Hedonic Pricing of Bulls

By

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Abstract

Bulls account for half of the genetic input when making improvements in cattle herds. Therefore, to make a rapid, less costly improvement a cattle producer is more likely to change bulls than cows. One of the problems that breeders who supply bulls face is that the attributes of bulls come bundled together so that it is difficult to determine what the value of improvements in a bull might be worth. This research estimates what values beef producers implicitly place on particular characteristics when deciding which bull will best fit the needs of their farm. A hedonic pricing model was estimated using actual transaction data and reveals the value buyers of bulls implicitly place on specific traits. For example, a ribeye area of 12.8 in^2 at the mean sale price reveals a buyer would be willing to pay an additional $80.39 for a bull with an additional square inch. Likewise, a bull with a 1242 lb. 365-day weight at the mean sale price reveals a buyer would be willing to pay an additional $1.83 for an additional pound. Therefore, this research reveals an incentive for bull producers to focus on improving the genetic make-up of their bulls they offer for sale.

Acknowledgements

I wish to express my sincerest appreciation to my honors advisor, Dr. Ken Foster. Dr. Foster's patience and willingness to help me succeed in the program have made this experience not only challenging, but truly rewarding. I would also like to thank Dr. Christine Wilson for her help in placing me in the Honors Program and answering my questions. The entire faculty and staff in the Department of Agricultural Economics at Purdue University are great. I appreciate all the help and advice I have received from the faculty while studying at Purdue University.

Finally, I want to thank my parents for supporting me and helping me develop my interest in agriculture. It was through that interest that I was able to decide what to study while in college. In addition, they helped me develop into the hardworking individual I am. I truly appreciate all that my parents have done for me in the past and will do for me in the future.

Beef producers depend heavily on their bulls when making genetic improvements in their herds. Bulls account for more rapid improvements in heritable traits in cattle, because it is less costly to change bulls than cows since a single bull sires multiple offspring each year. For example, 85-90% of the genetics within a herd comes from bulls used in the last three generations assuming that replacement heifers are kept each year (Lemenager, 2005). That is why the selection of a new herd bull is an important aspect of beef production. During that process, a beef producer evaluates different bulls looking for desirable characteristics that will be passed on to offspring hoping their selection will result in a more profitable herd. This is of even more concern because there was a decline of 65.9% in retail beef demand from 1976 to 1999 (Marsh, 2003). In 1980, the per capita consumption of retail beef was 76.4 pounds; however, by 2003 it had fallen to 64.9 pounds per person (United States, Food, 2006). At the same time that demand declined, there was a shift in the beef industry towards the promotion of differentiated and value added products, such as Certified Angus Beef, Laura's Lean, and organic beef, where quality standards are set in order to be included in that product line. Producers of these specialty products place greater emphasis on bull selection in order to meet the certified beef program requirements. Consumer demand also seems to have changed with greater emphasis on lower fat and lower cholesterol intake. This, in turn, causes cattle producers to pay more attention to the consumptive attributes of the animals they produce. One of the problems faced by both, the breeders who supply bulls and the purchasers of bulls is that the attributes of bulls come bundled together so that it is difficult to determine what the value of specific improvements in a bull might be worth.

Consequently, it is difficult for them to make sound economic decisions concerning trade-offs between competing genetic improvements.

A value for a specific attribute of a bull can be found within the bundled price through the use of hedonic pricing and regression analysis. This approach allows one to estimate the values that beef producers implicitly place on particular characteristics, such as consumptive[1] and productive[2] traits, when deciding which bull will maximize profit from cattle production on their farm. By knowing what traits producers value most, a bull producer would then be able to focus his/her efforts on producing bulls that are of greater value to the buyer. In addition, buyers of bulls might be able to use this information to avoid overpaying or to avoid offering a price that is too low and miss an opportunity. Therefore, the purpose of this research is to estimate the value cattle producers implicitly place on both productive and consumptive traits of bulls when they make purchases. Such information in turn, can help bull producers focus their efforts on producing bulls with more desirable traits.

Hedonic Pricing Theory

Hedonic pricing posits that the price of a good is the combination of the values of the individual characteristics that make up that good. Therefore, a good is a collection of characteristics that are sold as one basic unit for one observed price. The overall price of the good consists of the sum of the values of the individual characteristics.

When the attribute price is not revealed directly, it is said to be an implicit price. It is the unobservable nature of bull attributes for example that makes applied research such as this paper necessary. Researchers can estimate implicit prices using statistical

[1] Consumptive traits are those traits which deal with the edible beef product.
[2] Productive traits are those traits that deal with growth and performance of the animal.

methods such as regression analysis. While the values of attributes that bulls possess are not directly observed, comparing the observed prices paid for bulls with different attributes allows for estimation of the implicit prices that buyers were willing to pay for the various attributes. In the case of beef producers (the buyers of bulls), they are able to understand what traits are good for a bull to possess. These producers respond to prices and premiums that reflect the derived demand for cattle in the packing industry and deduce the values of consumptive traits such as ribeye area. The original source of this value information is the consumer making purchases in the retail outlet. The retailer uses this information about consumer demand when purchasing beef from a packer. The packer then takes the derived demand for quality products and learns to identify what cattle have those desired characteristics and offer premiums accordingly.

In the case of productive traits, a producer would be able to recognize the desired traits through lower cost of production. For example, if it takes less feed to get cattle to market weight, then producers would recognize the decrease in feed cost due to more rapid rate of gain and better feed conversion. To the extent that the use of a bull improves such performance among its offspring, the producer would pay a marginally higher price while all else is held constant for this greater profit potential.

Literature Review

Hedonic pricing has been used in numerous livestock studies that have looked at how a group of items are bundled together and valued based on the grouped attributes. One of the more recent studies that used hedonic analysis to evaluate the price of an Angus bull as a function of actual production measures, production EPD, ultrasound EPD, marketing factors, sire, and sales was conducted by Dhuyvetter, et al. (2005).

Other recent research was conducted by Lawrence and Yeboah (2004) that examined how source verification of feeder cattle is important. Regressions were estimated separately for calves that were grouped in different weight classes and genders to take into account the differences. Likewise, hedonic analysis was used by Holt et al. (2004), to see what characteristics producers based their purchasing decision on when buying a bull. In their model, conformation ratings were included. Their final conclusions consisted of finding that producers want bulls that are heavy in weaning and yearling weights, while having a low birth weight.

McDonald and Schroeder (2003) used hedonic pricing models to explain the inconsistency that is achieved when looking at profit per head for fed cattle that are sold on a grid basis. An additional hedonic pricing study conducted by Coatney, et al. (1996) estimated price determinants of feeder cattle in 2,441 sale lots and 790 no-sale lots. Hedonic pricing was also used to estimate the value of quality improvements in swine breeding stock in research conducted by Walburger and Foster (1994).

Model, Methods, and Data

Using hedonic pricing and regression analysis, we can estimate the value of specific attributes of a bull from within the bundled price. The regression would treat the price of the bull as a function of various traits. The traits would consist of productive, consumptive, and physical traits.

Certain traits are expected to have a specific effect on the price of a bull. In the case of rib fat, one expects that an additional unit of fat would have a negative effect on bull price because consumers view fat with disfavor. Traits that have this effect are those for which having a lower value is desirable, such as birth weight. Likewise, it is expected that the larger the ribeye area, the higher the price of the bull. The reason being because it is more desirable to have a larger ribeye in hopes that this trait will be passed on to offspring thus increasing their market value. Other traits that are expected to have a positive influence on the price of a bull would include average daily gain, Angus genetics (due to the Certified Angus Beef Program), and hide color.

The regression will be estimated using data from the biannual Indiana Beef Evaluation Program (IBEP) sale and the characteristics of those bulls provided from the recorded information. The data extend from the fall 1998 sale through the fall 2005 sale and consist of 1145 bulls sold in an auction format. The bulls in this data consist of Angus, Charolais, Simmental, Hereford, Chiangus, Limousin, Maine Anjou, Red Angus, Gelbvieh, Salers, Gelbvieh Balancer, Shorthorn, and crossbred Angus bulls and come from various producers. Descriptive statistics for the variables included in the regression analysis is included in figure 1.

In the estimated model, the productive traits included were 365-day weight, birth weight, and average daily gain. Consumptive traits that were included are intramuscular fat, ribeye area, and rib fat. A binary variable was used to include breed information into model. Based on the suggestion by Professor Ronald Lemenager (Purdue University Animal Scientist), the model is estimated comparing all other breeds to Angus. Within the data, 75% of the bulls were Angus. Binary variables for each sale were also used. The sale binary variable for the fall 2005 was omitted to avoid the dummy variable trap. This sale consisted of 44 bulls.

When estimating the model, natural logarithmic transformations were used on all variables (except binary variables). This was done to allow the implicit prices of attributes to vary with the amount of the attribute present as a result of diminishing returns associated with the level of the attribute. The following discussion of the ribeye area variable provides a good example of this concept. Producers' value ribeye area because it gives rise to more and higher valued retail product. Therefore, when selecting a bull to increase the size of the ribeye in cattle they produce, buyers are expected to pay more for an additional square inch of ribeye area. When the bull has a small ribeye, the buyer would be more willing to pay more for one additional square inch of muscling than if the ribeye is already large. Thus, once the ribeye area gets large, buyers are willing to pay less for an additional square inch of ribeye area. This situation results in a downward sloping relationship between the marginal increment in value for the bull for an increase in ribeye area (the implicit price of ribeye area) as the ribeye area gets larger (figure 3). Essentially, this downward sloping curve maps out the demand for ribeye area in bulls. A linear specification of the hedonic regression would result in a constant marginal value of ribeye area for any size.

The model was tested for heteroskedasticity using the White Test in EViews. Using a significance level of 0.01, the model was found to be heteroskedastic. To adjust the model for heteroskedasticity, the White Heteroskedasticity-Consistent Standard Errors & Covariance internal program within EViews was used.

Mathematically, the hedonic regression for bull price can be represented by

$$\ln P_i = a_o + \sum_{j=1} a_j Sale_j + b_1 Angus_i + b_2 \ln(BirthWeight_i) + b_3 \ln(365Weight_i) + b_4 \ln(Ribeye_i) + b_5 \ln(Ribfat_i) + b_6 \ln(IMFat_i) + b_7 \ln(ADG_i) + \varepsilon_i$$

where P_i is the auction price of the i^{th} bull, $Sale_j$ is the binary variable indication the j^{th} sale date, $Angus_i$ is the binary variable that indicates whether or not the i^{th} bull is an

Angus bull or not, $BirthWeight_i$ is the birth weight of the i^{th} bull, $365Weight_i$ is the weight of the i^{th} bull at 365-days, $Ribeye_i$ is the ribeye area of the i^{th} bull, $Ribfat_i$ is the rib fat depth of the i^{th} bull, $IMFat_i$ is the intramuscular fat of the i^{th} bull, ADG_i is the average daily gain of the i^{th} bull, ε_i is the random error term for the i^{th} bull, ln represents the natural logarithm transformation, and the a's and b's are the regression parameters to be estimated.

In order to compute the implicit prices of continuously measured attributes from this regression, it is necessary to revisit some calculus and compute the marginal contribution of the attribute to the price of the bull. That is, one must compute the $\frac{\partial \ln P}{\partial \ln A}$, where A could represent any of the continuously measured attributes in the hedonic regression above. While the necessary derivative is in the levels of the variables, the hedonic pricing model will be estimated in the logarithms. Thus, some additional manipulation is required. In order to start with the manipulation, it is important to realize that $\frac{\partial \ln P}{\partial \ln A}$ is equal to $\frac{\partial P}{\partial A} \times \frac{A}{P}$, which is b_a in terms of the hedonic regression posited above. Through algebraic manipulation one finds that $\frac{\partial P}{\partial A} = b_a \times \frac{P}{A}$, where $\frac{\partial P}{\partial A}$ is the implicit price of variable A, b_a is the coefficient associated with variable A, P is the Price of the bull, and A is the specified attribute. The mean of the bull price provides a convenient place to compute the implicit price of the various attributes for different levels of the attribute within its observed range.

Results

The results of the estimation are presented in figure 2. Looking at the coefficients for each of the specified sale variables, it is important to note that due to the negative value for each coefficient, it means that each test had prices that were on average, lower than the average price for the fall of 2005, except the fall of 2004. Part of this may be due to the changes in minimum bids between sales. The minimum bid was raised to $1100 in the spring 2001 and raised again in spring of 2004 to $1200. Prior to spring 2001, the minimum bid was $1000. It is also possible that these sale date terms account for changing profitability in cattle production as cattle and feed prices changed over time. The general upward trend in the coefficients for each of the specified sale variables could also be due to changes in the marketing system that has re-oriented to meet the demands of the end consumer.

The ribeye area coefficient is positive, which means that buyers value a larger ribeye area more than a smaller one. Figure 3 shows a graph of the implicit price of ribeye area that reveals the value a buyer would be willing to pay for an additional square inch of ribeye area at the mean sale price of $1838.36. Interpreting it for a specific value such as a 12.8 square inch ribeye would reveal that a buyer would be willing to pay an additional $80.39 for a bull with an additional square inch of ribeye area. As the plot in figure 3 clearly shows, if the bull possessed a smaller ribeye, a buyer would be willing to pay more for an additional square inch, ceteris paribus. Likewise, if a bull possessed a larger ribeye, a buyer would be willing to pay less for the additional square inch. It is important to note that the implicit price should only be calculated for the values that fall within the range of ribeye areas that are included in the data. That range was 9.3 to 19.4

square inches. Anything outside this range should not be used to calculate the implicit price of ribeye area because it may not be accurately depicted by this regression. This is true for all of the attributes and their range of values can be found in figure 1.

The rib fat variable is estimated by ultrasound at the 12^{th} rib and adjusted based on the breed. A positive coefficient was estimated by the regression analysis. Figure 4 is a graph of the implicit price of rib fat varying from 0.08 to 0.67 inches at the mean sale price. If interpreted at the value of 0.32 inches of rib fat, the buyer would be willing to pay an additional $534.27 for a bull that has one more inch of rib fat. Figure 4 reveals that if the bull possessed a smaller amount of rib fat, a buyer would be willing to pay more for an additional inch, ceteris paribus. Likewise, if a bull possessed more rib fat, a buyer would be willing to pay less for an additional inch. A surprising result revealed by the graph is that buyers value a bull that has some rib fat because there is a large amount of over $2000 given to an additional inch of rib fat if the bull only has 0.08 inches at the mean sale price. This indicates that buyers prefer bulls that have some additional weight due to the fat instead of being extremely lean animals.

Intramuscular fat is associated with a positive coefficient of 0.159 in the regression analysis. This is consistent with the notion that buyers want a bull that possesses some intramuscular fat but do not want one with too much. When looking at the graph of the implicit price of intramuscular fat in figure 5 and selecting a bull with an intramuscular fat percentage of 3.76 at the mean sale price, you can tell a buyer would be willing to pay an additional $77.74 for a bull with another percentage of intramuscular fat. If a bull possesses a smaller percentage of intramuscular fat, a buyer would be willing to pay more for an additional percentage, ceteris paribus. Similarly, if a bull possesses more intramuscular fat, a buyer would be willing to pay less for an additional unit of intramuscular fat, ceteris paribus.

The 365-day weight is a productive trait that is associated with the end test weight adjusted to 365 days of age and for the age of the dam. The positive coefficient associated with the 365-day weight is used to reveal the plot of the implicit price of the 365-day weight in figure 6 at the mean sale price. Interpreting it for a specified value such as 1242 pounds reveals that a buyer would be willing to pay an additional $1.83 for a bull with one more pound assuming everything else remains constant. As the plot in figure 6 shows, if a bull possessed a lighter weight, a buyer would be willing to pay more for an additional pound, ceteris paribus. Likewise, if the bull was heavier, a buyer would be willing to pay less for an additional pound, ceteris paribus.

The productive trait of average daily gain is based on the daily weight gain the bull had during the 125-day test. It allows a buyer to identify a bull that could pass on traits that would result in faster growing offspring. Therefore, the coefficient associated with the average daily gain variable is positive and results in the graph of the implicit price that is showed in figure 7. In the specific case of a 3.88 average daily gain, a buyer would be willing to pay an additional $486.60 for a bull with one more pound of daily gain at the mean sale price of $1838.36. As seen in figure 7, if a bull possessed a lower average daily gain, a buyer would be willing to pay more for an additional pound of daily gain, ceteris paribus. Equally, if a bull possessed a higher average daily gain, a buyer would be willing to pay less for an additional pound of daily gain, ceteris paribus.

The coefficient associated with the birth weight variable is negative which reveals that buyers prefer a smaller birth weight than a heavier one. The smaller birth weight is desired due to its association with calving ease. However, a buyer does not want a calf that is so light weight that its potential to survive is jeopardized. Figure 8 looks at the implicit price of birth weight within the acceptable range of the test data at the mean sale price. The plot can be interpreted by selecting a specific birth weight such as 75 pounds and realizing that a buyer would be willing to pay $12.40 less if the bull weighed one more pound heavier at birth. Therefore, if a bull possessed a birth weight that was heavier than 75 pounds, a buyer would be willing to pay a smaller amount less for an additional pound of birth weight, ceteris paribus. Likewise, a buyer would be willing to pay a larger amount less for an additional pound of weight at birth if the bull possessed a birth weight that was smaller than 75 pounds within some reasonable range. In all likelihood this pattern emerges from the data because bulls that were "too" light to survive are not sampled.

The Angus binary variable is associated with the positive coefficient of 0.079, which means that producers value a bull with Angus genetics more than one that is of different breeding. The implicit price of Angus genetics is revealed by multiplying the coefficient associated with the Angus binary variable by the various sale prices within the range of sales prices in figure 2. Figure 9 shows a graph of the implicit price of Angus genetics which reveals that buyers would be willing to pay an additional $221.20 for a bull that has Angus genetics if they were already paying $2800 for the bull. As the graph shows, the more a buyer is paying for a bull, the more they would be willing to pay for the bull to be of Angus genetics, ceteris paribus. Likewise, the less a buyer is spending on the bull, the less they would be willing to pay for the bull to be of Angus genetics.

Conclusions and Implications

A hedonic pricing model was developed to look at how beef producers value specific traits in a herd bull. Productive, consumptive, and physical traits were evaluated to determine the implicit price that buyers place on the specified trait. It revealed that buyers would be willing to pay a smaller amount more for each additional unit of ribeye area, rib fat, intramuscular fat, average daily gain, and 365-day weight each independently. Likewise, a buyer would be willing to pay a smaller amount less for an additional pound of weight at birth. The model also revealed that buyers are willing to pay more for a bull that possess Angus genetics. Therefore, this provides an incentive for producers of bulls to focus in improving the genetic make up of their bulls that they offer for sale. If a bull producer knows their individual marginal cost for producing a unit increase of a bull trait, then they can compare this to the implicit price for that trait for bulls of the type that they produce. Successive comparisons across traits will lead to a strategy for the bull producer of allocating scarce resources to those traits where the marginal revenue for an attribute (its implicit price) most greatly exceeds the marginal cost of making the improvement.

Both the buyers and the sellers of the bulls can use the information provided to improve the genetic base of the cattle being produced. By purchasing bulls that possess a specified trait, cattle producers will see the improvement made in the area of that trait over time in their offspring they produce for market. Bull producers can use the information to determine what traits would be beneficial to focus on improving in order to produce higher valued bulls. Ultimately the improvements made, both by the buyers and sellers, will result in meat that is available to consumers that are more desirable.

Appendix

Figure 1.

Summary of Statistics for Bull Price and Variables Included in the Hedonic Pricing Model

Variable	n	Mean	Std. Dev.	Minimum	Maximum
Sale Price ($)	1145	1838.36	792.88	1000	7200
Productive Traits					
Birth Weight (lbs)	1143	83.78	9.85	45	116
365-day Weight (lbs)	1145	1273.87	91.53	892	1601
Average Daily Gain (lbs per day)	1145	3.94	0.39	2.68	5.37
Consumptive Traits					
Ribeye Area (in^2)	1145	13.23	1.45	9.3	19.4
Rib Fat (in)	1145	0.29	0.09	0.08	0.67
Intramuscular Fat (%)	1145	3.05	0.75	1.26	6.98

Figure 2.

Estimated Coefficients of the Hedonic Pricing Model for Bull Characteristics

Variable	Estimated Coefficients	t-Statistic
Fall 1998	-0.582 ***	-10.36
Spring 1999	-0.457 ***	-9.87
Fall 1999	-0.576 ***	-10.68
Spring 2000	-0.301 ***	-6.68
Fall 2000	-0.251 ***	-4.46
Spring 2001	-0.254 ***	-5.84
Fall 2001	-0.308 ***	-5.77
Spring 2002	-0.346 ***	-8.12
Fall 2002	-0.443 ***	-9.96
Spring 2003	-0.394 ***	-8.88
Fall 2003	-0.182 ***	-3.70
Spring 2004	-0.111 ***	-2.62
Fall 2004	-0.034	-0.61
Spring 2005	-0.265 ***	-6.13
Angus	0.079 ***	3.42
Birth Weight	-0.507 ***	-6.80
365-day Weight	1.236 ***	7.81
Ribeye Area	0.560 ***	6.63
Rib Fat	0.094 ***	3.19
Intramuscular Fat	0.159 ***	3.81
Average Daily Gain	1.027 ***	9.01
Constant	-1.814 *	-1.71
R^2	0.436	

*** Significant at the 0.01 level
** Significant at the 0.05 level
* Significant at the 0.10 level

Figure 3.

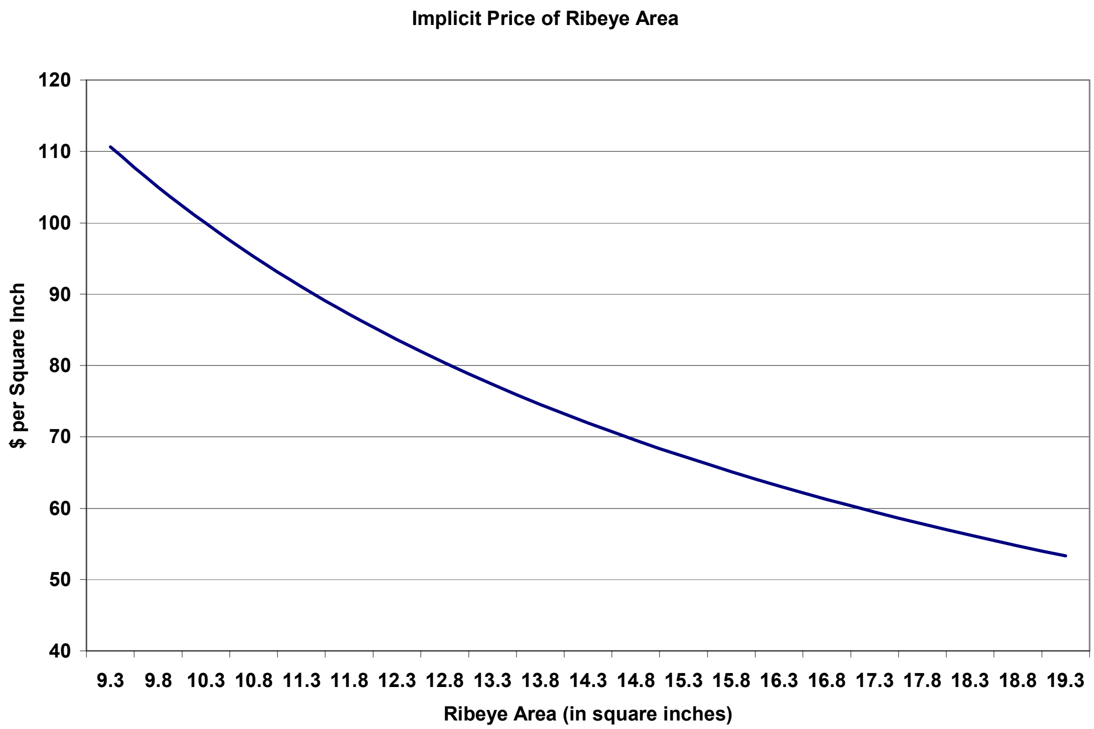


Figure 4.

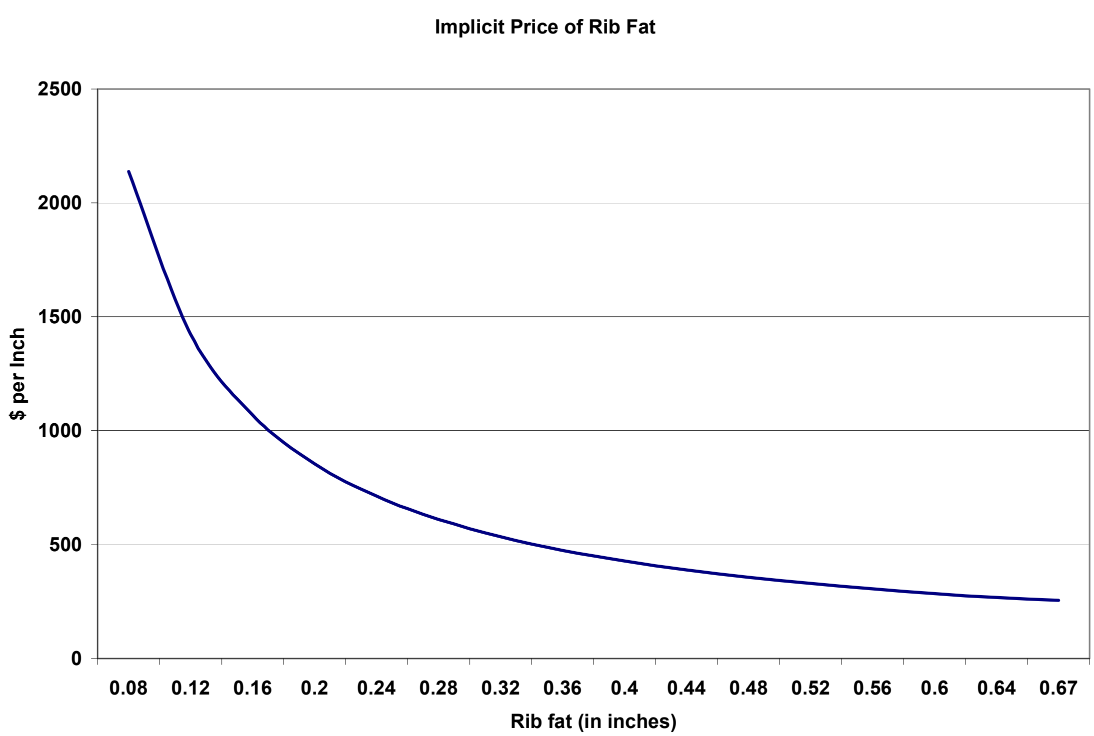


Figure 5.

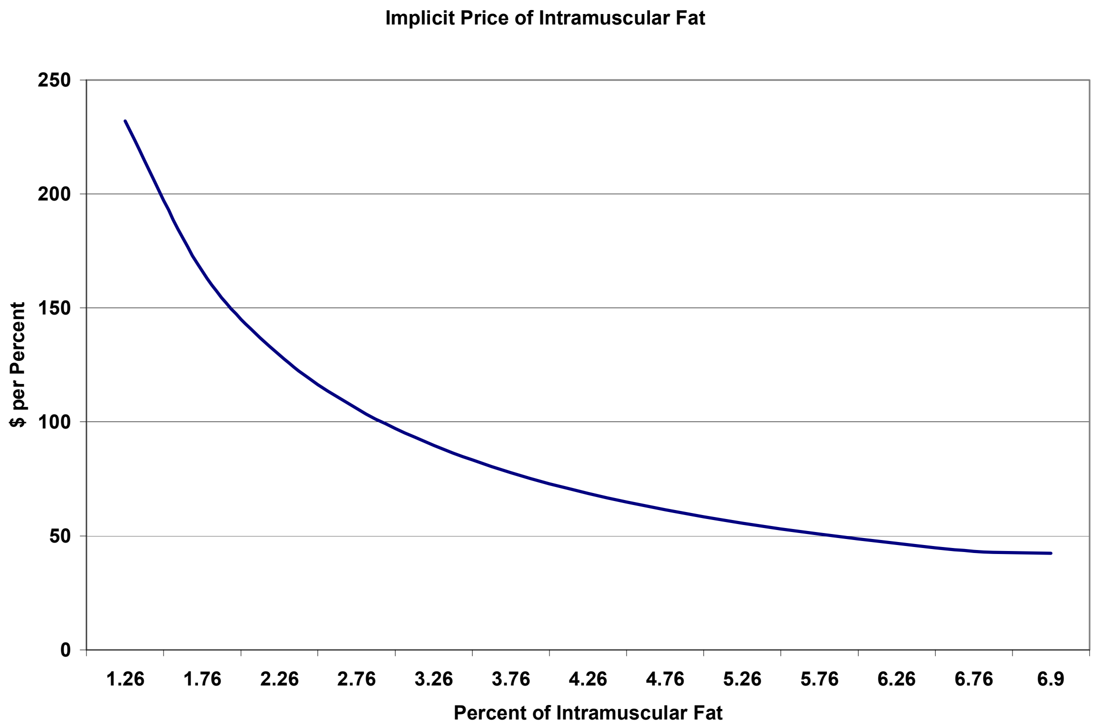


Figure 6.

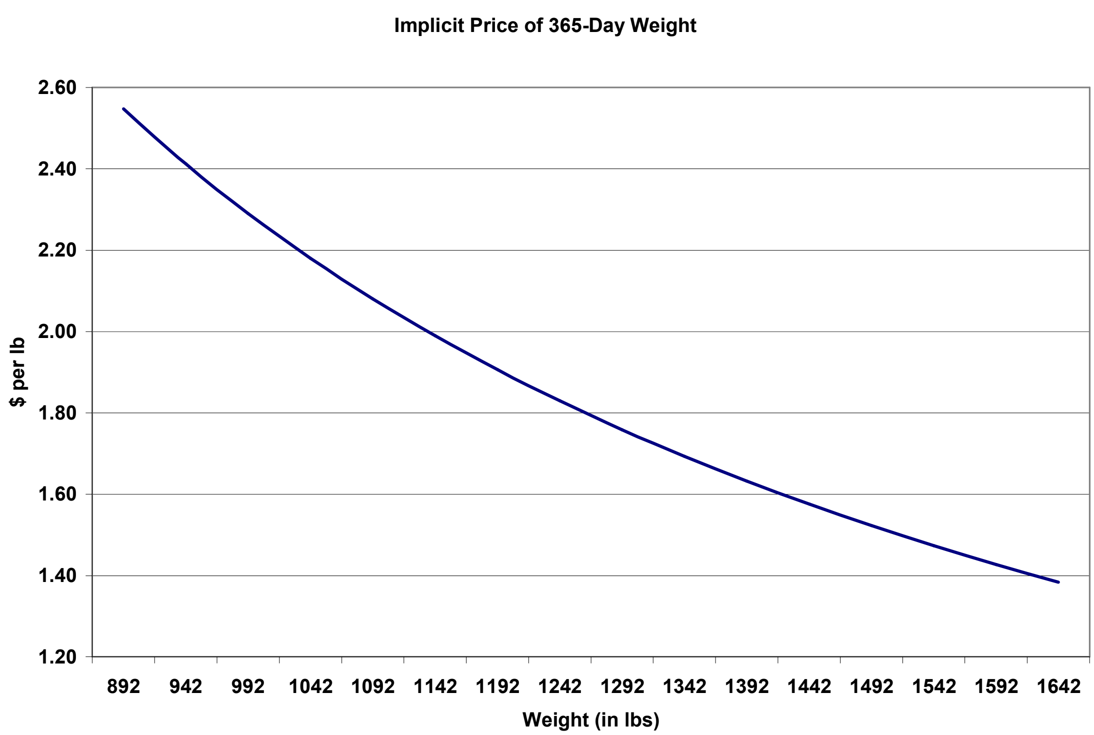


Figure 7.

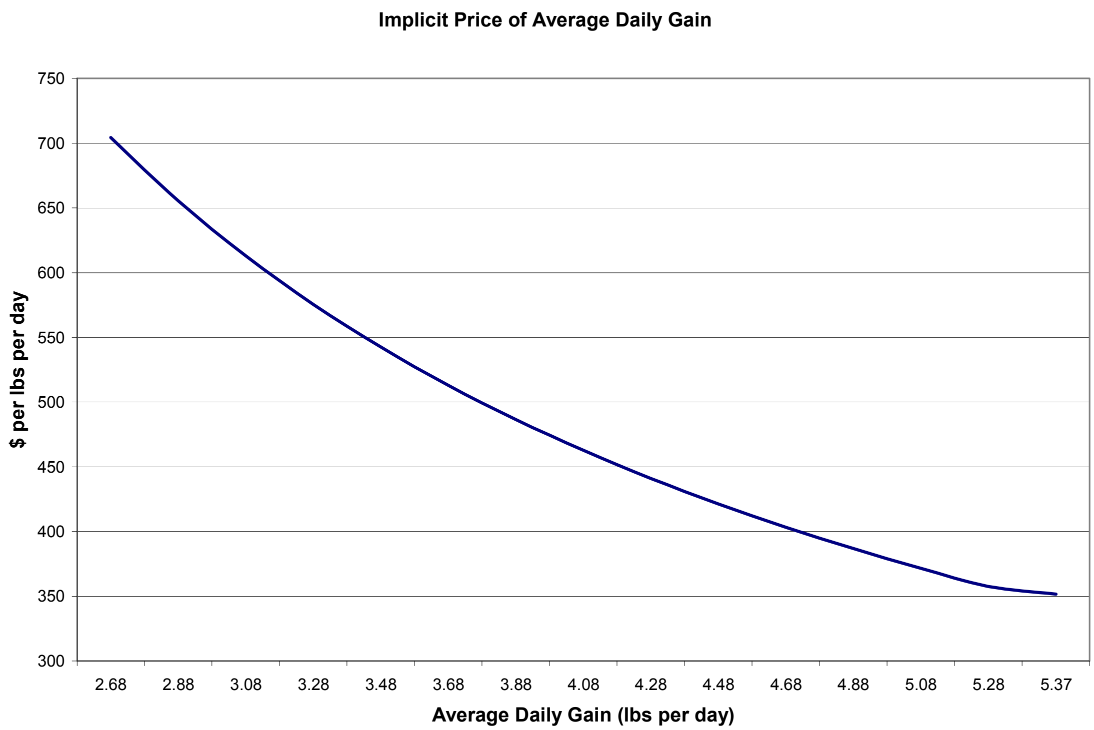


Figure 8.

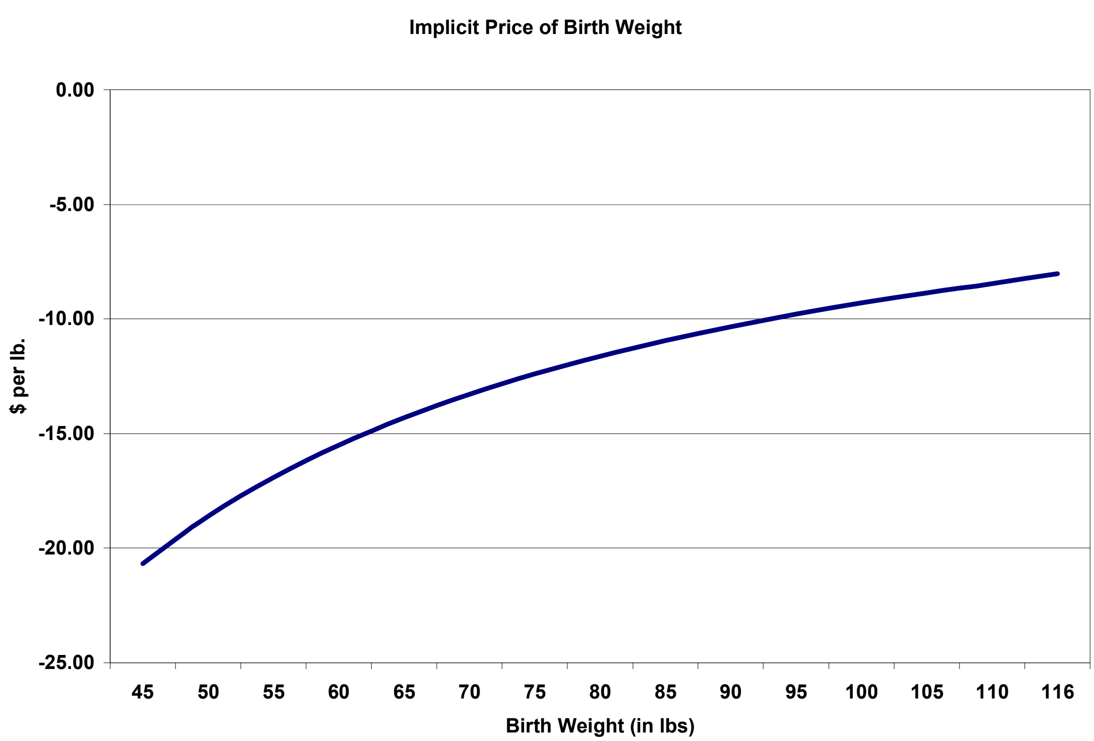
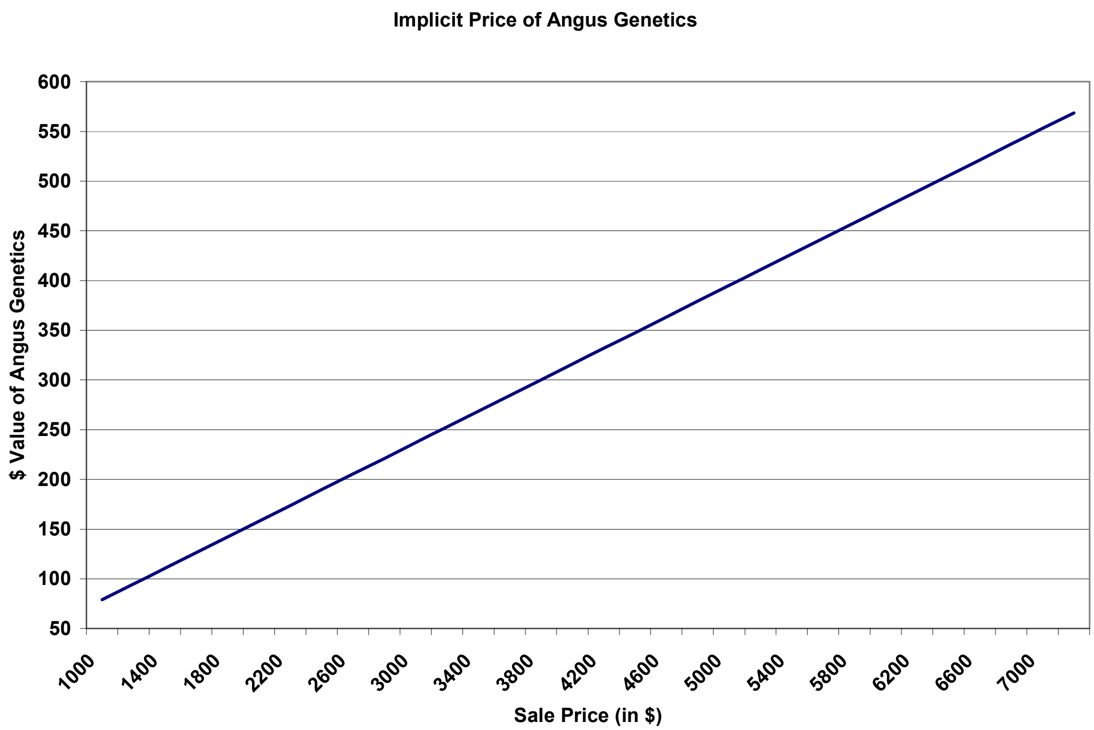


Figure 9.


Implicit Price of Angus Genetics
$ Value of Angus Genetics
600
550
500
450
400
350
300
250
200
150
100
50
1000
1400
1800
2200
2600
3000
3400
3800
4200
4600
5000
5400
5800
6200
6600
7000
Sale Price (in $)

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