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Determination of the Value of Minimum Sire Accuracy Traits

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Using Missouri Show-Me-Select Replacement Heifers Inc. sale data, this article uses hedonic modeling to assess the marginal implicit values of physical and genetic characteristics, expected performance characteristics of calves, and market factors to bred heifer price. In 2008, a higher quality standard, known as Tier II, was created combining minimum expected progeny difference (EPD) accuracies for a heifer's sire with previous heifer standards. Heifer characteristics and market factors as well as yearling and carcass weight EPDs were found to significantly influence heifer price. Results suggest that Tier II heifers receive a premium compared with traditional Show-Me-Select heifers.

Key Words: beef, EPD, hedonic, product life cycle, value-added

JEL Classifications: Q11, Q13, R32

The declining U.S. cattle inventory can be at least partially explained by rising costs for feed and pasture. The increased value of grain and profitability of farming pasture land for grain and oilseed crops drives cost increases in cattle production. Consequently, some producers adjust their herd inventories to manage rising input costs such as feed and pasture land. To compete in the long run, cow-calf producers must continue to assess how to increase the value of calves, which inherently increases the value of the beef herd. Quality-based marketing represents one management strategy for adding value to the beef herd. Much attention to quality-based marketing focuses on sire selection. Less attention has been given to choice of the dam. Simple reproductive biology facts dictate why the sire is a short-term operational decision for improving calf genetics across the herd, but managing for female genetics represents a long-term strategic decision that can consistently guarantee improved calf carcass merit (Parcell et al., 2011). Because the genetic merit of the calf is relatively equal between the dam and sire, the management decision to move the herd toward a higher and consistent carcass merit should represent a significant financial investment in the herd because the cost of culling, recordkeeping, and identifying the best female animals is expected to be large. One management alternative for raising on-farm replacement heifers is to purchase replacement heifers with the progeny expectations to improve the carcass merit of the calf crop.

Determining market prices producers are willing to pay for bred heifers whose grown

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calves are expected to grade well at slaughter is one way to estimate what these same producers would be willing to invest in retaining their own heifers whose progeny would have the same characteristics. Higher quality carcasses should demand a premium, which should be reflected in a higher-valued weaned calf price for producers. For example, if a buyer is willing to pay $50 per head more, ceteris paribus, for heifers expected to have a higher probability of yielding a better quality carcass merit calf over the reproductive life of the female, then an on-farm retained ownership cost of $50 per head can be assumed at the margin.

The economic hypothesis tested here is that buyers of commercial replacement heifers pay no premium for quality developed heifers bred to sires with a known pedigree background. When buyers prove this hypothesis to be true by failing to pay a higher price for the heifers with a pedigree background, their decision represents a market failure in the sense that the sellers developed an animal attribute when no market for the attribute existed. Sellers absorb all costs, whereas rejecting the null hypothesis presents a market where buyers are willing to compensate sellers for their innovation. The average value estimated represents the marginal value, and this value can be used to assess a market value for the innovation. The innovation may not be economically justified if the cost of the innovation is higher than the compensation. The value will signal to other potential heifer sellers whether the innovation is worthy of consideration. To test the hypothesis and, if rejected, assess the level of value, a hedonic pricing model of bred heifer prices is specified and estimated. Data for this study are from Missouri Show-Me-Select Replacement Heifer sales from 2008 through 2010.

A secondary outcome of this study was a clearer understanding of the life cycle for using heifers produced from sires with minimum expected progeny difference (EPD) accuracies, Tier II heifers. The marginal values for these enhanced value-added products, i.e., Tier II heifers, will be shown. Over time, the Tier II marginal values represent a proxy for how buyers learn about the market, adjust buying patterns, and change their willingness to pay for an attribute as the attribute becomes available. All other hedonic model research for cattle attributes (e.g., Dhuyvetter et al., 1996; Dhuyvetter and Schroeder, 2000; Parcell et al., 2006, 2010; Parcell, Schroeder, and Hiner, 1995) have specified models with a commonly understood attribute set. This study is the first hedonic study designed for livestock sales to examine an attribute's life cycle. Because data for the new attribute are only available for a relatively short period, i.e., the Tier II heifers sales' introductory lifecycle phase, the hypothesis is that the premium (or value of Tier II heifers) increases over the period of data used here. This represents the learning period for buyers.

Standards must be met with respect to management, production, and genetics for heifers to qualify to be sold in Show-Me-Select (SMS) sales. The requirements are shown in Table 1. One requirement of the program is that the producer must have owned the animal 60 days before breeding. Health examinations and vaccinations at weaning, prior breeding, and pregnancy examinations are required for the program. SMS requires the animal to be dehorned, scurs removed, and treated for parasites 30 days before sale. The service sire's breed and pedigree birth weight or calving ease EPD information is required for the heifer. If the heifer was bred by using artificial insemination (AI), then the service sire must have a minimum accuracy of 0.6 for its respective EPD requirement. In addition, the heifer must weigh at least 800 pounds, have a body score of "5," and be free of blemishes to be entered in the program. The program started in 1997. More than 23,000 heifers have been sold in SMS sales during the program's life.

The program changed in 2008 when a higher heifer quality standard, known as the Tier II, was created. Tier II heifers have the same quality standards as heifers from previous years, but they have additional quality criterion wherein minimum EPD accuracies for the heifer's sire must be met. If the heifer's sire meets the EPD accuracies along with the heifer meeting the traditional requirements, the heifer can be sold as a Tier II heifer. However, if the heifer does not qualify for the Tier II classification, she can

Table 1. SMS Heifer Program Requirements

SMS Heifer Requirements	Tier I	Tier II
Animal ownership		
60 Days before breeding	X	X
Health examinations/vaccinations		
Weaning	X	X
Prior breeding	X	X
Pregnancy	X	X
30 Days before sale		
Dehorned	X	X
Scurs removed	X	X
Treated for parasites	X	X
Day of sale		
Minimum 800 pounds	X	X
Body condition score of 5	X	X
Frame score of medium	X	X
Muscle score of 20	X	X
Free of blemishes	X	X
Service sire		
Registered by breed registry	X	X
Maximum birth weight EPD	X	X
Minimum calving ease EPD	X	X
Heifer's sire		
Minimum calving ease (direct) EPD accuracy	—	X
Minimum calving ease (maternal) EPD accuracy	—	X
Minimum weaning weight EPD accuracy	—	X
Minimum carcass weight EPD accuracy	—	X
Minimum marbling EPD accuracy	—	X

SMS, Show-Me-Select; EPD, expected progeny difference.

still be sold as a SMS heifer if she meets the other basic requirements. The Tier II program has essentially created a new product (higher quality bred heifers) by using minimum EPD accuracies for calving ease and expected calf and carcass performance measurements for the heifer's sire. Managing the heifer's paternal side genetics by selecting a sire with maximum EPD accuracies can increase the probability of creating a higher quality offspring. EPD accuracies are indicators of reliability in EPD estimates. The higher the accuracy, the higher the probability that the offspring will meet an estimated EPD level. The value of the new Tier II added value product attribute and the traditional characteristics of SMS heifers are explored. The resulting information will help to determine buyers' willingness to pay and the speed at which buyers react to the availability of a new animal attribute. Producers who understand the value of specific heifer characteristics can make better culling and replacement decisions; this affects the operation's profitability.

Previous Research

Previous research on the price characteristic relationship includes research on cow-calf pairs (Parcell, Schroeder, and Hiner, 1995), purebred bulls (Dhuyvetter et al., 1996), and feeder calves (Avent, Ward, and Lalman, 2004). This research follows prior research by Parcell et al. (2006) that examined characteristics (heifer characteristics, calf and carcass expected characteristics, and market factors) that impact heifer/cow price variation.

Studies show that females bred by artificial insemination receive a premium (Parcell et al., 2006, 2011; Parcell, Schroeder, and Hiner, 1995). Females that will calve within a short span receive a premium (Parcell et al., 2006, 2010). Synchronized AI heifers receive a premium of

$25 to $80 per head (Parcell et al., 2010, 2011). Parcell et al. (2006) found that buyers are willing to pay a higher premium for pens of heifers bred to the same sire. A heifer that is bred to an Angus sire will sell at a price premium (Parcell et al., 2006; Parcell, Schroeder, and Hiner, 1995).

A heifer's weight influences price (Parcell et al., 2006; Parcell, Schroeder, and Hiner, 1995). Weight is normally expressed in a quadratic or squared weight term. However, Parcell et al. (2006) found a linear relationship between weight and price based on the need for heifers to qualify for the program. Parcell et al. (2006) did not find discounts for higher birth weights because some service sire breeds had a maximum allowed (within the breed) birth weight EPD program requirement. Parcell et al. (2006) found that calf carcass characteristics such as carcass weight, marbling, and ribeye area are also significant in explaining price. This study specified marbling and milk in a logarithmic form so lower scores were discounted.

Pen size has been commonly used as a predictor of animal value (Bailey, Peterson, and Brorsen, 1991; Faminow and Gum, 1986; Parcell, Schroeder, and Hiner, 1995; Schroeder et al., 1988; Turner, McKissick, and Dykes, 1993; Ward, 1992). Typically, buyers prefer larger lots and lots with heifers bred to the same sire, and they pay the highest prices during the midpoint of the sale (Parcell et al., 2006).

Conceptual Model

Hedonic price modeling can be used to estimate the marginal implicit value of product characteristics from variation in price among heterogeneous products. Although Lancaster (1971) and Rosen (1974) are often given credit for deriving the theoretical underpinnings of the modern hedonic pricing models, application of the hedonic model's conceptual format can be traced to Court (1939) and Waugh (1928).

The basic hedonic framework suggests that a heterogeneous product can be represented as an aggregation of homogenous characteristics (Chwelos, Berndt, and Cockburn, 2008). Through hedonic modeling, a heterogeneous good can be viewed through its characteristic make-up. Griliches (1971) and Pakes (2003) defined hedonic regression as a reduced form of optimizing behavior. Hedonic prices are implicit prices of product characteristics derived from the prices of differentiated goods and the characteristic quantities associated with the product (Rosen, 1974).

Ladd and Martin (1976) performed groundbreaking research by creating a new hedonic theoretical model for agricultural commodities as an input into production. Following their example, the hedonic model framework developed in this article will be extended to quality-differentiated bred heifers. A bred heifer will, therefore, be considered an input that produces calves.

Ladd and Martin's model shows how input prices equal the summation of characteristic values. The characteristic value is found by multiplying the yield of the characteristic by the value for one unit of the characteristic. Demand for a product is affected by the product's characteristics. Ladd and Martin's model is a neoclassical firm model that defines the production function as the amount of input characteristics needed for the production process. This model allows one to look at products that are heterogeneous. Heterogeneity in products can be achieved by creating a product that has different amounts of several characteristics or creating one product that contains a characteristic that other products lack. Heterogeneity can also arise if all products contain unique characteristics. Thus, a product can be thought of as a collection of characteristics.

With the Ladd and Martin theoretical model guiding the process, our first step is to define the variables of the framework as follows:

v_{ih} = quantity of the ith input in the hth product
r_i = price paid for the ith input
p_h = price received for product h
q_h = quantity of the hth output produced
x_{jih} = amount of characteristic j provided by one unit of input i and included in product h
x_{jh} = total quantity of characteristic j into product h

This framework assumes that x_{jih} are parameters that the producer cannot control. Where Equation 1 represents the production function for product *h,*

$$(1)\qquad q_h = F_h(x_{1\cdot h}, x_{2\cdot h}, \ldots, x_{m\cdot h}).$$

Equation 1 states that the output of h is influenced by the quantities of input characteristics. The total quantity of a characteristic is influenced by the input quantities and the amount of the characteristic provided for each input. Characteristic quantity is defined in Equation 2 as,

$$(2)\qquad x_{j\cdot h} = X_{jh}(v_{1h}, v_{2h}, \ldots, v_{nh}, x_{j1h}, x_{j2h}, \ldots, x_{jnh}).$$

The production function is expressed in Equation 3 as,

$$(3)\qquad q_h = G_h(v_{1h}, v_{2h}, \ldots, v_{nh}, x_{11h}, x_{12h}, \ldots, x_{mnh}).$$

The firm's profit-maximizing function is defined in Equation 4 as,

$$(4)\qquad \begin{aligned}\pi = &\sum\nolimits_{h=1}^{H} p_h F_h(x_{1\cdot h}, x_{2\cdot h}, \ldots, x_{m\cdot h}) \\ &- \sum\nolimits_{h=1}^{H} \sum\nolimits_{i=1}^{n} r_i v_{ih}.\end{aligned}$$

From the profit function, first-order conditions can be expressed in Equation 5 as,

$$(5)\qquad \begin{aligned}&\frac{dF_h}{dv_{ih}} = \sum\nolimits_j \left(\frac{dF_h}{dx_{j\cdot h}}\right)\left(\frac{dx_{j\cdot h}}{dv_{ih}}\right) \text{ that} \\ &\frac{d\pi}{dv_{ih}} = p_h \sum\nolimits_{j=1}^{m} \left(\frac{dF_h}{dx_{j\cdot h}}\right)\left(\frac{dx_{j\cdot h}}{dv_{ih}}\right) - r_i = 0\end{aligned}$$

and Equation 6 is found by rearranging Equation 5 to solve for r_i as,

$$(6)\qquad r_i = p_h \sum\nolimits_j \left(\frac{dF_h}{dx_{j\cdot h}}\right)\left(\frac{dx_{j\cdot h}}{dv_{ih}}\right).$$

$\frac{\partial x_{j\cdot h}}{\partial v_{ih}}$ is the marginal yield of characteristic j of the hth product from the ith input; $\frac{\partial F_h}{\partial x_{j\cdot h}}$ is the marginal physical product from one characteristic unit j used to create the hth product; and $\frac{p_h \partial F_h}{\partial x_{j\cdot h}}$ is the value of the marginal product of the jth characteristic used to produce output h. It can be interpreted as the marginal implicit (or imputed) price paid for the jth product characteristic used in product h. This lets $\frac{p_h dF_h}{dx_{j\cdot h}} = T_{jh}$ (Ladd and Martin, 1976). Where Equation 7 is defined as,

$$(7)\qquad r_i = \sum\nolimits_j T_{jh}\left(\frac{dx_{j\cdot h}}{dv_{ih}}\right).$$

$\frac{T_{jh} dx_{jh}}{dv_{ih}}$ is the value of the marginal yield of the jth characteristic by using the ith input for the production of h (Ladd and Martin, 1976). It is assumed that $\frac{dx_{j\cdot h}}{dv_{ih}} = x_{jih} = constant$ and $T_{jh} = constant$. This allows for the creation of Equation 8. This means that the yield of each characteristic by an input is not affected by how the input is used (Ladd and Martin, 1976). When applied to this study, this no-affect on input use assumption means that an additional pound of feed will have the same yield across heifers. With T_{jh} being constant, this means that the marginal implicit price is constant with a change in a characteristic across all heifers. Where Equation 8 is defined as,

$$(8)\qquad r_i = \sum\nolimits_j T_{jh} x_{jih}.$$

However, Ladd and Martin (1976) provide a quadratic adaption to the model if T_{jh} is not assumed to be constant. This is seen in Equation 9. The functional forms of the variables will be created by conceptual knowledge of the industry. Equation 9 is defined as,

$$(9)\qquad \begin{aligned}r_i &= \sum\nolimits_j x_{jih} B_j + \sum\nolimits_j x_{jih}^2 B_{jj} \\ &= \sum\nolimits_j x_{jih}(B_j + x_{jih} B_{jj}).\end{aligned}$$

For example, the variable for the number of heifers in a pen is expressed in a quadratic form. The marginal implicit price for the number of heifers in a pen can be represented as $(\beta_1 + \beta_2 * x_{number\ of\ head})$. The betas are the estimated parameters.

This study incorporates the product attribute life theory, which predicts that profits will increase as sales increase (Gedikoglu and Parcell, 2009). The new heifer product attribute is the additional requirement that the heifer's sire EPD accuracy levels must meet minimum accuracy levels. This attribute requirement is recognized in SMS sales brochures by denoting heifers as Tier II compliant. SMS started the Tier II classification in 2008. This classification has potentially created a new value-added product as compared with Tier I heifers.

The Tier II heifers represent a new branded product. The potential additional value for Tier II heifers is attributable through using proven genetics on the heifer's paternal (sire) side. The Tier II heifers should have a higher probability of having calves unassisted with fewer difficulties in giving birth. In addition, the heifers should have a higher probability of passing the expected EPD characteristics of weaning weight to their calves and the EPD characteristics of carcass weight and marbling to their offspring's carcass. The Tier II heifers can potentially add value to a producer's operation by reducing the time spent by the producer monitoring heifers calving for the first time. In addition, the heifer's sire side is backed with proven genetics, which should give operators a higher quality and more consistent calf crop, which should give producers higher premiums when they sell their calves.

The product life cycle theory suggests that products will go through four stages: introduction, growth, maturity, and decline (Gedikoglu and Parcell, 2009). It suggests that profits start out as negative and grow positive in the introduction stage (Gedikoglu and Parcell, 2009). It is expected that discounts may grow into premiums for the Tier II pens. According to the product life theory, as a product approaches the end of its life cycle, profits will become negative as a result of the competitive environment (Gedikoglu and Parcell, 2009). If profits exist for Tier II heifers, the competitive economic environment will drive these profits to zero. This could happen if more individuals or groups create a similar branded product and enter the market, which creates competition. These new market entrants may find a way to lower their costs of developing the same product, thus giving them the ability to lower their heifer price as compared with the SMS Program, or the new market entrants may have developed heifers that give producers even more added valued by managing genetics for several generations or managing for additional or different characteristics. As new technologies become available to manage herd genetic make-up, this gives additional possibilities for new value-added products. If the SMS program does not adapt to the Tier II program in the future in relation to new technologies used in the industry, they would likely see the added value in the Tier II heifers dissipate. In addition, over time producers looking to purchase replacement heifers may value different characteristics. If the SMS program wants to keep a value-added product, they will need to be responsive to the market demand for replacement heifers and monitor whether buyers' preferences for characteristics in heifers change over time. However, as the SMS Tier II program continues, premiums will likely continue to increase for these heifers with the Tier II "product" moving from the introduction stage into the growth stage where at the end of the growth stage, premiums should reach their maximum level. If no adjustments are made to the Tier II product, it will continue through its life cycle and reach the maturity stage, in which the rate of the increase in sales and premiums plateaus. Subsequently, the Tier II product will move to the decline stage characterized by a rapid decline in total sales and decline in profits.

Data

Sales data used for this study come from SMS Replacement Heifers Inc. between 2008 and 2010. To ensure that the program enrolls quality bred animals, a producer must prove that heifers have met minimum quality and health criteria throughout their lives before those animals can be entered in a sale. A heifer that meets the criteria will be given a "SMS" ear tag.

For the Tier II classification, the heifer's sire must meet the minimum accuracy benchmark in the traits of calving ease (direct; 0.65), calving ease (maternal; 0.3), weaning weight (0.75), carcass weight (0.20), and marbling (0.20). Calving ease accuracies are important to the probability of a heifer having a calf with little or no assistance from the producer. The other accuracies point to the potential for the heifer to give birth to a superior calf that has the ability to gain more weight at weaning and produce a superior carcass.

The data were collected from seven sale locations throughout Missouri from 2008 to 2010. The subset of those data used for this study's analysis included information for 2,162 heifers. Both spring- and fall-bred heifers are included in the data. The spring sales were held in May, and the fall sales were held in November and December. Summary statistics for selected variables used and the expected signs for variables are reported in Table 2.

Empirical Model

A hedonic model was used to acquire the heifer's value based on her characteristics, expected calf and carcass characteristics, and market characteristics. Each bred heifer was purchased as a result of her collective characteristics (e.g., breed, calving span). The hedonic model was used to estimate the marginal contribution of each characteristic to the bred heifer's total price.

Two models were estimated in which the average price of the bred heifer in pen i for sale k is a function of:

Table 2. Data Summary Statistics and Expected Signs of Variables Used in the Hedonic Heifer Price Regression

Item	Average	Standard Deviation	Expected Impact on Heifer Price
Average price of heifer in pen ($/head)	1268.38	216.46	NA
Average weight of heifer in pen	1098.67	114.63	+
Percentage of pens AI sired	46.49	49.88	+
Calving period (% of pens calving in specified period)			
January and February	39.20	48.83	+
March, April, and May	30.62	46.10	Default
August and September	17.24	37.78	+
October and November	12.94	33.57	+
Calving span between first and last expected birth for pen (days)	6.65	24.91	–
Calf production EPDs (only for Angus pens with one sire)			
Birth weight	0.32	1.53	–
Weaning weight	48.71	9.08	+
Yearling weight	90.47	14.41	+
Maternal milk	25.08	7.09	+
Carcass EPDs (only for Angus pens with one sire)			
Carcass weight	8.96	6.58	+
Marbling	1.35	4.53	+
Ribeye area	0.24	0.19	+
Sale location (% of pens sold at location)			
Northeast	13.47	34.15	?
North–central	8.70	28.18	?
West–central	13.12	33.77	Default
Southeast	20.15	40.12	?
Southwest	40.84	49.16	?
South–central	3.68	8.51	?
No. of head per pen	2.60	18.83	+
Percentage of pens sold in the fall	70.67	45.54	?
Percentage of pens with ALL Tier II heifers			
Tier II in 2008 (n = 51)	1.49	12.13	+
Tier II in 2009 (n = 42)	1.70	12.92	+
Tier II in 2010 (n = 51)	2.61	15.93	+
Percentage of pen with more than one sire used	33.93	47.35	–
Percentage of heifers in pens with Angus sire used	56.44	49.59	+

AI, artificial insemination; EPDs, expected progeny differences; NA, not available.

$$\begin{aligned}(10)\quad & \text{Model 1: Average Bred Heifer Price}_{ik} = f(\text{Average weight per heifer}_{ik}, \text{AI sired}_{ik},\\ & \text{Calving period}_{ik}, \text{CalvingSpan}_{ik}, \text{ Calf Production EPDs [Angus pens with one sire]}_{ik},\\ & \text{Carcass EPDs [Angus pens with one sire]}_{ik}, \text{ Sale Location}_{ik}, \text{Lot order}_{ik}, \text{Lot order squared}_{ik},\\ & \text{Number of heifers}_{ik}, \text{ Number of heifers squared}_{ik}, \text{Season}_{ik}, \text{All Tier II heifers}_{ik},\\ & \text{Pens with more than one sire}_{ik}, \text{All Angus Sires}_{ik})\end{aligned}$$

$$\begin{aligned}(11)\quad & \text{Model 2: Average Bred Heifer Price}_{ik} = f(\text{Average weight per heifer}_{ik}, \text{AI sired}_{ik},\\ & \text{Calving period}_{ik}, \text{ Calving Span}_{ik}, \text{Calf Production EPDs [Angus pens with one sire]}_{ik},\\ & \text{Carcass EPDs [Angus pens with one sire]}_{ik}, \text{Sale Location}_{ik}, \text{Lot order}_{ik}, \text{Lot order squared}_{ik},\\ & \text{Number of heifers}_{ik}, \text{Number of heifers squared}_{ik}, \text{Season}_{ik}, \text{All Tier II heifers in 2008}_{ik},\\ & \text{All Tier II heifers in 2009}_{ik}, \text{ All Tier II heifers in 2010}_{ik}, \text{Pens with more than one sire}_{ik},\\ & \text{All Angus Sires}_{ik})\end{aligned}$$

The only difference between the models is that Model 1 has one Tier II dummy variable, providing the average Tier II premium between 2008 and 2010, and Model 2 has a Tier II dummy variable for each year, indicating how the premiums of all Tier II pens may have changed over time. The specification creates one binary variable in Model 1 indicating pens with all Tier II females. Model 2 contains three binary variables created by interacting each dummy year variable by the dummy variable of whether a pen contains all Tier II females.

Heifer characteristics analyzed include weight, heifers bred using AI, expected calving period, expected calving span, pens with more than one sire used, and Angus breed. Calf expected progeny difference (EPD) values (birth weight, weaning weight, yearling weight, and maternal milk), carcass EPDs (carcass weight, marbling, and ribeye area), and market factors (location, lot order, pen size, and season) are used to examine the impact on heifer prices. In addition, this study covers the impact of pens with all Tier II heifers (where the heifers' sires met minimum accuracies). EPDs were calculated by using the animal's own performance records and any information available through their progeny and ancestors. EPDs are used to estimate what genes will be passed to the offspring. Weight EPDs are expressed in pounds as a plus or minus according to the increase or decrease in performance for a given trait that can be expected from the progeny of the animal compared with the breed average. Marbling is expressed as a fraction of the difference between the USDA's marbling score of the sire's progeny compared with the breed average. Carcass ribeye area is expressed in square inches as compared with the breed average. For this study, EPDs are used to compare the influence of the traits of birth weight, weaning weight, yearling weight, carcass weight, marbling, and carcass ribeye area on bred heifer prices.

Birth weight EPDs are used to predict calf growth and heifer calving ease, which is important when a heifer gives birth for the first time, because she is not fully mature. Weaning weight, yearling weight, and maternal milk EPDs are used to predict calf growth potential. The birth weight EPD is a predictor of a sire's ability to transmit birth weight compared with other sires. Heavier birth weights have been associated as a major factor in calving difficulties. A lower birth weight EPD suggests lower calving difficulty expected from using the associated sire. The lower the birth weight EPD, the more value the heifers have because of the higher probability that the heifer will give birth unassisted. Weaning weight EPD is a predictor of a sire's potential to pass weaning growth to his progeny compared with other sires. Yearling weight EPD is a predictor of a sire's potential to transmit yearling growth to his progeny compared with other sires. Higher weaning and yearling EPDs are associated with heavier calves, which increases returns per head. Maternal milk EPD is a predictor of a sire's genetic value for milk and mothering ability that is expressed in his daughters compared with daughters of other sires. It is part of the calf's weaning weight associated with milk and mothering ability. For example, if Sire A has a maternal milk EPD of +20, it would mean that Sire A's daughters would be expected to wean calves that average 20 pounds heavier because of genes associated with milk as a result of that sire compared with other sires. However, if Sire B has a maternal milk EPD of –5, it would mean that Sire B's daughters would be expected to wean calves that average 5 pounds lighter because of genes associated with milk as a result of that sire compared with other sires.

Carcass weight EPD is a predictor of differences in lot carcass weight of a sire's progeny compared with the progeny of other sires. Higher carcass weight EPDs are associated with heavier carcass weights. Marbling EPDs are a predictor of differences in intramuscular fat in the ribeye of a sire's progeny compared with progeny of other sires. Higher marbling EPDs are associated with higher marbling scores. Carcass ribeye area EPDs are a predictor of differences in the area of the longissimus dorsi muscle at the 12th rib of a sire's progeny compared with progeny of other sires. A higher carcass ribeye area EPD is associated with a larger ribeye area.

Prices used in the model represent the average heifer price per head for a pen of heifers. Thus, some characteristics are aggregate pen averages. Previous research has specified weight as a nonlinear relationship to capture discounts associated with lighter weight animals; however, in this study, the heifers have a minimum weight requirement to enter the sale, so lighter weight heifers are not expected to be discounted as a result of the program requirement. Heifer weight is expressed linearly to capture the greater price for more pounds of beef.

A binary variable was created for pens where all heifers were artificially inseminated; in this case, the variable was set to one. It was expected that AI pens would receive a premium.

Four binary time variables (January/February, March/April/May, August/September, and October/November) were created to represent the expected calving month for a pen of heifers with the period of March through May serving as the default. The default period between March and May when the heifers will calve will result in calves being weaned and sold during the seasonal peak of calves coming onto the market during September when feeder cattle prices are at their seasonal low. Heifers that calve in August/September and October/November should carry the highest premium because calves born in these times will be weaned between February and May, a nonpeak period for calves coming onto the market. In addition, it is expected that heifers that calve in January/February should carry a slight premium because calves born in this period will be weaned in July, slightly before the peak period of calves coming onto the market. Thus, these calves will receive a premium as a result of the seasonality of the area's cattle production.

A binary variable was created to represent a pen's calving span. It was set to one when the difference between the first heifer and last heifer expected to give birth is greater than 30 days. A discount is expected as a result of additional management needed for different vs. same aged calves, which is reflected in nonuniform calves having less value.

One data specification change was made with respect to EPD values. The EPDs of birth weight, maternal milk, and marbling needed to be expressed in a natural logarithmic format. According to the literature, it is expected that these variables would be discounted at lower levels relative to higher levels. Specifically, we followed the specifications outlined in Parcell et al. (2006). Using the natural logarithms of data generates a nonlinear marginal value curve to account for producer preferences associated with an optimal birth weight, maternal milk, or marbling. For example, some increase in birth weight is desirable, but a birth weight that is too high signals the potential for birthing issues. Similarly, some marbling improves carcass quality, but too much marbling makes the carcass fatty.

The original EPD values ranged from negative to positive. Transformed EPD values were created by adding a constant (25) to each observation so that resulting EPDs could be converted to logarithms. However, the constant was subtracted when simulating impacts of the variables. These values were then interacted with a dummy variable that was created by determining whether a pen held Angus heifers (1 = yes) and whether the pen only had one sire used to breed the heifers (1 = yes). The dummy variable designated that the pen held Angus heifers and had only one sire used. This procedure was done because EPD levels vary across breeds and only pens with one sire could be used because different sires have different EPDs. The EPDs used in this analysis are only from pens with Angus animals and pens where one sire was used to breed the heifers. Expected birth weights were expressed in natural logarithmic form so that greater weights would be discounted relative to lower weights. Both expected weaning and yearling weights were expected to result in premiums for heavier weights. Expected maternal milk is expressed in logarithmic form so that lower milk EPDs are discounted. It was expected that higher milk levels would result in a premium as a result of the potential for female progeny to have higher milk production that would contribute to the growth of calves.

Besides calf EPDs, carcass EPDs were also used in the analysis. Expected carcass weight and ribeye area were expressed linearly. Marbling was expressed in a natural logarithmic form. Marbling was expressed in this form so that lower scores would be discounted as a result of the loss in grid value. Expected carcass weight was expected to show a premium for higher weights, which represents that amount of meat a calf would produce. In addition, it was expected that premiums would be shown for carcasses with a higher ribeye area, a highly valuable cut of meat.

Market factors were also used in the analysis. Binary variables were created for six regions of Missouri: northeast, north–central, southeast, southwest, south–central, and west–central. West–central served as the default. Some differences may exist regionally as a result of differences in localized markets.

Lot order was expressed in a quadratic form with the expectation that pens that sell later are discounted relatively as buyers start to leave the sale. Pen size was specified in a quadratic form with the expectation that larger pens relative to smaller pens would receive a premium. A binary variable was created for the season of the sale; the variable was set to one when the sale was held in the fall. A binary variable was created to indicate whether all heifers in a pen were bred by the same sire, and it was set to one when the pen had more than one sire used to represent a discount. A binary variable was created to represent whether the pen of animals was Angus or Angus-cross. The variable was set to one when all heifers in the pen were Angus or Angus-cross. A premium was expected for Angus pens.

Results

The results of Model 2 are described because Model 1 was similar. The results of Model 1 and Model 2 are shown in Table 3 and Table 4, respectively. Heifer characteristics that were significant at the less than 1% level were heifer weight, AI heifer pens, expected calving period, and pens with multiple sires used. These findings are consistent with previous studies. A 1-pound increase in heifer weight led to a $0.82 per head increase in bred heifer price. This value represents the cull value of the heifer in the future. Artificially inseminated heifer pens garnered a $42.29 per head increase in heifer price. This indicates that buyers believe that AI provides premiums for the future value of the heifer's calf. Heifers that were scheduled to calve in January/February received $47.12 per head premium compared with heifers expected to calve in the March/April/May period. This is likely because the calving dates are earlier in the spring with respect to the default, and this gives producers more time to put weight on calves before they sell at weaning in the fall. This gives calves more time to use forage before the dry summer months and is valuable to producers because they do not have to invest more resources in a heifer before calving. For the August/September calving period, heifers received a $177.09 premium per animal. Heifers expected to calve in October/November receive a $159.18 a head premium. Premiums received for these animals most likely reflect the idea that the calves will be weaned in the spring when feeder cattle prices have historically hit their highs. Thus, the feeder cattle market's seasonality creates premiums for animals sold in the off-season (spring).

The calf and carcass EPDs that were significant at the less than 1% level in Model 2

Table 3. Model 1 (Tier II average) Quality Bred Heifer Characteristic Demand Model Price Estimates (dependent variable average price per pen and coefficients refer to dollars per head)

Item	Coefficient	SE	*p* Value
Intercept	256.93***	47.98	<0.01
Average weight of heifer in pen	0.82***	0.03	<0.01
Pens AI sired	41.66***	10.06	<0.01
Calving period (default = March, April, and May)			
January and February	49.42***	10.41	<0.01
August and September	171.77***	20.16	<0.01
October and November	159.87***	20.82	<0.01
Calving span = 1 if greater than 30 days	–5.29	14.83	0.72
Calf production EPDs (only for Angus pens with 1 sire)			
Birth weight (logarithmic)	–47.62	188.45	0.80
Weaning weight	6.02	3.82	0.12
Yearling weight	–12.40***	2.35	<0.01
Maternal milk (logarithmic)	–130.79	96.19	0.17
Carcass EPDs (only for Angus pens with one sire)			
Carcass weight	15.78***	2.39	<0.01
Marbling (logarithmic)	1140.74*	651.99	0.08
Carcass ribeye area	–104.79	80.19	0.19
Sale location (default = west–central)			
Northeast	–0.36	13.82	0.98
North–central	–127.40***	22.36	<0.01
Southeast	–96.91***	14.78	<0.01
Southwest	–107.42***	12.49	<0.01
South–central	–147.37***	18.85	<0.01
Lot order	7.29***	0.75	<0.01
Lot order squared	–0.07***	0.01	<0.01
Head per pen	39.13***	3.02	<0.01
Head per pen squared	–2.33***	0.34	<0.01
Season = 1 if fall	–46.87**	19.95	0.02
Pens with all Tier II heifers			
Tier II (n = 144)	30.43*	16.01	0.06
Pen with more than one sire used = 1	–60.85***	10.71	<0.01
Pens with all Angus sires = 1	12.64	10.97	0.25

***, **, * Significance at the <1%, <5%, and <10% levels.
SE, standard error; AI, artificial insemination; EPDs, expected progeny differences.

applied to yearling and carcass weight. The calf and carcass EPDs of birth weight, weaning weight, maternal milk, marbling, and ribeye area were not significant. Previous research found that these variables were significant in explaining price. Dhuyvetter et al. (1996) found the EPDs of birth weight, weaning weight, and maternal milk statistically significant in explaining beef bull prices. Parcell et al. (2006) found both calf production (birth weight, yearling weight, and maternal milk) and carcass (marbling and longissimus area) EPDs statistically significant in explaining bred heifer prices. A 1-pound increase in carcass weight was found to yield a premium of $13.41 per head. Heavier carcasses have more sellable pounds of meat. A 1-pound increase in yearling weight was found to have a $10.14 discount per head. The relationship was expected to be in the opposite direction. Expected birth weight was not found to be significant in either model, which was not unexpected as a result of the SMS program requiring that certain service sire breeds not exceed the maximum allowed breed-specific birth weight EPD requirement.

Table 4. Model 2 (Tier II by year): Quality Bred Heifer Characteristic Demand Model Price Estimates (dependent variable average price per pen and coefficients refer to dollars per head)

Item	Coefficient	SE	*p* Value
Intercept	249.26***	47.70	<0.01
Average weight of heifer in pen	0.82***	0.03	<0.01
Pens AI sired	42.29***	10.00	<0.01
Calving period (default = March, April, and May)			
January and February	47.12***	10.36	<0.01
August and September	177.09***	20.06	<0.01
October and November	159.18***	20.70	<0.01
Calving span = 1 if greater than 30 days	–3.52	14.74	0.81
Calf production EPDs (only for Angus pens with one sire)			
Birth weight (logarithmic)	165.29	191.43	0.39
Weaning weight	2.03	3.88	0.60
Yearling weight	–10.14***	2.39	<0.01
Maternal milk (logarithmic)	–134.81	95.97	0.16
Carcass EPDs (only for Angus pens with one sire)			
Carcass weight	13.41***	2.43	<0.01
Marbling (logarithmic)	477.34	665.66	0.47
Carcass ribeye area	–41.46	81.09	0.61
Sale location (default = west–central)			
Northeast	1.80	13.74	0.90
North–central	–122.70***	22.23	<0.01
Southeast	–93.67***	14.70	<0.01
Southwest	–105.60***	12.42	<0.01
South–central	–144.28***	18.75	<0.01
Lot order	6.94***	0.75	<0.01
Lot order squared	–0.07***	0.01	<0.01
Head per pen	39.74***	3.00	<0.01
Head per pen squared	–2.40***	0.34	<0.01
Season = 1 if fall	–42.94**	19.85	0.03
Pens with all Tier II heifers			
Tier II in 2008 (n = 51)	–78.42***	26.31	<0.01
Tier II in 2009 (n = 42)	32.72	28.39	0.25
Tier II in 2010 (n = 51)	111.47***	23.98	<0.01
Pen with more than one sire used = 1	–58.77***	10.65	<0.01
Pens with all Angus sires = 1	9.20	10.93	0.40

***, **, * Significance at the <1%, <5%, and <10% levels.
SE, standard error; AI, artificial insemination; EPDs, expected progeny differences.

Heifer pens that had more than one sire used in breeding had a $58.77 discount per head. When one sire is used to breed heifers, the heifers tend to have more uniform calves. It was interesting to find that the Angus breed was not significant in directly determining bred heifer price; however, this may be the result of the price effect being captured by the sire EPD data, because only Angus sire EPD data were used in the models. This contrasts with other findings (Avent, Ward, and Lalman, 2004; Dhuyvetter et al., 1996; Parcell et al. 2006; Parcell, Schroeder, and Hiner, 1995) that have found that Angus cattle receive a premium.

In Model 1, an increase in the natural logarithmic of marbling was found to increase a heifer's price. The relationship is linear. For each 0.1 increase in marbling score, an animal earns a $4.50 premium. This indicates that sellers are being compensated for using higher quality genetics that can produce a higher quality meat. This makes sense because a primary indicator

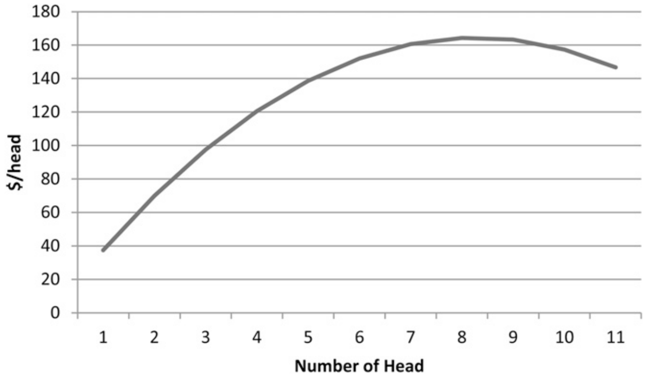

Figure 1. Effect of Number of Heifers on Average Price per Bred Heifer in the Pen

of USDA carcass quality is marbling. Ribeye area was not found to be a significant indicator of bred heifer price in either model. This is surprising because the ribeye area is one of the highly priced cuts of beef. It appears that buyers are willing to pay for most heifer characteristics and some calf and carcass expected characteristics. In addition, regional price differences were found for north–central, southeast, southwest, and south–central regions compared with the west–central region in both models. Regional price differences were also found in Parcell et al. (2006). Parcell et al. (2006) found premiums for heifers sold in the southeast and south–central regions in Missouri compared with the west–central region of Missouri. For the current study, regional price discounts were observed for heifers sold in the southeast and south–central regions of Missouri relative to heifers sold in the west–central region of Missouri.

Lot order was shown to have a quadratic relationship to price because the squared term was significant in both models. Heifers sold in the fall received a discount of $42.94 per head according to Model 2. The number of animals in the pen was shown to have a quadratic relationship with bred heifer prices; Parcell et al. (2006) found the same result. Figure 1 illustrates the quadratic relationship between number of heifers and price. The value of impact for the range of one to 11 heifers in a pen was simulated in the graph using the regression coefficients. For example, a pen of four heifers will obtain $444.90 a pen premium compared with a one heifer pen according to Model 2. According to Figure 1, the heifer premiums would begin to decline at a pen size of eight head. This research finding may be a reflection on the overall smaller operation size in Missouri.

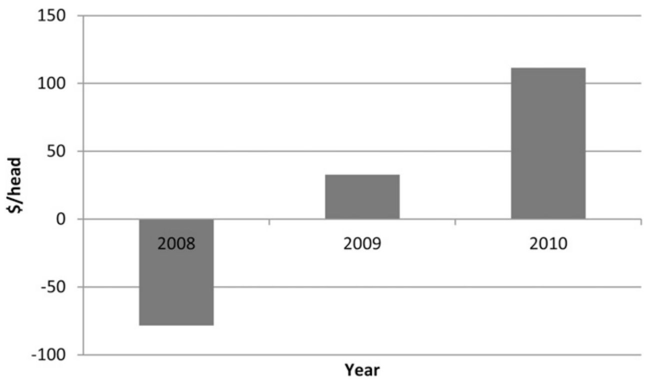

Figure 2. Premiums/Discounts for Tier II Heifer 2008–2010

The Tier II variable was found to be significant for 2008 and 2010 in Model 2. The Tier II program began in 2008, so buyers may not have understood the value of a Tier II animal. Figure 2 shows the Tier II premiums or discounts for 2008–2010. From 2008 to 2010, premiums for Tier II heifers increased. In 2008, a discount of $78.42 per head was shown, whereas positive premiums of $32.72 and $111.47 occurred in 2009 and 2010, respectively. This coincides with the introduction stage of the product life cycle theory, in which profits start out as negative and grow to become positive in this stage (Gedikoglu and Parcell, 2009). In Model 1, an average Tier II $30.43 premium was found for the period from 2008 through 2010. Producers will choose to raise more Tier II heifers when the premiums are large enough to offset the cost of using high-accuracy sires.

Implications

This study uses transaction-level data to estimate marginal implicit values for bred heifer characteristics including the value of minimum sire accuracies for a heifer's sire. The study focuses on tracking the marginal implicit value of a new attribute (Tier II) from inception. This study finds that heifers produced from sires with quality genetics receive premiums. In addition, the higher quality heifers, known as Tier II heifers, have received a premium for their value-added characteristics. The Tier II program requires minimum sire accuracies of the heifer's sire so that heifers raise higher quality calves that can be used as replacement heifers or that can produce carcasses that grade high on the rail. However, it needs to be noted that some heifers sold may not be tagged as Tier II heifers, but they still meet the Tier II characteristics. A limitation of this study is that individual animal sales prices are unobtainable as a result of the heifers being sold by the pen, resulting in an inability to capture all Tier II heifers and all AI bred heifers. Another limitation of this study is that potential market structural changes are unable to be accounted for that may impact marginal value of characteristic attributes. Futures market prices or daily cash prices were not able to be incorporated into the models because of the lack of a sufficient number of observations.[1]

The implicit marginal prices determined for Tier II heifers show the buyers' willingness to pay for the animal with respect to the expected value that the heifer creates over her lifespan and the genetics that the heifer passes to her calves, which may be raised as breeding bulls or replacement heifers.

The Tier II program could benefit from potential marketing efforts to increase awareness of the characteristics and value of Tier II heifers. Gedikoglu and Parcell (2009) studied the product and profit life cycle of a quality heifer program (SMS heifers). They found that marketing is vital to value-added programs generating premiums and profits in the long run. They found that the simulated price premiums were close to the actual premiums (Gedikoglu and Parcell, 2009). Because the

[1] Second-state hedonic modeling, or characteristic demand modeling, was developed to address how market forces shift the marginal implicit value by researchers such as Epple (1987), Mendelsohn (1984), Palmquist (1984), and Rosen (1974). Derived from a nonlinear specification of the hedonic model, a characteristic demand model is used to analyze attribute price changes resulting from structural shocks, e.g., change in the level of beef prices on the value of an EPD attribute. Bowman and Ethridge (1992) used such a technique to estimate changes in the marginal implicit price of cotton fiber attributes. Bowman and Ethridge show that it is necessary to have a sufficient number of locations and periods to derive the impact of structural change on marginal implicit prices. The current study lacks the sufficient number of observations to estimate the second-state hedonic price equation for any of the particular attributes. From an economic (statistical) methodology, there are too few observations to account for relative price changes in the cattle market. Each sale location represents several pens, of the overall total, sold on a particular date. During the fall or spring sale period, all regional sales occur within a 2- to 3-week period as regional cattle markets are price integrated, so there is no reason to believe cattle prices between regions vary for any reason other than transportation costs. For example, one cattle price for the fall 2007 sale period is sufficient to be used in a vector of data for market price observations. Thus, ultimately, there will only be six different cattle prices observed in the data. Achieving statistical inferences from so few observations is problematic.

program is still in the introductory stage of the product life cycle, it could benefit from marketing dollars being spent and moving the product into the growth stage. Marketing dollars spent in the introductory stage can have large impacts in the long run by decreasing the time that a product spends in the introductory stage and increasing the time that a product spends in the growth stage. The growth stage is characterized by increased sales and increasing profits. The marketing investment could increase producer participation in the Tier II program by building buyers' understanding of Tier II heifers' value and by increasing buyers' willingness to pay for these high-quality animals. The increase in premiums from 2009 to 2010 could be related to producers better understanding the value of Tier II heifers and realizing the value that they can earn from using high-accuracy sires to breed their females.[2] Females bred to high-accuracy sires have the potential to give birth to a heifer calf that could be marketed in the future as a Tier II heifer.

Because the Tier II program is in its infancy stage, premium values are likely still being determined. In accordance with the product life cycle theory (Gedikoglu and Parcell, 2009), sales of Tier II animals should continue to increase and premiums should continue to grow for these animals until the maturity stage of the attribute life cycle. As Tier II heifers move through their product life cycle, the competitive environment will eventually drive profits to zero. This could happen by another entity developing a different branded heifer replacement program. The entity may find ways to lower their costs in developing replacement heifers; this could be done through adopting new technologies as compared with the SMS program. In addition, the entity of a new branded heifer development program could manage different desired characteristics of heifers as compared with the SMS program. As buyers change their replacement heifer attribute preferences, replacement heifer suppliers such as the SMS program need to respond to buyer preference changes. Downward trending Tier II premiums and sales will indicate that Tier II has entered the maturity stage of its product life cycle. The growth stage—the time at which profits reach their maximum—is an ideal time to introduce a new value-added product so that producers can preserve quality premiums.

Producers who already participate in the SMS program and use artificial insemination to breed heifers may incur minimal additional costs if they were to upgrade to producing Tier II heifers. This is because Tier II heifers must be produced from a sire that has high accuracies for calving ease, weaning weight, carcass weight, and marbling. The only additional cost for these producers would be possibly buying a more expensive, higher quality sire semen that meets the required sire accuracies for the Tier II program. However, the producer may not even need to pay any more directly for higher quality semen; it may just involve an increase in cost associated with spending a little bit more time identifying semen that meets the minimum sire accuracies requirements and additional recordkeeping.

However, a producer who already participates in the SMS program and who uses a bull for natural service (where the EPDs do not meet the required accuracies) for their herd would incur higher costs to transition to producing Tier II heifers. This producer would have to start using artificial insemination and purchasing sire semen that meets the minimum required EPD accuracies. Using artificial insemination would also require that the producer invest additional time, labor, and equipment.

The hedonic approach gives a better measure of buyers' willingness to pay for certain heifer characteristics. One reason for this is that net present value estimates normally only incorporate the value of an animal's offspring and assume that its offspring is sold and not

[2] A limitation of this study is that not all of the Tier II heifers were captured as a result of Tier II heifers possibly being mixed in pens with Tier I heifers. In addition, not all heifers that were bred using AI were captured as a result of AI bred heifers being mixed with heifers that were bred by a bull through natural service. These are the limitations of the study because individual animal sales prices are unobtainable.

kept to improve the overall genetic make-up of the herd. As a result of this, present value estimates of quality heifers are most likely underestimated.

More research needs to focus on identifying the value-added characteristics that receive premiums. Such research would help individuals better understand and improve the value marketing chain. In addition, more research should investigate the extent to which premiums for new value characteristics change throughout a product's life. This could include exploring how the rate of change in premiums for a branded product such as Tier II heifers would change over time and evaluating how many years a new branded product can maintain its premiums. This will allow market participants to understand the life cycle of a new value-added characteristic and more readily adapt their product line to capture premiums.

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