is the RFI.

Therefore, RFI is a measure of the variation in feed intake beyond that which is needed to meet maintenance and a specified growth rate (Archer et al. 1999).

Actual MBW and ADG are not used in the final regression because of gut fill problems with weighing cattle on feed. For example, just prior to a weight measurement, one animal could have consumed a large amount of water or feed which causes BW errors. Predicting BW and ADG through regression minimizes BW measurement error.

RFI can only be computed for cohorts of animals (tested simultaneously) which remove differences caused by weather and environmental conditions. Additionally, RFI

is computed within breeds of a contemporary group provided sufficient numbers of animals can be tested. Computing RFI for small numbers of animals (groups less than 40) within a breed can present flawed values.

MBW is used to predict RFI because it is a more accurate estimate of feed consumption by an animal, and is proportional to maintenance feed intake. MBW is a measure of BW but also describes the surface area of the animal. Therefore, an animal weighing 1,400 pounds has a greater nutrient requirement than an animal weighing 1,000 pounds. For example, if both animals consume a similar feed resource, the 1,400 pound animal will need to consume more feed to meet its nutrient requirement. However, an animal that is 10% heavier does not consume 10% more feed. Research shows that for a 10% increase in BW, feed intake will increase by only 7% (Rasby, 2009). Therefore, MBW is used so that the metabolic rate per unit of body size is consistent for all animals.

A positive RFI indicates an animal is consuming more feed than expected and is, therefore, not feed efficient. A negative RFI indicates an animal is consuming less feed than expected and is, therefore, feed efficient. A zero RFI indicates an animal is consuming the amount of feed that is expected. Heritability estimates for RFI indicate a range from 0.16-0.43 which represents a moderately heritable trait (Herd et al. 2003). Carcass traits such as rib-eye area (0.70) and intramuscular fat (0.50) are considered highly heritable traits (Massey et al. 1993). Selecting for lower RFI cattle has the potential to decrease feed intake in cows and fed cattle without compromising mature cow size, cow performance, or feedlot growth performance.

Improvements in feed efficiency can have a considerable economic impact. Suppose a feeder calf enters a feedlot weighing 700 pounds and will be harvested at 1,300 pounds in six months. The 600 pounds of gain represent 3.33 pounds of gain/day. Given a 6.5 F:G ratio, the calf must consume 21.6 pounds of feed/day or 3,888 lbs. of feed during the 6 month feed period. Assuming feed costs $0.25/lb., feed expenditures will total $972. However, a 5% improvement in feed efficiency reduces the F:G ratio to 6.18. This lowers feed consumption to 20.6 pounds of feed/day or 3,708 lbs. of feed during the 6 month feed period. This reduces feed costs to $927 and reduces feedlot breakeven prices by $3.50/cwt.

Feed savings in terms of hay and grazing may also be realized by selecting more efficient cows. In 2009, private grazing rates for non-irrigated land in Montana were $18.00 per animal unit month (AUM) (Chard and Anderson, 2010). An AUM is defined as the amount of forage needed by an animal unit (AU) grazing for one month. An AU is defined as a 1,000 pound cow and her calf eating an average of 26 pounds of dry matter per day (Ruyle and Ogden, 1993). In 2009, a 1,000 pound cow and her calf grazing for 12 months represent a total graze cost of $216. A 5% improvement in feed efficiency would reduce this cost by $10.80/cow.

The majority of genetic improvements in the cattle industry occur through bull selection. Bulls are valued for their expected value in production (Dhuyvetter et al. 1996). To help producers evaluate bulls, expected progeny differences (EPDs) have been developed. EPDs are quantitative predictions of a bull's heritable traits that are passed to offspring. They are based on heritable traits and expressed to buyers relative to breed

averages. For example, a bull with a yearling weight EPD of 40 will be expected to sire calves 40 pounds heavier at 365 days of age than the average bull of that breed. EPDs are calculated using the physical characteristics of a young bull and its relatives prior to a bull reaching breeding maturity. Therefore, EPDs are simply an estimate of the characteristics of a bull's progeny (Vanek et al. 2008).

In most sale catalogs at larger bull sales, EPDs are available to help buyers make informed decisions. Midland Bull Test (MBT) in Columbus, MT annually tests approximately 1,200 bulls for hundreds of bull producers and obtains EPD performance traits. In addition, efficiency traits such as RFI have been measured since 2008[1]. Although EPD's for RFI have not been developed, RFI numbers are presented to buyers at MBT's annual bull sale.

The RFI concept is relatively new, and the continued development of RFI depends heavily on whether bull purchasers value and understand this measure. If bull purchasers place value on RFI, then bulls with a more negative RFI should sell for a higher price after controlling for other factors.

Research Methods:

This study estimates a hedonic price model using Spring 2008 and Spring 2009 bull test data from MBT to determine if bull purchasers value RFI characteristics, and if so, the relative importance of RFI with respect to other bull characteristics.

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[1] In 2008, MBT did not have the capacity to RFI test all bulls. However, in 2009 all bulls were RFI tested.

CHAPTER 2

LITERATURE REVIEW - RFI

RFI has only recently garnered attention of the beef industry because of desires to improve animal feed efficiencies. However, the concept has been around for almost half a century. One of the first to note differences in feed intake and utilization was Koch et al. (1963) who suggested that feed intake could be divided between expected intake for a given level of production and a residual that is the difference between actual and expected intake. This residual could be used to identify animals with low (negative) RFI or animals with high (positive) RFI. Figure 2.1 shows two feeder steers with similar initial weights, ADG, and expected feed intakes. However, a visual observer cannot identify that the steer on the right consumed less feed than expected and is considered RFI efficient.

Performance data during a 77-day growing trial

538 lb	Initial body weight	535 lb
2.11 lb/day	ADG	2.16 lb/d
1502 lb	Expected feed intake	1509 lb
1717 lb	Actual feed intake	1232 lb
+215 lb	Residual feed intake	-277 lb

Figure 2.1. Two similar steers cannot be selected for RFI based on visual observation.

Although variations in feed intakes have been observed within and across cattle breeds, the biological reasons underlying these observations are largely unknown. Weather, feeding behavior and activity, body composition, rate of gain, digestion of feed, BW, prolificacy, protein turnover, overall tissue metabolism, and other factors are believed to influence variations in feed intake (Johnson et al., 2003; Richardson and Herd, 2004).

Research indicates that methane production, measures of metabolic rates, and dietary energy partitioning differ between low and high RFI cattle. Nkrumah et al. (2006) reported methane production was 28% and 24% less in low RFI cattle compared to high and medium RFI cattle. This suggests that lower feed consumption contributes to slower passage through digestive tracts and reduces manure production.

Limited research exists regarding the effects of RFI on dam productivity traits such as postpartum interval (number of days after parturition until the female begins reproductive cycling), percent breed back (percent of females bred for the next calving season), milk yield, and other traits. Basarab et al. (2007) found cows with low RFI (more efficient) progeny possessed greater body fat, fewer twinning rates, less calf loss, and equivalent calf weaning, pregnancy, and calving rates compared to cows producing less feed efficient progeny. However, RFI efficient cows calved 5-6 days later suggesting reproductive cycling may be delayed.

While RFI has the potential to benefit the cattle industry, genetic selection strictly on the basis of RFI could be counterproductive. The majority of genetic progression in cattle production occurs through the use of bulls or bull semen. Bulls are selected for a mix of performance, efficiency, and other traits to maximize profitability. Therefore, identifying correlations between RFI and other economic traits such as F:G ratios, feed intake, subcutaneous fat (measure of lean carcasses), and other carcass traits could be valuable to cattle producers. Baker et al. (2006) studied the effects of RFI on meat quality and palatability and found no differences between high and low RFI animals. Minimal correlations between RFI and body composition traits have allowed researchers to develop multi-trait economic indexes to aid producers in selection of feed efficient genetics. The ultimate goal of RFI research is to use DNA or other predictive markers to identify genes that carry this feed efficiency trait (Moore et al., 2008). Additionally, insulin-like growth factor-I (IGF-I), a hormone regulating growth and cellular metabolism, has been shown by Bishop et al. (1989) and Stick et al. (1998) to be

associated with improved feed efficiency. However, IGF-I is related to growth traits which decreases its effectiveness in selecting low RFI cattle (Moore et al. 2005).

Research has shown that RFI measures based on phenotypic regression is not genetically independent of ADG and BW. This makes interpretation of selection responses to RFI difficult. Also, it is argued that RFI adds no new genetic information because RFI and production traits are correlated to feed intake and production traits (Kennedy et al. 1993).

Additionally, research has shown that low RFI may be associated with a 5% decrease in intramuscular fat. Lower levels of intramuscular fat reduce carcass quality and consumer eating experiences. Further research will be required to verify these results (Basarab, 2005). Other researchers are concerned that simply selecting for RFI as a single trait might force other favorable traits in undesirable directions. Also, there is limited RFI data because of measurement costs, and existing data may be prone to selection bias because of ranch commitments needed for experimental research.

EPDs and Hedonic Models

Bull EPD's have been used for many years in the beef cattle industry to facilitate genetic selection. At bull sales, buyers have access to sales catalogs with two different types of biological performance measures: simple performance measures (SPMs) and expected progeny differences (EPDs). These performance measures reduce information costs and help buyers make more informed decisions. SPMs are actual performance measures of a bull which include birth weight, weaning weight, yearling weight, scrotal

circumference, and ultrasound measures of back fat and rib-eye area. EPDs combine information from SPMs as well as similar measures from a bull's relatives as predictors of the future performance of a bull's progeny. EPDs are estimated from linear statistical models which allow for within-breed animal comparisons (Chvosta et al. 2001).

An emphasis is placed on bull genetics because they represent 50% of the genetics of a calf crop and 90% of the genetic change in cowherds for producers who retain replacement heifers (Wagner et al. 1985). The value of a bull is determined by the length of time a bull is to be used and measured physical traits such as temperament, fertility, structural soundness, age, BW, number of offspring, and EPD performance traits. Most producers consider the purchase of a bull a long-term investment and plan to continue to use the bull based on physical soundness. Therefore, producers must be well-informed when making bull purchases (Dhuyvetter et al. 1996).

Historically, bulls were selected using visual appraisals which included structural soundness, appearance, conformation, breed, temperament, price, and reputation of the breeder (Dhuyvetter et al. 1996). Studies have examined other factors that might affect bull prices. Bull prices have been found to respond to calf price and cowherd inventory (Greer and Urick, 1988), calf weaning weight, ADG, and calving ease (Kerr, 1984), and performance characteristics, yearling weight ratio, frame score, and sale promotion programs (Commer et al. 1990). Dhuyvetter et al. (1996) found positive correlations among bull price and weaning weight and milk production EPDs and a negative correlation for birth weight EPD. Jones et al. (2008) reported that buyers placed higher value on birth weight EPD's than on actual birth weight numbers for purebred Angus

bulls. They also found buyers valued bull pedigrees, the reputations of bull producers, and bull carcass ultrasound measurements.

Vanek et al. (2008) used a hedonic model to determine the influence of EPDs on Angus and Red Angus bull prices. They found buyers are willing to pay more for bulls exhibiting superior carcass quality traits such as rib-eye area (REA). Chvosta et al. (2001) also used a hedonic model and found buyers value SPMs such as actual birth weight and weaning weight in addition to EPDs. However, when comparing animals within a herd, the explanatory power was greater for SPMs than EPDs. Conversely, the explanatory power was greater for EPDs than SPMs when comparing animals across herds. This suggests that buyers find EPDs more useful than SPMs when making comparisons of animals between herds.

Faminow and Gum (1986) evaluated short-run price differentials for feeder cattle sold at Arizona auctions using nonlinear lot size and weight variables. Because the supply of cattle at an auction is fixed, they argued that prices are determined by individual cattle characteristics; specifically weight, lot size, sex, breed, auction location, and sex-weight interactions. Similarly, Schroeder et al. (1988) considered feeder cattle price differentials at Kansas auction markets and found prices are influenced by individual cattle characteristics as well as conformation and health characteristics. Additionally, Schroeder et al. (1988) found the sale order of feeder cattle had a positive correlation with price as sales progressed. In the second and third quarters of a sale, cattle received $1 to $2 per hundredweight premiums compared to the first quarter. They concluded this was caused by increased numbers of buyers who were present later in the

sale. In contrast, Vanek at al. (2008) found lower sale prices for bulls sold later at auctions. This result, however, is a product of bull sellers selecting the order of bull sales based on expected bull quality.

Hedonic pricing models have been used to determine the value of individual thoroughbred horse characteristics in Kentucky. Vickner and Koch (2001) considered a hedonic hammer price (final auction selling price) model for thoroughbred yearlings. The data included horses that did not sell because they failed to meet reservation prices set by consignors. Three variables were statistically significant in explaining hammer price at auctions: date of sale, influence of same-sired progeny, and buyer visits to an on-site repository for health records.

CHAPTER 3

MODEL AND EMPIRICAL APPROACH

This study uses a hedonic price model to estimate the implicit value of RFI and

other bull characteristics on bull sale prices. Ordinary least squares (OLS) methods are

used to estimate the model. The hedonic model used in this analysis is similar to the

models of Becker (1965), Lancaster (1966), Rosen (1974), Ladd and Martin (1976), and

Palmquist (1989).

The hedonic model specifically follows that of Ladd and Martin (1976) and

Dhuyvetter (1996). The model is shown as:

(1) $$p_i = \sum_j T_j \, x_{ji}$$

where p_i is the sale price of the bull, T_j is the marginal implicit price paid for the jth

characteristic, and x_{ji} is the quantity of the characteristic j that bull i possesses.

Therefore, the estimated model is:

(2)   PPRICE = α + β_1 * RFI + β_2 * AGE + β_3 * BWEPD + β_4 * BYGEPD + β_5 *
      REAEPD + β_6 * IMFEPD + β_7* YEAR08 + ε

PPRICE is the sale price of a bull. RFI refers to residual feed intake and is

measured in pounds per day. AGE refers to the age of a bull in days at the time of sale.

BWEPD (birth weight EPD) and BYGEPD (birth to yearling gain EPD) are both

measured in pounds. REAEPD (rib-eye area) is measured in square inches and IMFEPD

(intramuscular fat; marbling) is measured as the percentage of fat throughout the muscle.

Finally, a year dummy variable (YEAR08) is used to distinguish bulls sold in 2008 and

2009. Alpha (α) is the intercept term, epsilon (ε) is the regression error, and β_i's are the estimated implicit values for each bull characteristic.

<div align="center">Interpretation</div>

The partial derivatives of each bull characteristic represent the marginal implicit value of each characteristic. For example, the partial derivative of PPRICE with respect to RFI yields:

(3) $$\frac{\partial \; PPRICE}{\partial \; RFI} = \beta_1$$

The parameter estimate denotes the marginal value of RFI to the purchasers of bulls.

Collinear Bull Traits:

By construction, BWEPD, WWEPD (weaning weight EPD), and YWEPD (yearling weight EPD) are collinear because the birth weight of an animal plus its 205 day gain (weaning age) equals weaning weight. Additionally, birth weight plus 365 days of gain (yearling age) equals yearling weight. This collinearity is a violation of classical linear regression assumptions. Collinearity causes higher standard errors (inefficiency) and decreased t-values. Ultimately, one is likely to reject the significance of a variable that does, in fact, impact bull sale prices. To address this problem, a birth to yearling gain EPD (BYGEPD) was calculated by subtracting the BWEPD from the YWEPD. This is used as an independent variable in place of WWEPD and YWEPD in the regression analysis.

Heteroskedasticity:

Heteroskedasticity also violates classical linear regression assumptions. The problem is often present in cross-sectional data and is reflected by unequal variances of error terms. Although heteroskedasticity does not bias coefficient estimates, it influences standard errors in the following two ways: (1) rejecting the significance of a variable that impacts the sale price of a bull, or (2) failing to reject the significance of a variable that has no impact on the sale price of a bull. Heteroskedasticity will be tested using the Breusch-Pagan test.

CHAPTER 4

DESCRIPTION OF DATA

Data were collected from Midland Bull Test (MBT) in Columbus, MT from their Spring 2008 and Spring 2009 tests. MBT is the largest RFI bull test facility in North America and uses the GrowSafe technology. MBT has the capacity to simultaneously test 1,200 bulls making it a premier facility for purebred (seed stock) breeders from across the United States. MBT conducts an efficiency test (RFI and F:G ratio), a performance test (ADG), an ultrasound test for rib-eye area, intramuscular fat (marbling), and back fat, and a semen test for fertility. At the conclusion of the bull testing (the beginning of April), MBT reports bull test results in sale catalogs and facilitates a large bull sale.

Most test data were published in sale catalogs and available to prospective buyers at both bull sales. In 2008, the RFI variable and ultrasound measurements were available to buyers as supplements to the sale catalog. Prices paid for each bull were obtained from MBT and used as the dependent variable in equation (2). Initially, 2,303 bulls from 11 different breeds (Angus, Red Angus, South Devon, Salers, Charolais, Gelbvieh, Simmental, Murray Grey, Maine Anjou, Pinzgauer, and Braunvieh) were considered for the analysis. However, MBT does not sell bulls in the sale from the bottom 30% of combined testing.

A number of bulls offered in the sale did not sell or did not meet consignors' reservation prices. Additionally, some bulls were missing key variables of interest (i.e. RFI, BWEPD). In both cases, bulls were deleted from the analysis. Furthermore, bulls

with a PPRICE greater than $20,000 were removed from the analysis. Most likely, these bulls were purchased by other purebred breeders and not commercial cow/calf operations.

Finally, adequate numbers of Black and Red Angus bull transactions for the regression analyses were available for both years. Data for several other breeds either included only a few observations, or were not available for both years. Hence, the empirical model focuses only on Black and Red Angus bull transactions. This left 924 useable observations.

Description of Variables

MBT provides sale catalogs to prospective buyers with information on bulls from multiple breeds. Purchase price (PPRICE) of the bull in dollars is the dependent variable for this analysis and is determined by open out-cry auction. The main independent variable of interest is RFI which is measured in pounds per day. Higher RFI indicates increased feed intake and should lower bull value.

Birth weight EPD (BWEPD) is a prediction of the birth weight of a bull's progeny. Typically, heavier birth weight calves are associated with birth delivery problems that may require ranch hand intervention, mechanical assistance, or the services of a veterinarian. Assisted deliveries present risk of structural damage or mortality to the calf or cow. In addition, veterinary services decrease a producer's profitability. The sign on BWEPD (measured in pounds) is expected to be negatively correlated with the purchase price of a bull.

The birth weight, weaning weight, and yearling weight EPDs are collinear by construction. Therefore, a birth to yearling gain EPD (BYGEPD) was created by subtracting BWEPD from YWEPD (Vanek et al., 2008). This measure predicts the gain in pounds from birth to yearling age. Because most commercial producers sell calves by the pound, heavier calves generally increase profits. Therefore, BYGEPD is expected to have a positive effect on PPRICE.

Historically, buyers value bull carcass characteristics because beef processors strive to meet consumer demands for quality (i.e. rib-eye area, intramuscular fat). Rib-eye area (REAEPD) is measured in square inches. A greater rib-eye area is associated with higher carcass value. REAEPD should be positively correlated to purchase price. Additionally, intramuscular fat EPD (IMFEPD), also referred to as marbling, is measured as the percentage of fat throughout the muscle. Because increased marbling is associated with higher quality eating experiences, the sign on IMFEPD is expected to be positive.

MBT bulls are considered yearling age. However, variations in birth dates exist. Therefore, AGE (measured in days) was used as an independent variable. The sign is expected to be positive because bulls with greater maturity are expected to have a higher breeding capacity than younger bulls.

MBT sells their highest quality bulls early in each sale. MBT generates an index (MBTINDEX) to rank bulls and organize the order of sale. A series of ratios are used to calculate MBTINDEX. Ratios with a score of 100 indicate an average ranking. Average daily gain ratio (ADGRATIO) compares the ADG of all bulls. A bull with a score of 89 indicates a below average ADG. Yearling ratio (YR) is an index of the adjusted 365 day

weights, RFI ratio (RFIRATIO) (only 2009 bulls) compares all RFI values, and nursing

ratio (NR) is an indication of the dam's maternal performance and the bull's pre-weaning

growth. MBTINDEX was calculated differently in each year. In 2008, the index was

calculated as (¼ * NR + ¼ * YR + ½ * ADGRATIO). In 2009, the index was calculated

as (¼ * NR + ¼ * ADGRATIO + ¼ * YR + ¼ * RFIRATIO). The MBTINDEX (i.e. the

sale order) will not be used in the final regression specification due to collinearity with

other independent variables. This collinearity will be discussed in more detail in Chapter

5.

Finally, a year dummy variable (YEAR08) was used to distinguish any

differences specific to the 2008 and 2009 sale years. Table 4.1 gives a summary of the

variables and their expected sign.

Table 4.1. Description of variables and expected sign.

Variable	Name	Abbreviation Description	Expected Sign
Price	PPRICE	Sale price of bull ($)	N/A
Residual feed intake	RFI	Efficiency (lbs./day)	-
Age	AGE	Age of bull in days	+
Birth weight EPD	BWEPD	EPD (lbs.)	-
Birth to yearling gain EPD	BYGEPD	EPD (lbs.)	+
Carcass rib-eye area EPD	REAEPD	EPD (square inches)	+
Intramuscular fat EPD	IMFEPD	EPD (marbling ,%)	+
Year dummy 2008	YEAR08	2008 dummy variable	N/A

Summary Statistics:

Table 4.2 lists descriptive statistics for Black and Red Angus bulls. The average

purchase price of a bull was $2,897 with a standard deviation of $1,886. The RFI range

was -10.74 to 7.12 pounds per day. Therefore, one bull consumed 10.74 pounds less than

expected while another was eating 7.12 pounds more than expected.

Table 4.2. Summary Statistics for Midland Bull Test Data (Spring 2008 and 2009; only
Black and Red Angus breeds)

Variable	Obs.	Mean	Std. Dev.	Min	Max
PPRICE	924	2896.54	1886.31	1000	19000
RFI	924	-0.05	1.81	-10.74	7.12
AGE	924	429.44	23.10	351	482
BWEPD	924	1.75	1.64	-6.7	6.2
BYGEPD	924	81.81	15.65	34.4	122.1
REAEPD	924	0.19	0.19	-0.32	0.93
IMFEPD	924	0.18	0.18	-0.21	0.95
YEAR08	924	0.45	0.50	0	1

Bulls ranged from 351 to 482 days of age with a standard deviation of 23.1 days.

The BWEPD shows bulls sold at MBT are expected to produce offspring that are 1.75

pounds heavier at birth than the average bull of that breed.

BYGEPD indicates, on average, that these bulls' progeny are expected to produce

81.8 more pounds of gain between birth and yearling age than the average bull of that

breed.

As a measure of carcass performance, the mean of rib-eye area EPD (REAEPD),

and intramuscular fat EPD (IMFEPD) were 0.19 (standard deviation = 0.19) and 0.18

(standard deviation = 0.18), respectively.

CHAPTER 5

EMPIRICAL RESULTS

Data from the MBT 2008 and 2009 bull sales were used to estimate a linear

hedonic model. Sufficient numbers of Black and Red Angus bulls were used for the

analyses.

The final model specification is represented by:

2) $\text{PPRICE} = \alpha + \beta_1 * \text{RFI} + \beta_2 * \text{AGE} + \beta_3 * \text{BWEPD} + \beta_4 * \text{BYGEPD} + \beta_5 * \text{REAEPD} + \beta_6 * \text{IMFEPD} + \beta_7 * \text{YEAR08} + \varepsilon$

Four bulls with selling prices exceeding \$20,000 were excluded from the analysis. These

bulls were clearly outliers and were likely purchased by other seed stock producers rather

than by commercial livestock producers.

The order in which bulls are offered for sale is frequently included as an

explanatory variable when explaining seed stock sales (Vanek et al. 2008). The primary

reason is that many seed stock producers offer bulls that are expected to garner the

highest prices early in auction sales. However, MBT uses a formula to calculate an index

(MBTINDEX) as described in Chapter 4 for determining sale order. Bulls receiving the

highest MBTINDEX score were sold first in each year. However, because RFI

(RFIRATIO) was used to calculate the MBTINDEX in 2009, these two variables were

highly collinear. Therefore, sale order was excluded from the final specification.

Red Angus bulls traditionally sell for lower prices than Black Angus bulls when

both are offered in common sales. However, a binary variable for Red Angus bulls was

not significantly different from zero in initial regression specifications. Hence, the binary variable was excluded from the final model.

Additionally, heteroskedasticity was tested using the Breusch-Pagan LM statistic. The *P* value was less than 0.01 which rejects the null hypothesis of homoskedasticity. To correct for heteroskedasticity, all regressions were estimated with Breusch-Pagan robust standard errors.

Table 5.1 summarizes the results of the final OLS regression specification. The parameter estimates are interpreted as the marginal value of each specified bull characteristic on bull sale prices. All parameter estimates have the expected sign, and except IMFEPD, are each statistically significant at the $P < 0.01$ level.

Table 5.1 Empirical results of Hedonic model linear regressions

Variable	Final Regression Coefficient (t-value)	Standardized Regression Coefficient (t-value)
RFI	-124.43 (-4.53) **	-0.114 (-4.17)**
AGE	12.21 (5.81) **	0.150 (5.82)**
BWEPD	-227.66 (-5.73) **	-0.198 (-5.65)**
BYGEPD	35.99 (6.53) **	0.291 (6.65)**
REAEPD	1069.73 (3.70) **	0.103 (3.45)**
IMFEPD	215.69 (0.50)	0.031 (0.81)
YEAR08	474.60 (3.73)**	0.061 (0.01)
Constant	-5347.87 (-5.63)**	0.040 (0.00)
Observations	924	924
R-squared	0.16	0.16
** Significant at 1%		

Bull purchasers pay approximately $124 more for each one pound per day improvement (decrease) in RFI. To determine the relative size of this premium, assume a bull possesses a RFI of -1 and services 30 cows per breeding season. Given that RFI heritability is approximately 0.4, 40% of a bull's progeny are expected to possess a one pound per day increase in feed efficiency. Therefore, 12 calves will each consume 365 fewer pounds of feed annually. If feed costs average $0.25/lb., a savings of $91.25 per

calf or $1,095 for 12 calves is realized. Considering the bull could have a useful life of up to 6 years, savings would equal $6,570 on a nominal basis. Furthermore, collecting or buying semen from this bull could accelerate the RFI genetic makeup of the next calf crop, thus increasing the realized cost savings. However, it is important to recognize that calculated feed savings represent maximum reductions. Because of risk and uncertainty associated with new technologies, producers are likely to discount the maximum calculated feed savings. Nonetheless, bull purchasers are willing to pay a premium for the RFI trait.

The maturity of a bull is also valued by bull purchasers. The coefficient estimate for AGE is 12.21. Therefore, buyers are willing to pay $12 more for each additional day of a bull's age. This result indicates that buyers value more mature bulls and is consistent with Vanek et al. (2008) who reported a coefficient estimate for a specific bull sale of 13.33. Additionally, that sale includes bulls sold in late March to early April which is similar to the MBT sale date. Furthermore, the mean price of bulls sold at that sale is similar to those sold at the MBT sale.

Buyers at the MBT sales pay an additional $228 for a one pound decrease in BWEPD. As expected, buyers pay premiums for bulls that deliver lower birth weights holding all other factors constant. Lower birth weights reduce labor costs and calf mortality. Vanek at al. (2008) reported similar coefficient estimates for two specific and separate bull sales (-183 and -287, respectively).

The parameter estimate for BYGEPD is 35.99. Buyers pay approximately $563 more for bulls that have a one standard deviation improvement in birth to yearling gain.

This result shows buyers prefer bulls with higher weight gain potential. These results are relatively consistent with coefficient estimates of 16.18 and 56.03 for bull sales with similar mean prices as those experiences at MBT (Vanek et al. 2008). A one standard deviation improvement in BYGEPD increased PPRICE by $228 and $545, respectively.

Carcass trait parameter estimates must be evaluated carefully because of the scale of EPDs. In this analysis, a one unit increase in rib-eye area and intramuscular fat EPDs represent five to six standard deviation changes. For example, bull purchasers are willing to pay $1,070 for a one square inch increase in REAEPD. However, this translates into an additional $202 for a one standard deviation increase in rib-eye area.

Conversely, IMFEPD is not statistically different from zero. However, collinearity between IMFEPD and the independent variables may be causing this result. Therefore, IMFEPD was regressed on the independent variables to determine if collinearity was a major problem. Although many of the independent variables were significant, the low R-squared value of 0.25 indicates that collinearity was not the major cause of the lack of statistical significance of IMFEPD

Vanek et al. (2008) found that both REAEPD and IMFEPD were significant at one of four bull sales, but only REAEPD was significant at a second sale. Buyers paid $364 for a one standard deviation improvement in REAEPD at one sale and $375 at another.

Finally, the YEAR08 dummy variable was used to control for unobservable factors in the cattle industry such as feed prices, differences in cattle prices, fuel prices,

and other market factors between the two years. The estimate shows bulls offered in

2008 sold for $475 more than in 2009.

Figure 5.1 illustrates a scatter plot of the forecasted PPRICE using actual RFI

numbers and regression results. The prediction equation is described as:

$$\widehat{PPRICE}_i = \alpha_o + \hat{\beta}_1*RFI_i + \hat{\beta}_2*\overline{AGE} + \hat{\beta}_3*(\overline{BWEPD}) + \hat{\beta}_4*(\overline{BYGEPD}) +$$

(4)

$$\hat{\beta}_5*(\overline{REAEPD}) + \hat{\beta}_6*(\overline{IMFEPD}) + \hat{\beta}_7*(\overline{YEAR08})$$

where $\hat{\beta}_1$ to $\hat{\beta}_7$ are the predicted coefficient estimates from the final regression, RFI_i is the

actual RFI value for each bull, and $(\overline{AGE})$, $(\overline{BWEPD})$, $(\overline{BYGEPD})$, $(\overline{REAEPD})$, $(\overline{IMFEPD})$,

and $(\overline{YEAR08})$ are the means of the other independent variables. As the actual RFI value

of the bull improves (more negative), the predicted PPRICE increases.
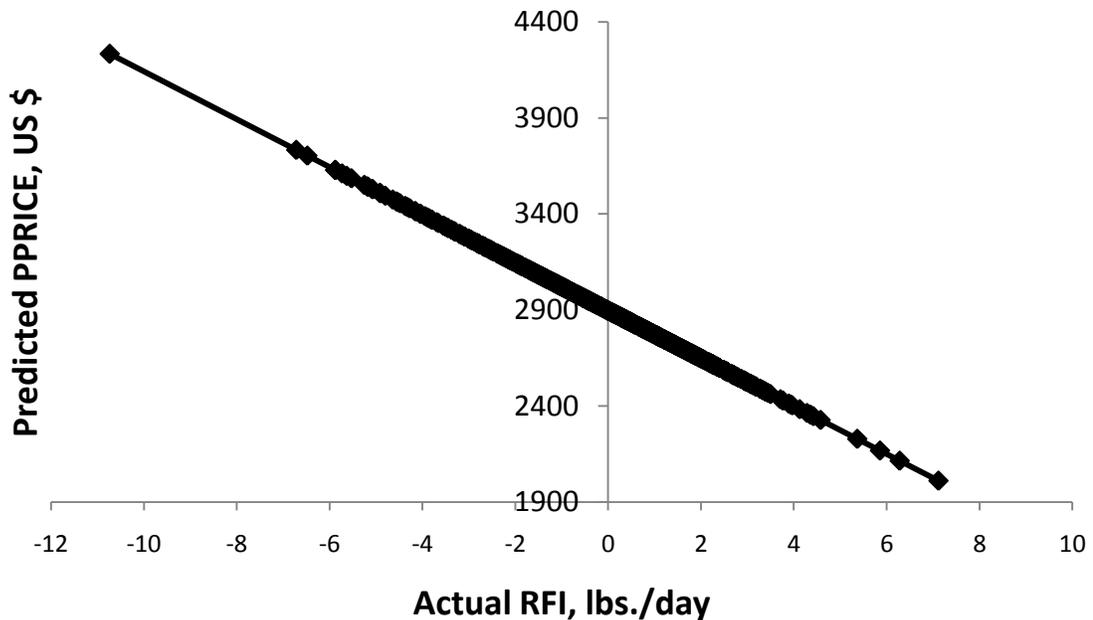

Figure 5.1. Predicted PPRICE from final regression using actual RFI values and holding
all other factors at their means.

The R^2 value of 0.16 indicates a relatively low fit for the final regression

specification. Vanek et al. (2008) reported an R^2 value of 0.59, but the composition of

producers, and likely, bull purchasers were relatively homogeneous compared to the

MBT sales. Given heterogeneous bulls and buyers at the MBT sales, the low fit is

probably not surprising.

Standardization of Variables

One method for determining the relative importance of each independent variable

in explaining variation in the dependent variable is to run an OLS regression of the final

model after standardizing each independent variable. As noted by Pinduck and

Rubinfeld,

> The standardized coefficients allow for changes in the dependent variable to be
> measured in standard deviations, for a one standard deviation increase for the
> independent variable (Pindyck and Rubinfeld, 1997, p. 98).

Variables are standardized mathematically by the following formula:

(5) $$(x_i - \overline{x}_i) / \sigma_{xi}$$

where x_i is the value of the ith variable, $\overline{x}_i$ is the mean of the ith variable, and σ_{xi} is the

standard deviation of the ith variable. The standardization of each variable is performed

on an annual basis. The binary variable YEAR08 cannot be standardized.

After standardizing, the magnitude of the absolute value of each OLS parameter

estimate indicates the relative importance of each in explaining bull price variation.

Therefore, these absolute values are ranked from highest to lowest. The parameter

estimate with the highest absolute value indicates the bull characteristic that buyers value the most.

The second column of Table 5.1 presents the regression results of the hedonic model using standardized data. Buyers value weight gain traits more highly than other traits. The absolute value of the parameter estimate for the standardized BYGEPD is 0.291. BWEPD is ranked second (0.198) followed by AGE (0.150), RFI (0.114) and REAEPD (0.103).

F-tests can be used to test for linear restrictions so that differences in the parameters of the standardized regression model can be evaluated. The bull characteristics ranked 3, 4, and 5 were fairly similar in value (AGE, RFI, REAEPD). Therefore, the null hypothesis is that these parameter estimates are equal. The result of the F-test (F stat = 22.15; P-value = 0.00) rejects the null hypothesis. Thus, the coefficient estimates of these three variables are statistically different from one another.

It is important to note the discrepancy in t-values between the final and standardized regressions. Differences occur because the variables were standardized by year (two different means and two different standard deviations) because of variations in variable means and standard deviations between the two years. If variables were standardized using one mean and one standard deviation, the resulting t-values would be identical.

Summary of Results:

Although RFI is a relatively new and measureable trait in cattle, bull purchasers are placing some positive value on it. However, RFI is only the 4th most important trait

in the 2008 and 2009 MBT sales suggesting buyers value historical characteristics of weight gain, birth weight, and age as more important characteristics. Of course, RFI is a new technology. Nevertheless, MBT has demonstrated that buyers value RFI traits.

Vanek et al. (2008) revealed that buyers value bull characteristics differently at several seed stock bull sales. In addition, previous studies have shown that bull purchasers at other sales value both growth and carcass traits. Buyers at MBT appear to value growth traits most highly, but are also willing to pay for a carcass trait (rib-eye area). However, buyers are not willing to pay for a second carcass trait (intramuscular fat). These results are relatively consistent with previous research. However, it is also important to note that the results of this study are based on the sale of bulls that originate from more than 100 different owners. Most previous research on bull selections evaluate the trait characteristics of bulls that originate from a single owner. Consequently, MBT's sale structure may contribute to the approach buyers undertake in valuing bull characteristics.

CHAPTER 6

SUMMARY

To maintain profits, cow/calf producers search for advantages that increase revenues or decrease costs. Cattle genetic selection has historically focused on growth traits which has led to increases in cattle size and, consequently, feed consumption per animal. Higher feed consumption reduces profit margins. But, genetic selection based on feed efficiency ratios have not reduced per animal feed consumption.

Genetic improvements in the cattle industry are mainly facilitated through bull selection. In addition to growth traits, bull purchasers have increasingly focused on carcass quality traits. Advances in technologies for measuring individual animal feed intake have resulted in a new measure of feed efficiency; residual feed intake (RFI). RFI is independent of growth traits and is calculated as the difference between actual feed intake and expected feed intake. An animal with a negative RFI consumes less feed than expected and is considered more feed efficient.

Information on bulls (expected progeny differences, simple performance measures) is provided at bull sales as marketing tools and to help buyers make informed purchasing decisions. Data from the 2008 and 2009 Midland Bull Tests in Columbus, MT were used to determine if bull purchasers value RFI. A linear hedonic model was estimated for Black and Red Angus bull sale prices. Bull prices were estimated as a function of growth, carcass, age, and RFI traits.

The regression results support previous research of Dhuyvetter et al. (1996), Chvosta et al. (2001), and Vanek et al. (2008). Buyers value low birth weights, high

birth-to-yearling gain, greater bull age, and a larger rib-eye area. However, the

intramuscular fat EPD did not affect MBT bull purchase prices. Finally, buyers placed a

positive value on RFI. If this purchasing behavior is emulated in other markets over

time, one might expect the development of an RFI EPD in the future.

Conclusions

As with any new technology, the beginning stages of development and adoption

include much risk and uncertainty. Although buyers value RFI, they appear to be valuing

this trait well below its theoretical contribution to cost reductions. Therefore, MBT bull

purchasers value growth, birth weight, and age traits more highly than the RFI trait. As

buyers observe the progeny of bulls they have selected for RFI and analyze their

profitability, the value of RFI traits may increase in the future.

Finally, MBT appears to be using a first-mover advantage in using RFI measures

to differentiate their bull sale. Bulls that command higher prices because of this trait

increase MBT's revenue. One would expect that this marketing technique will attract

producers with bulls exhibiting greater genetic potential for RFI.

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