Determinants of Replacement Heifer Price Differentials

by

Vern Pierce, Joe Parcell, and Richard Randle

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Abstract

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 improve production efficiency. This study uses transaction level data to empirically estimate the marginal implicit trait values of replacement bred heifer characteristics. Results indicated premiums were received for pens of heifers having ten animals, and black in color. Offspring having an expected progeny difference for birth-weight near zero were not discounted. Pens of heifers of Amerifax breed relative to Angus, and having a calving season of early to late March relative to late January to late February were the primary factors that were discounted.

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. 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 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 physical 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

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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 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 to 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 level-value 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 having semen rights. The current study builds on these studies in developing a model of replacement bred heifer trait level -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 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:

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

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 jth heifer characteristic used in beef production, $x_{j.}$ is the total quantity of the jth characteristic used in the production process, and v_i is the quantity of the ith 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 ith 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, the marginal contribution of a characteristic to the entire production process from one heifer is not dependent on the number of heifers in the process. Therefore, equation (1) can be re-specified as:

$$p \quad \sum_j T_j \; x_{ji} \tag{2}$$

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:

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

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 of bred heifer characteristics to determine how differences in physical and genetic characteristics, expected calf characteristics, market factors, and buyer demographics affect prices of bred replacement heifers. A Characteristic demand model, i.e., hedonic model, of heifer characteristics, market factors and buyer demographics is developed following previous work by Dhuyvetter et al. and Parcell, Schroeder, and Hiner. The dependent variable is the sale 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 buyer demographics 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:

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

Variable definitions and expected signs are presented in table 1. The cattle breed variables are separate 0 or 1 binary variables for Angus (*default*), Other British, Continental, Amerifax, and Other Breed. Parcell, Schroeder, and Hiner found significant discounts for cow-calf pair pens where the cow was a breed other than Angus. Similarly, Dhuyvetter et al. found Angus bulls received premiums relative to non-Angus bulls. In the current study, it is expected that Other British, Continental, Amerifax, and Other Breeds will sell at a discount relative to Angus giving these variables an expected negative sign.

A binary (0 or 1) color variable is included to determine whether black or mostly black cattle receive premiums over non-black cattle. Black or mostly black cattle are expected to receive premiums over non-black cattle due to expected performance differences. Dhuyvetter et al. found significant premiums for black bulls.

Cow Frame and Body Condition Score are categorized into dummy variables representing categories for small, average (*default*), and large frame and thin, average (*default*), and fat condition, respectively. It is expected that buyers will discount small frame heifers due to possible calving difficulty. Similarly, buyers are expected to discount thin conditioned heifers because of possible calving difficulty. Additionally, there may be health problems associated with small, thin, heifers. Heifers of large frame and high condition score are expected to receive discounts due to expected high feed maintenance costs after maturity. Therefore, a negative coefficient is expected for deviations in these variables from the default. 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 pen is included as a continuous variable. Heifer weight and calving performance are not correlated; yet, many producers perceive there to be a positive relationship between these factors. Thus, there is no *a priori* expectation for this variable.

Expected progeny differences (EPDs) for birth weight, weaning 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 indicate potential calving difficulties. Therefore, the birth weight EPD variable was specified nonlinearly using a squared term.[2] An increase in EPDs for weaning and 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 Central, Northeast (*default*), Northwest, South Central, Southeast, and Southwest. A binary variable for whether the pen of heifers was artificially inseminated is specified. It is expected that animals that are artificially inseminated will receive a premium over pens that were all bred naturally due to improved chances of sire identification and sire performance testing. Expected calving date was separated into three different dummy variables representing late January to late February (*default*), early March to late March, and early April to late April. Heifers expected to calve later in the year are likely to be discounted due to problems with post-partum rebreeding with first calf heifers.

The order in which the heifer pens were sold at each auction is included to determine if heifers sold earlier in the sale received a premium. Bailey, Brorsen, and Thompson; Dhuyvetter et al. Schroeder et al. (1988); and Turner, Dykes, and McKissick found that pens of feeder cattle sold later in sales were discounted over earlier pens. However, Parcell, Schroeder, and Hiner did not find sale order to be important in explaining cow-calf price variability. These value added quality heifer sales with known and consistent quality throughout the sales are likely to maintain demand and hence price better then commodity sales giving an expected postive coefficient.

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 a quadratic price relation for pen size. Therefore, pen size is specified as a quadratic in this model. It is expected pen size representative of the typical cull rate for Missouri cow-calf producers.

At the conclusion of each sale buyers were surveyed to determine various demographic factors about their operation. Information from this survey is used in this study. The distance that the buyer traveled to the sale is specified as a binary variable equaling one if the buyer traveled over fifty miles. It is expected that buyers traveling a greater distance will pay more for

[2] To allow squaring negative values associated with the birth weight EPD, an average birth weight of seventy pounds was added to the variable.

heifers. This is due to the opportunity costs of attending the sale and being outbid, and buyers traveling further are expected to perceive the quality differences in these cattle over commodity cattle thus investing in the trip and giving a positive coefficient. Finally, buyer herd size is specified as a dummy set equal to one of the buyer has over seventy cows with no *a priori* expectation on this variable.

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 auction sales from October 31, 1998 to January 13, 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. A total of 103 pens were eliminated due to incomplete data on heifer expected progeny difference for calves and due to some pens of heifers requiring a clean up bull that had not EPD score records. This criteria yielded a total of 227 pens used in the estimation of the hedonic price model. Frame score was scored by USDA graders present at each sale.

The empirical model specified in equation 4 was estimated in *SHAZAM* 8.0. Two alternative functional forms, linear and semi-log, were estimated and data compatibility was tested (nonnested) using the Davidson and MacKinnon *P*-test[3]. 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 proportions matrix (Belsley, Kuh, and Welsch). Degrading collinearity was observed between sale dummy variables and maternal milk EPD. The focus of this study was on characteristic value differences and not differences in price associated with sale location; therefore, this was not a concern. The Jarque-Bera test statistic was computed to test the residual series for normality. Under the null-hypothesis of normality, the test statistic is distributed Chi-square with two degrees of freedom. The computed *P*-value for the test statistic was 0.08, indicating the residuals are distributed normally.

Regression results from the estimation of equation 4 are reported in table 3. The explanatory variables explained 47% 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 0.10 level.

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

Genetic and physical characteristics

Black and mostly black pens of heifers received a $29.46/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 $0.36. While the animal weights were recorded for analysis purposes, the actual weights were not available to the buyers until after the sale. This result suggests buyers perceive weight and heifer calving performance to be positively correlated, which is inconsistent with research. Apparently, producers need to be better educated about this relationship.[4]

There was no statistical difference between the price paid for small and large frame pens relative to medium frame pens. Similarly, prices for pens with thin and fat heifers were not significantly different from medium frame pens. 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. As summary statistics indicate, for the current study heifer pens sold were typically of large frame and above average condition. Heifer pens of Continental breed received a $67.74/head premium relative to Angus. Heifer pens of Amerifax breed received a -$36.05/head discount relative to Angus Breed.

Expected progeny differences

Birth weight EPD and birth weight EPD squared were both statistically significant and of the expected sign. As expected, heifer pens with birth weight EPD's deviating from zero were discounted (figure 1). 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. Weaning and yearling weight EPD's were not significant 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.

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. Heifers per pen and heifers per pen squared were statistically significant and of the expected sign. Furthermore, the value of one additional heifer in the pen increased up to ten heifers per pen and declined thereafter (Figure 2). Parcell, Schroeder, and Hiner found similar results for the case of cow-calf pairs in a pen. Furthermore, the magnitude of the impact in the current study is nearly identical to that estimated by Parcell, Schroeder, and Hiner. The average herd size in Missouri is near 35, a cull rate of 20% would require replacing 7 cows per year. Typically, producers will initially replace about 1.5 times their expected need to allow for more critical selection. Therefore, the optimal number of ten heifers per pen found in this study suggests these producers were attempting to buy all of the replacement candidates from a single

[4] An extension program incorporating results of this study addressed this topic

source. Artificial insemination had no significant impact on heifer pen price. Additionally, order sold was not significant in determining price differentials between heifers. Parcell, Schroeder, and Hiner found similar results for sale order of cow-calf pairs.

Buyer characteristics

As expected, buyers further from the sale paid a premium relative to buyers near the sale. Buyers further than fifty miles from the sale location paid a premium of $16.38/head. Buyers with more than seventy head of cattle paid $18.26/head less than buyers with smaller herds. Buyers with larger herds may have bid on pens with more heifers; thus, reducing competition because smaller producers would not be interested in larger pens. The average herd size of the Missouri cow-calf producer is about thirty-five.

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, marketing factors, and buyer characteristics. Results indicated heifers premiums were received for pens of heifers having ten animals, black in color, and offspring having an expected progeny difference for birth-weight near zero. Pens of heifers of Amerifax breed relative to Angus, having a calving season of early to late March relative to late January to late February, and an increase in the offspring expected progeny difference for maternal milk were discounted. Furthermore, buyers traveling greater distances to the sale paid premiums for heifers; however, buyers with larger herds paid less for heifers.

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 the 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. One of the initial steps in this process is finding breeding stock of know quality. Therefore, buyers and sellers of bred replacement heifers need information on the trait-value relationships to make good management decisions.

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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* ($/head)	
Physical and genetic characteristics		
Color	Color dummy variable = 1 if heifer is black; = 0 o.w.	+
Weight	Average heifer weight (lbs)	?
Frame$_f$ [a]	Frame binary variables = 1 if heifer has frame *f*; = 0 o.w. *f* = 1,2,3; default = 2; where 1 is M0 to M90 (Small), 2 is L0 to L50 (Medium) and 3 is L60 to L90 (Large).	
Condition$_m$	Condition binary variables = 1 if heifer is condition *m*; = 0 o.w. *m* = 1,2,3 default = 2; where 1 is thin, 2 is average, and 3 is fat	
Breed$_j$	Breed binary variables = 1 if heifer is breed *j*; = 0 o.w. *j* = Angus, Other British, Continental, Amerifax, Other Breed default = Angus	
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	
Weaning weight	Expected progeny difference of sire for weaning weight of calf	+
Yearling weight	Expected progeny difference of sire for yearling weight of calf	+
Maternal milk	Expected progeny difference of sire for maternal milk of calf	+
Marketing factors		
Sale$_k$	Sale binary variables = 1 if heifer sold at sale *k*; = 0 o.w. *k* = Central, Northeast, Northwest, Southeast, South central, and Southwest; default = Northeast	?
Artificially inseminated	AI dummy variable = 1 if heifer artificially inseminated; = 0 o.w	+
Order	Order pen was sold in sale *k*	
Head	Head per pen	+
Head squared	Head per pen squared	
Expected calving period$_t$	Calving period binary variables =1 if heifer is to calve in period *t*; =0 o.w. *t* = late January to late February (default), early March to late March, and early April to late April	
Buyer characteristics		
Buyer miles	Buyer miles traveled to sale binary variables = 1 if greater than fifty miles; =0 o.w.	+
Buyer cows	Head of cows owned by buyer =1 if greater than seventy head; =0 o.w.	?

[a] Based on USDA grading for frame

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

Characteristic	Average	Standard Deviation	Minimum	Maximum
Price ($/head)	779.38	85.93	560	990
Color (Black)	0.65	0.48	0	1
Head Per Pen	3.95	2.65	1	16
Weight (lbs.)	980.21	97.81	750	1290
Artificially inseminated	0.65	0.48	0	1
Frame[a]	2.64	0.56	1	3
Body condition score[b]	2.37	0.55	1	3
Calving Season[c]	1.77	0.79	1	3
Buyer miles traveled[d]	1.48	0.50	1	2
Buyer cows owned[e]	1.27	0.45	1	2
Birth weight EPD	0.19	1.20	-3	2
Weaning weight EPD	30.76	9.02	7.40	53
Yearling weight EPD	59.08	16.06	5	89
Maternal milk EPD	18.24	6.88	2	34

[a] Heifer frame graded as small=1, medium=2, large=3

[b] Heifer body condition score graded as thin=1, average=2, fat=3

[c] Expected heifer calving season recorded as late January to late February=1, early March to late March=2, early April to late April=3

[d] Buyer miles traveled recorded as less than fifty miles=0 and greater than fifty miles=1

[e] Buyer cattle owned recorded as less than seventy=1 and greater than seventy=2

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

Characteristic	Coefficient	t-stat
Genetic and physical characteristics		
Color dummy variable, =1 if Black	29.46**	2.67
Weight	0.36**	6.55
Frame dummy variable (*default* = medium)		
Small	12.67	0.58
Large	4.15	0.37
Body condition score (*default* = average)		
Thin	5.95	0.26
Fat	8.18	0.85
Breed dummy variable (*default* = Angus)		
British other than Angus	23.26	0.70
Continental	67.74**	2.68
Amerifax	-36.05**	2.31
Other	-13.61	1.32
Expected progeny differences		
Birth weight	917.23**	2.32
Birth weight squared	-6.57**	2.38
Weaning weight	0.86	1.13
Yearling weight	-0.14	0.31
Maternal milk	-2.22**	2.94
Marketing factors		
Regional dummy variable (default = Notheast)		
Central	3.48	0.22
Northwest	-147.25**	6.76
Southeast	68.91**	4.02
South central	-6.18	0.33
Southwest	-79.80**	4.63
Head/pen	26.73**	5.24
Head/pen squared	-1.29**	3.33

Note: One and two asterisks indicate coefficients significantly different from zero at the 0.10 and 0.05 level.

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

Characteristic	Coefficient	t-stat
Artificial insemination dummy variable, = 1 if AI	6.90	
Order sold	0.10	
Calving Season (default = late January to late February)		
Early March to late March	-22.461*	-1.884
Early April to late April	-7.493	-.047
Buyer characteristics		
Buyer distance dummy, =1 if more than fifty miles	16.38*	1.93
Buyer cows owned, =1 if more than seventy head	-18.26*	1.84
Constant	-31667**	
F-statistic	1336**	
R – squared	0.47	
Number of observations	227 pens	896 head
Mean of dependent variable	$779.38/head	

Note: One and two asterisks indicate coefficients significantly different from zero at the 0.10 and 0.05 level.

Figure 1. Effect of Birth Weight EPD on Price Per Bred Heifer

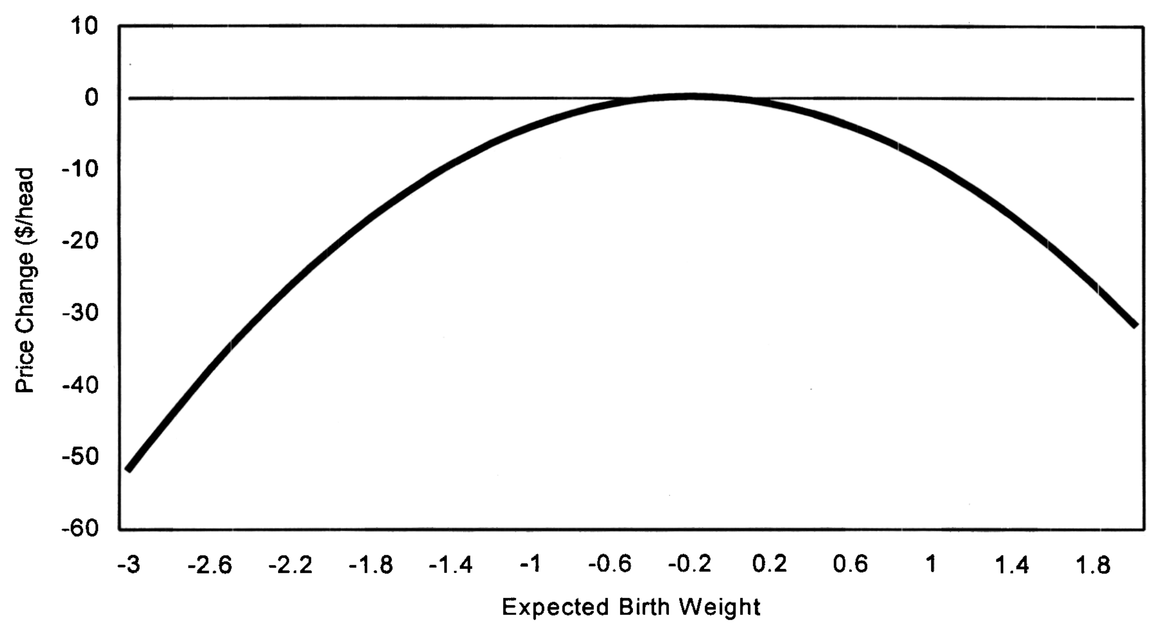

Figure 2. Effect of Number of Heifers Per Pen on Price Per Bred Heifer