Determinants of Sale Price and Farm value in The Missouri Show-Me Select Replacement Heifer Program

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Introduction

The selection and management of replacement heifers in a cow-calf operation has both short and long-term impacts on the process and profitability of that phase in the beef production system. Cow-calf producers have had to make significant management changes during the last few years in response to low farm prices and consumers demanding a better quality product. The most significant change in herd management has occurred through herd genetics to improve product quality and production efficiency. Herd genetics can be partially altered by sire selection and holding back breeding stock; however, to ultimately change herd genetics, replacements for cull cows must be of better genetic quality. Management tools that provide producers with information to improve the selection process are valuable. The selection process for replacement heifers has largely been subjective with each producer attempting to determine how a potential replacement heifer would fare in his production system. Measurement of objective heifer quality characteristics including reproductive maturity and calving potential have been technologically feasible for some time. However, there has been little economic analysis determining values for these and other measurable traits. The lack of this information along with thin public markets for quality replacement bred heifers available to small producers has reduced the ability of buyers and sellers of bred-heifers to respond efficiently to price signals. To peform effectively, producers would require information on the premiums and discounts offered for certain product characteristics, genetic characteristics of the calf, and market factors. The objective of this study is to estimate a characteristic demand model to determine the marginal implicit values of replacement heifer characteristics.

In response to a progressively more discriminating consumer (Barkema), the cattle industry is developing a trait-value based marketing system with the result of giving price signals to participants that will call a consistent quality product to the market to meet changing consumer demand. This system allows cattle finishers to receive a price consistent with measurable carcass characteristics for each animal. However, research has shown that pricing cattle on an individual animal basis increases price variability relative to selling pens on a live weight basis (Feuz). The increased price variability is associated with the diverse quality of animals within a pen (Graff and Schroeder). Against this background, cattle feeders have limited

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ability to project how cattle placed in their feedyards will eventually perform on this trait-value merit system. Thus, the success of a such a marketing system is measured by cattle feeders ability to reduce the variance of cattle quality around a target trait zone which depends on their ability feed calves of known quality. This can only be facilitated by a system of source-identifying prospective feeder cattle to evaluate genetic and phenotypic likelihood of trait levels. For example, a feeder will have a better chance of delivering a fed steer into a specific trait characteristic zone if he can correlate trait levels at slaughter with production, genetic and performance information early in the animals life. Cattle producer's management decisions are hindered because of their inability to source breeding stock of known quality and their inability to assess values of individual breeding stock traits. Similarly, sellers of breeding stock have little understanding of the value of these traits to their customers.

No previous study has evaluated the marginal implicit values of replacement bred heifer characteristics. Previous research evaluating trait-value characteristic relationships for breeding stock has been limited to either cow-calf pairs (Parcell, Schroeder, and Hiner), purebred beef bulls (Dhuyvetter et al.), or Dairy bull services (Schroeder, Espinosa, and Goodwin). In evaluating cow-calf pairs, Parcell, Schroeder, and Hiner found significant nonlinear characteristic-price relationships between calf weight, number of pairs in pen, and cow age. Additionally, significant linear characteristic-price relationships existed for cow health, cow breed, bred back cows, registered cows, calf health, and calf frame. In analyzing purebred bull price differentials, Dhuyvetter et al. regressed bull price on physical and genetic characteristics, performance characteristics, expected progency differences (EPDs), and marketing factors. Dhuyvetter et al. found nonlinear characteristic-price relationships for bull age and pen size. Additionally, Dhuyvetter et al. found significant linear characteristic-price relationships for breed, most physical characteristics, birth weight, weaning weight, some expected progeny differences, and several marketing factors, e.g., sale date, picture, and percent of bulls in sell having semen rights. The current study builds on these studies in developing a model of replacement heifer characteristic-price relationships.

In providing a research agenda for analyzing value-based marketing of cattle, Schroeder et al. (1998) noted, "As the beef industry shifts towards more value-based pricing, cow-calf producers will need information regarding the relationship between carcass quality, genetics, management, and production costs to make informed decisions." (p.132) Determining factors affecting replacement heifer price differentials is one area in the production process cow-calf producers need better characteristic-value information. The present study uses transaction level data on heifer price, physical characteristics, performance characteristics, expected progeny differences, marketing factors, and buyer survey data for over 300 pens (1,300 head) of bred heifers marketed through the **Missouri Show-Me Select Replacement Heifer Program™** during 1998. The results of this study will help buyers and sellers of replacement heifers make informed management and marketing decisions as they provide genetic germplasm into production systems aimed at selling fed cattle into target trait merit pricing systems.

Conceptual Model

Cow-calf producers produce calves for use in the production of beef. Bred heifers are inputs in the production of calves; therefore, bred heifers are inputs in the production of beef. The contribution of bred heifers to beef production is dependent on the inherent characteristics of the heifers. Assuming, cow-calf producers maximize profits, the price (p_i) paid for a replacement heifer used as an input in beef production can be specified according to Ladd and Martin:

$$p_i = \sum_j T_j \left(\partial x_{j.} / dv_i\right), \qquad (1)$$

where *i* refers to a bred heifer, *j* refers to a specific characteristic of heifer *i*, T_j is the marginal implicit price paid for the *j*th heifer characteristic used in beef production, $x_{j.}$ is the total quantity of the *i*th input used for the production of the *j*th characteristic, and v_i is the quantity of the *i*th input used for beef production. The final term, $\left(\partial x_{j.} / dv_i\right)$ is the marginal contribution of characteristic *j* in beef production from the *i*th input. For example, this value represents the marginal change in total pounds of beef used in expected beef production as a result of an additional pound of calf weight approximated by the expected progeny difference for birth weight of the heifer's calf.

Equation (1) specifies the price paid for heifer *i* equals the sum of the value of the *j* characteristics of the heifer. Following Ladd and Martin, $\left(\partial x_{j.} / dv_i\right)$ is assumed constant and equals x_{ji}. That is, using the calf weight example, increasing the expected weight of the calf by one increases the expected total pounds of cattle used in beef production by one. Therefore, equation (1) can be re-specified as:

$$p_i = \sum_j T_j \; x_{ji}, \qquad (2)$$

However, the marginal implicit value (T_j) need not be constant. Ladd and Martin indicated that T_j could be specified using a nonlinear functional form where the marginal implicit price for an individual heifer is dependent on the level of the characteristic. Bailey, Peterson, and Brorsen; Faminow and Gum; Mintert et al.; and Parcell, Schroeder, and Hiner specified characteristic demand models of different inputs into cattle production, i.e., feeder cattle and cow-calf pairs, as a function of the level of the characteristic using a quadratic functional form. That is, the level of a given input will influence the value of any additional quantity of that input.

Therefore, some of the characteristics in this study are modeled such that the marginal implicit price varies with the level of the characteristic. As an example, using a quadratic functional form for one variable, expected calf weight, yields:

$$p = \beta_1 x_{weight} + \beta_2 x^2_{weight} = x_{weight}(\beta_1 + \beta_2 x_{weight}), \quad (3)$$

where β 's are estimated parameters, and ($\beta_1 + \beta_2 x_{weight}$) is the marginal implicit price of expected calf weight and varies with the level of expected calf weight.

Empirical Model

The objective of this study is to estimate a characteristic demand model to determine the marginal implicit values of replacement heifer characteristics to determine how differences in product and genetic characteristics, expected calf characteristics, and market factors affect prices of bred replacement heifers are described. A Characteristic demand model, i.e., hedonic model, of heifer characteristics, and market factors is developed following previous work by Dhuyvetter et al. and Parcell, Schroeder, and Hiner. The dependent variable is the sales price of heifers (pen data) marketed through 1998 program sales of the **Missouri Show-Me Select Replacement Heifer Program™**. Equation 2 is modified to include expected progeny differences, market factors, and heifer characteristics leaving the characteristic demand model to be estimated for the average price of the replacement heifer ($Price_{ik}$) in pen i at sale k as:

$Price_{ik} = f$ (Physical and Genetic Characteristics$_{ik}$, Calves Expected Performance Characteristics$_{ik}$, Market Factors$_{ik}$). (4)

Variable definitions and expected signs are presented in table 1. A binary (0 or 1) color variable is included to determine whether black or black white-face cattle receive premiums over non-black cattle. Black or mostly black cattle are expected to receive premiums over non-black cattle due to current market premiums for black hided animals. Dhuyvetter et al. found significant premiums for black bulls.

Cow Frame Score and Muscle Score are indexed to reflect to amount of phenotypic dispersion within each lot of animals for sale. The index is calculated as the average difference between each animals score and the lot mean. It is expected that buyers will discount pens of cattle that are more dispersed in their physical condition. Therefore, a negative coefficient is expected for larger indexe values. Parcell, Schroeder, and Hiner found thin cows in cow-calf pens to be discounted relative to average condition pens, and they found large frame cows in cow-calf pens received premiums over average frame pens. The average weight of heifers in each lot is included as a continuous variable. It is expected that price will vary positively with weight. Expected calving periods were reported to potential buyers for each heifer lots. Lots with longer calving seasons and later calving seasons are expected to receive a discount.

Therefore, the variables for March and April calving (January and February are the default) and fifteen to thirty and thirty to forty-five (less than fifteen is the default) are expected to have negative coefficients.

Expected progeny differences (EPDs) for birth weight, yearling weight, and maternal milk were included as continuous variables. It is expected that as the birth weight EPD deviates from zero, pens will be discounted because light calves may not perform well and heavy calves can indicate potential calving difficulties. Therefore, the birth weight EPD variable was specified nonlinearly using a squared term.[3] An increase in EPDs for yearling weight is expected to increase the value of the pen. Maternal milk EPD is a measure of expected milk production of the female progeny and influences her calves expected growth performance during weaning. Because a female calf represents a possible replacement for the herd it is expected that a higher maternal milk EPD score is preferred.

Sale dummies are specified separately as 0 or 1 binary values. Sale locations for Missouri are Sedalia, Fruitland, Maryville, Palmyra, Vienna, and Joplin. A binary variable for whether the pen of heifers was naturally bred is specified (artificial insemination is the default). It is expected that animals that are artificially inseminated receive a premium pens that were all bred naturally due to improved chances of sire identification and sire performance testing.

Previous studies by Bailey, Peterson, and Brorsen; Faminow and Gum; Jones et al.; Parcell, Schroeder, and Hiner; Schroeder et al. (1988); Turner, McKissick, and Dykes; and Ward found included pen size as a predictor of animal value. Pen size is specified in this model. Most of the pens were relatively small (average pen size about 4) with only a few pens toward the large end (14 maximum). Missouri producers average about 35 cows per farm. If they replace 20 percent per year they will need about 7 replacement heifers. It is expected that larger pen within the range offered will receive premiums relative to smaller pens which would require buying multiple lots.

Data and Results

Summary statistics for selected variables used in the estimation of equation 4 are reported in table 2. Prices used in this model represent the average price per heifer for a pen of heifers. Therefore, characteristics were aggregated to pen averages. Data were collected from six sale locations in the state of Missouri during November 1998 through January 1999. Sales were widely advertised and open to the public. A total of 330 pens of heifers, 1362 heifers, were auctioned at the different sales. Two alternative functional forms, linear and semi-log, were estimated and data compatibility was tested (nonnested) using the Davidson and MacKinnon *P*-

[3] To allow squaring initially negative values associated with the birth weight EPD, a constant was added the variable.

test[4]. Pair-wise comparisons between alternative functional forms indicated data compatibility with the linear functional form. Therefore, the empirical model in equation 4 was specified in levels. Since heifers are sold as a bundle of characteristics and there may be dependency between the explanatory variables, multicollinearity among variables was tested for by evaluating the variance inflation factors.

Regression results from the estimation of equation 4 are reported in table 3. The explanatory variables explained 52% of the variation in heifer prices across pens. Positive parameter estimates indicate a premium relative to the base heifer price. Negative parameter estimates indicate a discount relative to the base heifer price. A majority of the coefficients were significant at the 0.05 level.

Product characteristics

Black and black white-face pens of heifers received a $51.00/head premium over pens not black. Dhuyvetter et al. found black Simmental, black Gelbvieh, and black Limousin bulls received premiums ranging from 12%/head to 50%/head over bulls of similar breeds that were not black. Average heifer weight in the pen was positive and statistically significant. A one pound increase in average pen weight increased the average heifer price per pen by $0.45. While the animal weights were recorded for analysis purposes, the actual weights were not available to the buyers until after the sale. There was no statistical significance for heifer pens that deviated from the default calving season or calving season length. Similarly, there was no evidence of buyers paying statistically more money for phenotypically uniform lots. Parcell, Schroeder, and Hiner found cow-calf pen price was lower for thin cows relative to average cow condition pens, and they found pen price was higher for large cow frame pens relative to medium frame cow-calf pens. Heifer pens of animals that were all bred naturally instead of artificial insemination were discounted $31.11 per head. There was a positive value placed on larger pen sizes.

Expected progeny differences

Birth weight EPD and birth weight EPD squared were both statistically significant and of the expected sign. Birth weight is correlated with expected calf growth and a low expected birth weight may indicate poor growth performance. Alternatively, heavy calves may cause calving problems for the heifer. The yearling weight EPD's were significant and positive in effecting average heifer price. The estimated effect for an increase in the maternal milk EPD on heifer pen price was negative, significant and unexpected. This variable has some correlation with weaning weight and thus may be carrying more of the price influence.

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[4] A double-log functional form could not be estimated due to a linear combination of the variables causing matrix singularity.

Marketing factors

Regional differences in heifer prices were found. This is due to the demographic characteristics of the buyers at different sales and the relative importance of cattle in that region.

Conclusions

No previous research has analyzed factors affecting replacement heifer price differentials. Using primary data, a characteristic demand model was estimated of how heifer prices varied for changes in genetic and physical characteristics, expected progeny differences, and marketing factors. Results indicated heifers premiums were received for black pens of heifers having a relatively larger number of heifers in the pen as well as larger heifers, and offspring having greater expected progeny differences for birth-weight, and yearling weight.

Sellers of replacement heifers can use the results from this study to produce heifers with trait levels that will receive premiums. Also, buyers of replacement heifers can benefit from this study by better understanding what the value of animal is they are bidding on. If the cattle industry is to develop a widely accepted value based marketing system, cattle producers need to produce cattle of known quality that will add value to the animal and simultaneously reduce price risk.

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Table 1. Definition and Expected sign of Variables Employed in the Hedonic Heifer Price Regression

Variable	Definition	Expected sign
Price$_{ik}$	Average heifer price in the *i*th pen at sale *k* ($/head)	
Marketing characteristics		
Sale	Sale binary variables = 1 if heifer sold at sale *k*; = 0 o.w. *k* = Sedalia, Fruitland, Maryville, Palmyra, Vienna; default = Joplin	?
Expected progeny differences		
Birth weight	Expected progeny difference of sire for birth weight of calf	+
B.W. squared	Expected progeny difference o sire for birth weight of calf squared	-
Yearling weight	Expected progeny difference of sire for yearling weight of calf	+
Weaning weight	Expected progeny difference of sire for weaning weight of calf	+
Product factors		
Black	Binary variable for black and black white face heifer pens; default=other	+
Frame Score Index	Average deviation of each heifer from the lot mean frame score	+
Muscle Score Index	Average deviation of each heifer from the lot mean muscle score	+
March Calving	Heifers expected to start calving in March	-
April Calving	Heifers expected to start calving in April	-
15-30 day calving season	Lot expected to calve within 30 days of eachother	-
30-45 day calving season	Lot expected to calve within 45 days of eachother; default = less than 15 days	-
Weight	Average weight of heifers in pen	+
Natural Service Sire	All heifers in pen from natural service sire; default=AI	-
Lot Size	Number of heifers in pen	+

Table 2. Summary Statistics of Selected Heifer Characteristics for Missouri Show-Me Select Heifer Program.

Variable	Mean	St. Dev.	Minimum	Maximum
Sedalia	0.15	0.36	0.00	1.00
Fruitland	0.23	0.42	0.00	1.00
Maryville	0.09	0.29	0.00	1.00
Palmyra	0.19	0.39	0.00	1.00
Vienna	0.13	0.34	0.00	1.00
Black	0.79	0.41	0.00	1.00
Frame Score Index	1.76	3.76	0.00	60.44
Muscle Score Index	0.89	1.24	0.00	12.33
March Calving	0.34	0.48	0.00	1.00
April Calving	0.11	0.31	0.00	1.00
15-30 calving Season	0.34	0.47	0.00	1.00
30-45 calving Season	0.10	0.30	0.00	1.00
Weight	983.30	97.87	750.00	1290.00
Natural Service Sire	0.41	0.49	0.00	1.00
Birth Weight EPD	3.16	1.05	0.10	4.90
BW squared	11.06	6.36	0.01	24.01
Yearling Wt. Epd	46.69	27.11	0.00	94.00
Maternal Milk EPD	12.90	9.00	0.00	32.00
Lot size	3.86	2.41	1.00	14.00

Table 3. Replacement heifer characteristic demand model price estimates (dependent variable is average price per pen and coefficients are in dollars per head).

Variable	Coefficient	St. Error	Test Stat	P-Value
Intercept	147.48*	56.51	2.61	0.0095
Sedalia	71.44*	15.85	4.51	0.0001
Fruitland	130.19*	16.19	8.04	0.0001
Maryville	-62.29*	17.40	-3.58	0.0004
Palmyra	71.84*	15.90	4.52	0.0001
Vienna	72.35*	15.61	4.63	0.0001
Black	51.00*	10.63	4.80	0.0001
Frame Score Index	-0.76	1.04	-0.74	0.4632
Muscle Score Index	-5.64	4.90	-1.15	0.2508
March Calving	-4.76	9.56	-0.50	0.6185
April Calving	4.44	15.75	0.28	0.7784
15-30 calving Season	10.49	8.88	1.18	0.2386
30-45 calving Season	7.55	14.12	0.54	0.5934
Weight	0.45*	0.04	10.28	0.0001
Natural Service Sire	-31.11*	11.12	-2.80	0.0055
Birth Weight EPD	42.66*	15.21	2.80	0.0054
BW squared	-7.38*	2.49	-2.96	0.0033
Yearling Wt. Epd	0.67*	0.23	2.86	0.0045
Maternal Milk EPD	-1.46*	0.63	-2.34	0.0202
Lot size	7.56*	1.96	3.86	0.0001