# Relationship between Attributes of Beef Cattle Raised Using Ultrasound Technology and Prices received at the Packers: A Hedonic Price Analysis

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*Abstract:* **Relationship between Attributes of Beef Cattle Raised Using Ultrasound Technology and Prices received at the Packers: A Hedonic Price Analysis**.

Sluggish growth in per capita consumption and a downward pressure on beef price at the farm level has required producers to raise cattle that precisely target the meat attributes desired by consumers. Ultrasound technology can help farmers to produce a carcass with an optimal mix of marbling and muscling, and external fat. The results of this study show a high level of accuracy of ultrasound technology in predicting carcass attributes. An estimated hedonic regression model shows that the carcass attributes are reflected on the implicit beef price. Ultrasound technology helps producers to produce carcass with the desired attributes, thus obtain a higher price.

Key words: Ultrasound, beef, Hedonic Pricing

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## Introduction

Sluggish growth in per capita consumption and continuous downward pressure on beef price at the farm level have progressively required beef producers to operate with narrowing profit margins. Farmers received 64 percent of the retail value of beef in 1970, which declined to 47 percent in 1998. Retailers' share, on the other hand, increased from 23 percent to 44 percent during the same period (Figure 1). US beef industry sectors at the farm level need to become more consumer oriented and address issues relating to meat attributes desired by the consumers to increase farmers' share. The producers in the field of production agriculture need every technological benefit, for example ultrasound to enhance profitability. Beef processors have used carcass grade and dressing percent to reduce the price paid for cattle (Preston, 1993). Due to this marketing strategy imposed by the packers, it is important that the producer be able to raise cattle that precisely target the desired point of the grid to maximize profitability. To do this one must produce a beef carcass that maximizes marbling (intramuscular fat) and muscling, but minimizes external fat (subcutaneous fat) at the same time. The relationship of the two is somewhat antagonistic making it difficult to optimize both to their full extent, but may be aided by use of real-time linear array ultrasound.

There have been numerous studies done on the efficacy of ultrasound as a predictor of body composition prior to harvest. Perkins et al. (1992a) showed that ultrasound measurements could be accurate predictors of carcass yield and carcass quality. Ultrasound measurements of breeding cattle could be useful in predicting breeding values for carcass traits (Moser et al, 1997). Perkins et al. (1992b) concluded that their preliminary results collectively indicated promising probabilities for the use of real-time linear array ultrasound technology for estimating genetic differences in the beef cattle population for carcass traits (i.e. carcass EPD's).

Currently in the United States, the dualistic grading system emphasizes leanness and palatability; both important to carcass price, but leanness and quality grade are often antagonistic (Brethour, 1989). Ultrasound is an imaging technology which holds great promise for elucidating compositional differences in animals (Smith et al., 1990). The ability to accurately identify individuals with superior carcass traits will enable the beef industry to abandon the current practice of trading cattle "on the average" and adopt a new value-based marketing system (Smith et al., 1990). Robinson et al. (1992) indicate their results confirm the accuracy of ultrasonic scanning and that it is an effective predictor of carcass measurements. Research indicates that ultrasound evaluation can predict carcass merit several months into the future on individual animals (Brethour, 1989).

Of primary interest to feedlot managers is the ability to identify and market groups of cattle that will consistently produce carcasses of similar weight with acceptable yield and quality grades (Houghton and Turlington, 1990). Therefore, many researchers have evaluated the use of real-time ultrasound as a method to predict these carcass traits in live animals (Houghton et al., 1990; Perry et al., 1989). Ultrasonic prediction is one possible avenue for increasing the accuracy of assessing carcass merit in the live animal (Robinson et al., 1992).

Studies dealing with the economic importance of ultrasound technology in the beef industry are scarce. Ability to estimate carcass attributes in the live animals allows cattle producers for sorting and selecting cattle; therefore, increase the potential of higher net income on a per head basis. Producers are unlikely to adopt the technology if the incremental cost is not recovered at the packers. If it is established that the prices received by the producers reflect the carcass attributes then producers are likely to adopt ultrasound technology to raise cattle in such a way that the desired attributes are met. This study used hedonic regression model to estimate implicit prices of beef (Rosen, 1974; Bowman and Ethridge, 1992). Two equations were separately estimated to evaluate the relationship between beef prices received at the packers and the attributes of the animal. The first equation included actual attributes of the carcass such as fat thickness, ribeye area, marbling score, and daily average gain. In the second equation, estimated attributes at the feedlots using the ultrasound technology replaced the actual attributes. The purpose of the second equation was to establish the price predictability of the estimated attributes. The impact of animal harvesting practices that is consistent with the prediction made by ultrasound technology on prices paid to farmers at packers was evaluated.

**Hedonic Pricing Model for Beef**

Hedonic prices can be defined as the implicit values of product characteristics determined by market price schedules relating observed prices of the differentiated products to the quantities of the characteristics contained in the product (Wahl et al., 1995.) There have been a number of studies using a hedonic price analysis to determine consumers' implicit valuation of the characteristics of the food products (Wahl et al., 1995; Ladd and Suvannunt, 1976; and Morgan et al., 1979.) According to Lancaster (1971), goods are seen as bundles of quality characteristics and the 'marginal value' consumers attribute to each of the characteristics explains the variation in prices of goods. The theoretical framework for the hedonic approach was developed by Rosen (1974), Triplett (1983), Fixler and Zieschang (1992), and Feenstra (1995) among others. Rosen (1974) first developed a market-based approach for deriving a hedonic price function. As proposed by Rosen, a differentiated product can be completely described by the vector of objectively measured characteristics of the product.

According to Rosen and explained by Wahl (1995), a market equilibrium hedonic price function is derived through tracing the tangency points between the buyers' bid (value) curves and the sellers' offer curves in characteristics space. The buyers' bid function is derived through maximizing the buyers' utility function and the seller's offer function is derived through maximizing the sellers' profit function. The following are the mathematical expressions of buyers' bid and sellers' offer functions:

$$\varsigma = \varsigma\ (z_1, z_2, \ldots\ldots, z_m; \gamma; \alpha)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\phi = \phi\ (z_1, z_2, \ldots\ldots, z_m; \boldsymbol{Y}; \beta)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where $(z_1, z_2, \ldots\ldots, z_m)$ is a vector of product characteristics, $\gamma$ is the buyer's total expenditure, $\alpha$ is a vector of taste parameter, ***Y*** is the quantity of the output, and $\beta$ is a parameter vectors whose value reflects factor prices and production technology. The first partial derivative of the buyers' bid function with respect to any of the product characteristics, $\partial\varsigma / \partial z_i$, reveals the buyer's marginal implicit bid for an additional amount of the characteristics. The utility function of the buyers is concave in nature, thus the marginal implicit bid value decreases with increase in the quantity of characteristics.

Similarly, the first partial derivative of the seller's offer function with respect to any of the characteristics, $\partial\phi/\partial z_i$, reveals the seller's marginal implicit value of the increased characteristic quantity. Under the assumption that the seller's cost function is convex in the characteristic space, the offer function is non-decreasing in the characteristics level.

Both buyers and the sellers maximize their utility and profit function, respectively when buyer's marginal bid for a characteristic is equal to the marginal implicit market price and seller's marginal offer for the characteristic is equal to the marginal implicit market price. This implies that market equilibrium results when buyers' bid price is equal to the sellers' offer price. The market equilibrium hedonic price function is estimated by regressing the equilibrium prices of the products on the characteristics of the product. A general hedonic price model for the beef at the packers can be written as:

$$P(z) = f\,(z_1, z_2, \ldots\ldots, z_m) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $P(z)$ is the price of beef at the packers and $(z_1, z_2, \ldots\ldots, z_m)$ is a vector of characteristics of beef.

**Fed Cattle Pricing**

Two factors are considered in grading and pricing beef carcass at the packers: (1) the quality and the palatability of the lean meat, and (2) the cutability or percentage of lean meat yielded by the carcass. Most of the livestock at the packers are bought on a live-weight basis, which requires estimation of the quality attributes on the part of both buyers and sellers. Popularity of dressed weight or carcass weight pricing has been increasing among the packers primarily for quality animal (Wad et al., 2002). Dressed weight pricing eliminates the risk of incorrectly estimating the dressing percentage. Although dressed weight prices on average are higher than live weight prices (Feuz, Fausti, and Wagner, 2001), the prices will vary depending on the carcass attributes, and discounts and premium assigned to those attributes.

With narrowing margins in the beef industry, coupled with the consumers' preference for beef with lean tissue and less external fat, the beef packing plants have implemented their own methods of purchasing live cattle. Beef packing plants have developed a "grid" based marketing system. It utilizes yield grade and quality grade as the indicators for the quality of the carcass. The carcass is then sold by carcass weight basis at the price that corresponds to the carcass's location within the grid. The current market price is generally established for "Low Choice" and yield grade 1. However, some grids award premiums for "Choice average or higher," and yield grade 1, 2 and 3 (Certified Angus Beef). A yield grade of 4 or 5 is termed an over-fat and is discounted a set price. A dark-cutter is also discounted a set amount as is a "no-roll", otherwise known as a carcass devoid of marbling. All of the quoted prices can be arranged into a grid-base format, hence the marketing name. Carcass and box beef value differences are highly dependent on the price spreads in both quality and yield grades (Dolezal, 1997). Trenkle and Iiams (1996) stated that there was a traditional $10/cwt. spread between U.S. Choice and U.S. Select and a discount of $15/cwt. for yield grade 4's in the beef industry.

The following empirical models using actual attributes of carcass at the packers and estimated attributes of the live animals at the feedlots were estimated. Several functional forms were used in the preliminary analysis including linear, semilog, and double log. In the final analysis, the linear functional form was justified and used based on the nonnested hypothesis testing method.

P = h(DAYS, DP, FTA, REA, MSA, ADGA)……………..(4)

P = h(DAYS, DP, FTU, REU, MSU, ADGU)……………..(5)

where, P = per pound price of carcass weight at the packers; DAYS = the number of days before or after the slaughter date recommended using ultrasound; DP = Dressing percentage; FTA = Actual carcass fat thickness; REA = Carcass ribeye area, $cm^2$;MSA = Carcass marbling score; ADGA = Actual average daily gain (lb); FTU = Ultrasound carcass fat thickness, cm; REU = Ultrasound ribeye area, $cm^2$;MSU = Ultrasound marbling score; and ADGU = Ultrasound average daily gain (lb)

**Data**

Two hundred forty-six crossbred steers were scanned ultrasonically for ribeye area, fat thickness, and percent intramuscular fat (for the equivalent to marbling score). Images were taken with an Aloka 500V linear array ultrasound unit (Corometrics Medical Systems, Wallingford, CT) equipped with a 3.5-MHz, 17.2-cm scanning width linear array transducer following procedures as those described by Perkins et al. (1992b). The location of transducer placement was determined by palpation between the 12$^{th}$ and 13$^{th}$ ribs on the side of each animal. Before contact with the transducer was made, this location was oiled (Mazola, CPC Foodservice, Englewood Cliffs, NJ), curried free of dirt and debris, and then oiled again. Fat thickness and ribeye area measurements were determined from chute-side recorded images using the Beef Image Analysis (BIA) computer software. The cattle used in this study were involved in the Texas A&M University Ranch to Rail – south program and were fed a common feedlot ration from a period of October 2001 to harvest after Spring 2002. Individual ultrasound values for fat thickness, ribeye area and percent intramuscular fat were used to predict optimal harvest endpoint (date) for each animal. The optimal endpoint occurred when the animal was projected to reach .40 inches (1.0 cm) of external fat thickness and/or 1400 (635 kg) pounds of live weight. Cattle were marketed as determined by visual assessment of the feedlot manager and project coordinator. This determination did not consider the projected optimal endpoint based on ultrasound. Cattle were harvested after 160, 167, 181, and 198 days on feed after being scanned. The steers were harvested in a USDA commercial packing plant, Sam Kanes Beef Processor, Corpus Christi, Texas. Carcass data was collected after chilling 48 hours post-harvest.

**Results and Discussions**

There was a wide variation in the carcass traits (actual and live estimated; Table 1). While actual carcass fat thickness ranged from 0.25 cm to 3.18 cm, the estimated fat thickness had a narrower spread between the minimum and maximum value. Despite such differences, the correlation coefficient reflected a high degree of predictability of the ultrasound technology. The results indicated that the correlation between estimated and actual carcass attributes including fat thickness, marbling, ribeye area and average daily gains were high and statistically significant. For example, the correlation coefficient (Rho) for estimated fat thickness and actual fat thickness was 0.65 ($p<0.0001$); for actual ribeye area and the estimated ribeye area was 0.53 ($p<0.0001$); for actual marbling and the estimated marbling was 0.41 ($p<0.0001$); and for actual average daily gain and estimated average daily gain was 0.70 ($p<0.0001$).

Hedonic regression models were used to estimate the implicit price of beef. First, a model was estimated using actual carcass attributes including fat thickness, ribeye area, marbling score, and actual average daily gain. Second, four actual carcass attributes were replaced by ultrasound estimated attributes for the live animals. The r-squared (Table 2) coefficients were 0.41 and 0.22 respectively for actual and estimated attribute equations. With respect to the equation with actual attributes, the results showed that the coefficients had the expected signs and were all significantly different from zero. In the case of equation using estimated attributes, estimated rib-eye area and marbling scores did not explain the variability in beef price at the packers.

Carcass attributes such as actual fat thickness, dressing percentage, marbling, and ribeye area had significant impact on the implicit beef price. From an examination of the regression coefficients in Table 2 and estimated elasticity of price of carcass with respect to the carcass attributes (Table 3), it is found that fat thickness in carcass is inversely related with the prices producers get at the packers. One hundred percent increase in fat thickness from the mean value ( 1.68 to 3.36 cm) is likely to decrease price by about 9 percent at the packers ($1.07 to $0.97 per lb). Dressing percentage is positively related with prices. A ten percent increase in dressing percentage from the mean value ( 66.14 to 72.15 percent) is likely to increase the price by 4 percent from the mean value ($1.07 to $1.11). If the sizes of the elasticities are meaningful, then dressing percentage, fat thickness and marbling seemed to have the most impact on prices received at the packers. Ribeye area, although significant, was not as important as the above variables. The magnitude of elasticities for equation with estimated attributes were different from those for the equation with actual attributes. Estimated fat thickness at the live stage had more impact on prices received at the packers than the actual fat thickness of the carcass. It implies that producers at the feedlot could develop an optimal marketing plan based on the fat estimation using ultrasound technology.

While conducting the ultrasound of live animals producers were given an estimated date for the slaughter of animal to obtain the best value based on the carcass attributes. The effect of deviation from that date was evaluated using a variable that measured the number of days away from the estimated date. Such deviation has negative impact on the prices received at the packers. Animals harvested on or close to the ultrasound recommended date of harvest tended to bring a better price than those harvested before or after the estimated days. That is, marketing plans adhering to the given dates for the slaughter obtained better prices than those that deviated from the dates. The negative relationship showed up for both the equations at a similar magnitude.

**Summary and Conclusion**

The study analyzed the potential for using ultrasound technology in marketing beef cattle. The results of the study supported previous studies showing a high level of accuracy of ultrasound technology. A hedonic price function for beef at the packers' level based on Rosen's theory of implicit characteristic market equilibria was developed. The results indicated that selected carcass attributes, both estimated and actual, had significant effects on prices received by the producers at the packers. In particular, fat thickness played a significant role in determining prices. Other attributes such as ribeye area and marbling were positively associated with prices received by the producers. Animals slaughtered close to the date prescribed through ultrasound technology tended to fetch better prices than those slaughtered many days before or after the date.

The findings in this study have important implications for the US beef industry. First, knowledge of the implicit values of carcass attributes aid producers in bargaining with the packers. Second, beef producers can differentiate their animals by raising cattle to meet specific characteristic. Ultrasound technology can be a helpful tool in this regard. As carcass attributes are directly reflected on the implicit beef price, farmers and ranchers can market cattle using this technology to achieve carcass attributes desired by the consumers, thus obtain a higher price from beef processors.

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**Table 1**:Carcass characteristics means and standard deviations of beef cattle estimated by ultrasound technology at the feeder lot and after slaughter

| **Characteristics** | **Mean** | **S.D.** | **Min.** | **Max.** |
|---|---|---|---|---|
| Actual carcass fat thickness, cm | 1.21 | 0.43 | 0.25 | 3.18 |
| Ultrasound fat thickness, cm[a] | 1.68 | 0.26 | 0.92 | 2.53 |
| Carcass ribeye area, $cm^2$ | 90.56 | 10.57 | 64.50 | 130.94 |
| Ultrasound ribeye area, $cm^2$ | 88.64 | 10.65 | 64.37 | 125.13 |
| Carcass Marbling score[b] | 434.08 | 73.80 | 280.00 | 800.00 |
| Ultrasound marbling score | 455.11 | 30.42 | 415.13 | 683.22 |
| Actual average daily gain, lbs | 2.98 | 0.48 | 1.18 | 4.26 |
| Ultrasound average daily gain, lbs | 3.67 | 0.66 | 1.29 | 5.20 |

[a]Live ultrasound estimates at the feed lot
[b]Marbling score: USDA Marbling Score assigned by carcass data collectors, 200 = Traces, 300 = Slight, 400 = Small, 500 = Modest, 600 = high.

**Table 2:** Hedonic price regression coefficients for producer price of beef at the packers (corrected for heteroscedasticity.)

| **Independent variables** | **Actual Attributes** | **Estimated Attributes** |
|---|---|---|
| Constant | 0.7386* | 0.9574* |
| Ultrasound Days (DAYS) | -0.0004* | -0.0004* |
| Dressing Percentage (DP) | 0.0036* | 0.0028* |
| Fat Thickness (FTA/U) | -0.0771* | -0.0926* |
| Ribeye Area (REA/U) | 0.0005** | 0.0001 |
| Marbling Score (MSA/U) | 0.0002* | 0.0001 |
| Average Daily Gain (AGA/U) | 0.0202* | 0.0138* |
| $R^2$ | 0.41 | 0.22 |
| F | 21.87* | 9.02* |
| n | 199 | 199 |

*=significant at p<05; and **=significant at p<10

**Table 3:** Estimated Elasticity Coefficients at Mean Values of Variables

| **Price elasticities with respect to** | **Actual Attributes Equation** | **Estimated Attributes Equation** |
|---|---|---|
| Ultrasound Days (DAYS) | -0.0117 | -0.0111 |
| Dressing Percentage (DP) | 0.2250 | 0.1700 |
| Fat Thickness (FTA/U) | -0.0873 | -0.1047 |
| Ribeye Area (REA/U) | 0.0429 | 0.0108 |
| Marbling Score (MSA/U) | 0.0999 | 0.0496 |
| Average Daily Gain (AGA/U) | 0.0680 | 0.0385 |

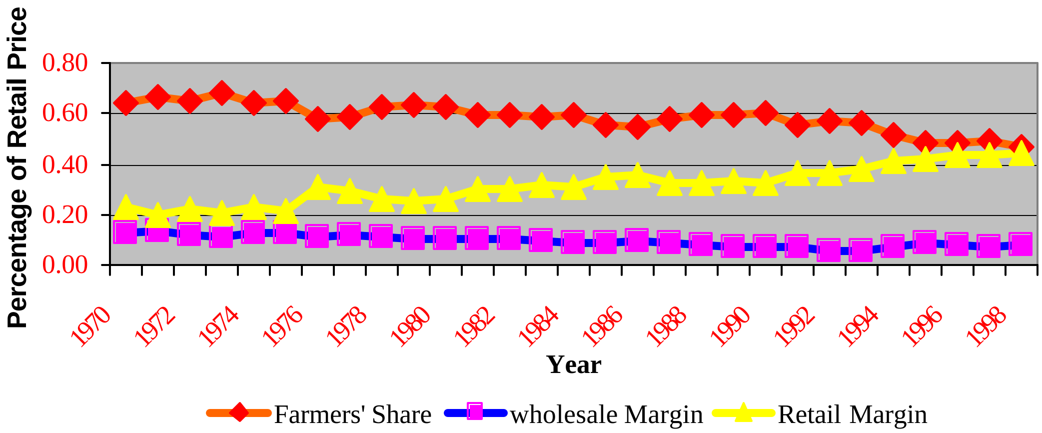


**Figure 1: Shares in beef marketing system (Source: USDA, 2002)**