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Live Animal Ultrasound Information as a Decision Tool in Replacement Beef Heifer Programs

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Abstract

Ultrasound data are used to sort heifers for immediate sale or for development as replacement stock. While ultrasound improves predictions about conception, the value of ultrasound the data is relatively small. This value is primarily influenced by heifer development costs and bred heifer premiums over commercial feeder heifers.

JEL Codes: Q130, Q160

Introduction

Recent changes in livestock pricing arrangements have created greater interest in the use of alternative technologies to improve livestock efficiency and beef quality. Real time ultrasound technology (RTU) is a management tool that provides information about relevant carcass characteristics of live animals. Research indicates a positive correlation (moderate to high) between carcass and ultrasound measurement of key physical traits (e.g., Brethour). Estimation of carcass characteristics in live animals potentially allows for sorting and selecting animals to be retained for finishing as well as allowing better projections as to the length of the animals' time on feed and target end point. Although this technology has been frequently applied to decisions in the finishing phase of production (Anderson, Ferguson, and Brethour; Lusk, et al.), little work has been done concerning the potential use of this technology in other aspects of beef production. Live animal ultrasound measurements can be used to predict not only carcass quality and yield grades prior to slaughter; it also can be a good physiological estimator of animal development and subsequent physiological functions throughout the animal's lifetime.

Replacement beef heifers represent an important investment in the genetic improvement of the cow-calf enterprise and as such are crucial to the future profitability of the cow/calf operation. In this context, the use of RTU technology allows the measurement of the physical attributes of females being considered as replacement animals. This relationship between this RTU information and key physiological characteristics (such as age of puberty) could provide a useful means of improving genetic selection decisions. RTU measurements may be of value in predicting which heifers are most likely to successfully reach puberty at the youngest age and conceive in an artificial breeding program and which animals should be sold or retained as feeder cattle. Reducing the number of heifers that fail to reach puberty at physiologic age (12 – 15 months) and not conceive in advanced artificial breeding systems could represent an important means of improving returns to such programs.

Focusing on the aforementioned characteristics and the potential benefit that RTU can bring to a replacement beef heifer breeding program, the objective of this study is to determine whether or not RTU information can be used to improve beef heifer retention decisions. Specifically, this study will quantify the value of ultrasound information on the relevant physical characteristics of yearling beef heifers in selecting individual animals to include in a replacement heifer development program. This work is unique in two important respects. First, while the value of ultrasound information as a marketing decision aid is explored in recent agricultural economics literature, investigations into the value of this technology in evaluating production decisions are scarce. Second, this research will measure the value of ultrasound information with reference to decision maker utility. This approach, capturing the effect of information on not only the level but also the variability of returns, has not been used in previous studies valuing live animal ultrasound information as a decision tool for livestock production. In addition the effects of risk on heifer retention decisions will be accounted in the analysis by calculating certainty equivalents (CE) for either using or not using ultrasound technology as a decision strategy.

Background

Since heifers typically replace 10 to 20 percent of the cowherd each year, heifer selection and development decisions significantly affect a cow/calf operation's productivity and profitability. This productivity and profitability is largely dependant upon reproductive performance. Research has shown, that heifers calving early in their first calving season continued to calve early and wean heavier calves throughout their lifetime than later calving heifers (Lesmeister et al., 1973). However, the growth and development of the replacement female as well as her fertility is one of the most economically important traits to the cow-calf producer. Realtime ultrasound has been developed as an effective tool for breeders to use in measuring body composition traits. This tool can potentially measure and accurately estimate some physiological changes and carcass attributes that seems to be related to the reproductive performance of female beef cattle.

Steiner (1987) suggested that changes in metabolism result in metabolic signals that are the cues for onset of puberty. Also, longissimus muscle area and body condition score curvilinearly increase as puberty approaches. In a study conducted at the Iowa State University with 7,471 ultrasound images from yearling Angus beef heifers, Leaflet (2000) found that heavier heifers and those with a greater amount of external rib fat at scanning had larger ribeyes. However, Leaflet concludes that the most efficient heifers with the largest ribeye area had the greatest amount of 12^{th}-13^{th} rib fat.

Another study conducted by Leaflet (2001) reporting data from carcass characteristics and reproductive performance on yearling beef heifers show that heavier heifers tends to have more rump fat than lighter heifers. As a consequence, heavier heifers with more rump fat are more likely to have more mature reproductive tracts at breeding and successful chance to early breed. Previous research supports the notion that heifers that are father along in growth and development, as evidenced by heavier weights, larger ribeye areas and more rump fat, are more likely to have higher reproductive tract scores and to be cycling at one year of age.

Considerable research has been done of the issue of culling and replacement decisions in the management of beef cattle herds. Meek et al. (2005), advocate comparing alternative cattle production systems using net present value in order to assess the investment potential of each system. Production systems may differ in the manner in which breeding females are acquired. For example, producers may choose to purchase competitively priced 4-years old replacements, as opposed to bred heifers, thus reducing the risk of reproductive failure and potentially providing greater future net returns.

Ibendahl, Anderson, and Anderson evaluate culling and replacement decisions using net present value. Their research finds that replacing open cows with bred heifers is not always the most profitable decision, depending on the relationship between cull cow and heifer prices and expected calf prices. Their work was similar to that and Tronstad and Gumm who investigated culling and replacement decisions in the context of an operation with bi-annual calving (i.e., both a spring and a fall calving season). While this previous work deals directly with the issue of when mature cows should be replaced in the breeding herd, none deals with the issue of deciding how to select heifers for breeding.

Ultrasound technology may offer the potential to improve decision making related to heifer retention decisions. In one of the first articles examining the economic benefit of ultrasound technology, Koontz et al. (2000) report that the use of ultrasound to sort cattle in feedlot system 80 days prior to slaughter could potentially increase profitability and efficiency within the beef production system. Their results indicate that sorting cattle in the feedlot exhibits diminishing marginal returns and that simple sorting regimes capture most of the benefits, but no study has evaluated the economic benefit of sorting replacement beef heifers before it a specific breeding or finishing program.

Lusk et al. (2003) evaluate the potential of ultrasound readings taken in the feedlot to guide fed cattle pricing decisions. They find that ultrasound measurements can be used to make reasonable predictions of actual carcass merits and that sorting cattle for live, dressed, or grid pricing based on those predictions could increase returns by as much as $25 per head compared to marketing all cattle on a live basis

These previous studies highlight one potential use of ultrasound technology as an aid to marketing decisions. This work focuses on the potential value of ultrasound technology in informing on-farm production management decisions – specifically, the decision of which females to retain into a development and breeding program. Due to the long amount of time required for a heifer development program and to the introduction of additional production risks (e.g., risk of failure to conceive in addition to usual morbidity/mortality risks), the benefits of improved cattle retention decisions is potentially significant.

Data and Methods

Data for this study was collected from 138 Angus-crossbreed heifers from a replacement heifer development project conducted at Mississippi State University's Brown Loam Experiment Station over two years (2004 and 2005). Each of these heifers was placed into one of five backgrounding programs at roughly one year of age. At that time, heifers were selected by age; weight and breed type, and ultrasound readings were taken on each heifer. Ultrasound data collected included measures of intra-muscular fat, back fat, rump fat, gluteus medium depth and ribeye area. After 84 days in the backgrounding program, heifers were artificially synchronized with a progesterone implant. Prior to receiving the progesterone implant, ultrasound readings were repeated, and each heifer was examined and given a reproductive tract score (RTS: 1 to 5) to estimate pubertal status and subsequent breeding potential. Heifers were artificially inseminated upon visual heat detection.

The basic process of determining the value of ultrasound information in selecting heifers for a breeding program is determined through a three-step process. First, the pregnancy status of each heifer after artificial breeding is used to develop two logit models. The first predicts whether or not a heifer will be successfully bred using readily observable explanatory variables (weight, age, RTS, average daily gain during backgrounding, etc.). The second model includes ultrasound information. Equations 1 and 2 describe the general form of these models.

1) $\text{Prob}(Bred = 1) = f(YEAR, TREAT_i, AGE, WGT, BCS, RTS)$, and

2) $\text{Prob}(Bred = 1) = f(YEAR, TREAT_i, AGE, WGT, BCS, RTS, USDAT_i)$,

where *Bred* is a binary variable with a value of 1 if the animal is found to be bred 60 days after artificial insemination. *YEAR* is a binary variable with a value of 1 for observations from year 1 of the heifer development study and a value of 0 for observations from year 2. $TREAT_i$ is a binary variable associated with supplemental feed treatment i in the heifer development study. There were five different supplementation groups in the development study, each differing in the level of energy supplied. *AGE*, *WGT*, *BCS*, and *RTS* are, respectively, variables or combinations of variables describing the age, weight, body condition score, and reproductive tract score of calf at the time the ultrasound reading is taken. In equation 2, $USDAT_i$ stands for the ultrasound measurement of physiological characteristic i. As noted, readings were taken on intra-muscular fat, back fat, rump fat, gluteus medium depth, and ribeye area.

The second step in the process of estimating the value of ultrasound data in heifer retention decisions is to use the results of the models from equations 1 and 2 to sort heifers into two groups: one to be sold as feeder cattle, the other to enter the heifer development program. Heifers that are successfully bred are valued as replacement breeding stock. Heifers that fail to breed are valued as feeder cattle (using prices appropriate to their weight). Costs for the replacement heifer development operation are determined from an existing enterprise budget.

The final step in estimating ultrasound value in this study is to use historic feeder and replacement heifer prices in a stochastic simulation to determine expected utility from three alternative sorting protocols: placing all heifers in the development program (i.e., no sorting), sorting based on external physical characteristics (equation 1), and sorting based on external physical characteristics and ultrasound information (equation 2). Certainty equivalents are calculated using a constant relative risk aversion (CRRA) utility function. The CRRA utility function is represented mathematically as

(3) $$\mathrm{E(U)}_r = \sum_{\mathrm{i=1}}^{\mathrm{n}} \omega_i \frac{W_i^{1-r}}{1-r}, r \neq 1$$

or

(4) $$\mathrm{E(U)}_r = \sum_{i=1}^{\mathrm{n}} \omega_i \ln(W_i), r = 1,$$

where $W_i = W_0 + NR_i$, r is a risk aversion coefficient, and ω_i is the weight associated with each observation i. W_i represents simulated ending wealth, and initial wealth is represented by W_0. Initial wealth is assumed to be $100,000. Utility values are calculated for risk aversion coefficients of 1, 2, and 3, with r=1 representing slight, r=2 representing moderate, and r=3 representing high risk aversion. CEs for each hedge ratio are calculated by inverting Equation 3 or 4 – solving for the level of certain net return that would result in an observed level of utility (Hardaker, Huirne, and Anderson, 1997). The value of ultrasound information is taken to be the difference in certainty equivalents between the latter two sorting strategies.

The basic process of determining ultrasound value is repeated for a comparison of two different decision points. First, equations 1 and 2 are estimated using information available prior to backgrounding (i.e., initial ultrasound readings and visual information available at that time). This allows heifers that are not expected to breed to be sorted out and sold as stocker or feeder calves prior to backgrounding. Alternatively, equations 1 and 2 will be estimated using information available at the time progesterone implants are applied (i.e., ultrasound readings taken at day 84 of the program and visual information available at that time, including reproductive tract scores). If the prediction from the logit model is that the animal will not breed, she is valued as a feeder calf and not artificially bred, though the backgrounding phase of the operation has basically already been completed. The specific variables used in estimating equations 1 and 2 using data from both Day 0 (initial ultrasound readings) and Day 84 (progesterone implant) are named and described in Table 1.

Results

The results of the estimation of equations 1 and 2 are reported in Table 2, including estimates made using both initial observations and observations taken at progesterone implanting. Note that the models using data from Day 0 and Day 84 do not use the same variables. This is true both of the models using visual data only as well as the models incorporating ultrasound information. The Day 84 models were initially estimated using the same variables as those in the Day 0 model; however, alternative specifications as reported in Table 2 were found to have greater statistical significance. For example, in the models using only visual data, the estimated parameter on weight per day of age was not significant on Day 0, but it was on Day 84. This may reflect the impact of performance (in terms of weight gain) during the backgrounding phase.

In the models incorporating ultrasound data, parameters on gluteus medium depth variables (linear and quadratic) were significant on Day 0 but not on Day 84. Conversely, the significance of rib-eye area was much greater on Day 84 than on Day 0, and parameters on rump fat (which had been investigated using Day 0 data and found not significant) were also found to be highly significant on Day 84. Again, the logical explanation for these differences is that certain variables, such as ribeye area and rump fat, provide a superior measure of growth and performance over the very critical backgrounding phase of heifer development.

Probability estimates from equations in Table 2 were used to sort heifers into different groups. In the first analysis using data from Day 0 (the beginning of heifer backgrounding), if the predicted probability of the heifer being successfully bred was less than 0.50, then the heifer was valued as a stocker calf being sold at that time. A stocker calf production cost of $350 was assessed to determine a net return for the calf. Other calves were valued as having been retained for heifer development and artificial breeding. These heifers were valued as either bred heifers (if successfully bred) or as commercial feeder cattle (if not successfully bred). Additional costs of $225 for backgrounding prior to breeding, $46.10 for progesterone implants and breeding, and $50 for maintenance and development costs from breeding to pregnancy check were assessed.[1]

Historic stocker and feeder cattle prices from Oklahoma City for the period 1991 through 2005 were used to stochastically simulate 5,000 possible outcomes for stocker, feeder, and bred heifer prices. Bred heifer prices are not readily available; however, prices from the Missouri Show-Me Select Heifer sale from 1998 through 2004 are available. The correlation between these prices and the Oklahoma City feeder heifer price series was very high (0.96). On average, the bred heifer prices were about 150% of the commercial feeder heifer price (ranging from 136% to 159%). Consequently, rather than simulate a separate bred heifer price series with limited data, simulated commercial feeder heifer prices were scaled up by 150% to derive a

[1] Actual progesterone implant and breeding costs from the heifer development study were used here.

stochastic bred heifer price series. Sensitivity analysis is conducted to assess the affect of alternative assumptions about backgrounding costs and bred heifer premiums on results.

Calculated certainty equivalents for no sorting, sorting based on visual characteristics observed at the beginning of backgrounding, and sorting based on ultrasound readings taken at the beginning of backgrounding are reported in Table 3. These results indicate that there is generally some positive value to the RTU data, however that value is rather small on a per head basis.

While the certainty equivalent associated with placing all cattle into the development program goes down as heifer development costs go up, the difference in certainty equivalents between the sorting model using visual characteristics and that using RTU data actually declines. Errors in both models tend to be in underpredicting the number of cattle that will breed. These cattle are valued as stocker cattle, and returns on these cattle are not influenced by increases in backgrounding or development costs.

At lower bred heifer values (lower premium relative to commercial heifer value), the value of ultrasound data is reduced. This results from the fact that at lower bred heifer prices, the value of accurately placing cattle into a breeding program is reduced. Certainty equivalents calculated at a lower bred heifer value (130% of the commercial feeder heifer price) are not reported but are available from the authors.

The value of ultrasound data taken at Day 84 (at progesterone implant) was also investigated. While ultrasound readings taken at this point do help to improved predictions of which cattle will successfully breed, the value of those predictions is limited by the fact that most of the costs associated with heifer development have already been incurred by the time this ultrasound data is collected. Sorting based on ultrasound data taken at progesterone implant actually resulted in a lower certainty equivalent than placing all cattle into the breeding program. The reason for this result is that the reduction in costs associated with animals that are accurately culled from the breeding program is not sufficient to offset the foregone income from animals that are inaccurately culled from the breeding program (and which could have been sold as higher valued bred heifers).

Summary and Conclusions

Data from a two-year heifer development program at Mississippi State University were used along with historic stocker heifer, feeder heifer, and bred heifer prices to estimate the value of real-time ultrasound (RTU) data used to sort heifers into groups for sale or for heifer development. Ultrasound measures taken at the beginning of the heifer development program, which allowed cattle with a low probability of breeding to be sorted out as stocker calves, were found to have a positive value in most cases. This value was relatively small, however, and is not likely to be sufficient to cover the costs associated with obtaining the ultrasound information.

Ultrasound data collected later in the development program improved the ability to predict which animals would successfully breed. Because of the fact that most of the costs associated with heifer development had already been incurred at the time this data was collected, this ultrasound data had little value compared to sorting on visual data or even not sorting at all (i.e., breeding all heifers).

It is very possible that real-time ultrasound data on replacement females could have additional value beyond simply in predicting fertility. Relationships between female carcass merits and the carcass merits of offspring could serve as a useful means of predicting grade and yield of those offspring. That would mean that ultrasound data on females could potentially be used as a guide to marketing decisions on their offspring in a similar fashion to that investigated in Koontz et al. and Lusk et al. Additional data and research will be needed to determine if this may be the case.

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Table1. Description of Variables used in Estimating Logit Model to Predict Outcome of Artificial Breeding of Beef Heifers

Independent Variable	Variable Description
Year	binary variable identifying the year of the heifer development study (2004 or 2005)
BCS	body condition score of heifer (1 through 5) as assessed on Day 0 and Day 84
WGT_DOA	weight per day of age (heifer weight divided by age in days)
$TREAT_1$	denotes supplementation with a lowfat (low energy) feed supplement
$TREAT_2$	denotes supplementation with a high fat (high energy) feed supplement
$TREAT_3$	denotes supplementation with protein tubs
$TREAT_4$	denotes supplementation with cottonseed-based ration
REA	rib-eye area (in square inches) estimated with RTU
D_REA	change in RTU estimate of ribeye area from Day 0 to Day 84
GMD	gluteus medium depth (in inches) estimated with RTU
RF	rump fat depth (in inches) estimated with RTU

Table 2. Estimated Parameters for Logit Model to Predict Outcome of Artificial Breeding of Beef Heifers using Visual and Real-time Ultrasound Data

Independent Variable	Visual Data Day 0	Visual Data Day 84	Ultrasound Data Day 0	Ultrasound Data Day 84
Intercept	-6.916 ***	-5.755 ***	-34.275 **	-30.077 ***
Year	0.212	0.506	1.036	1.046
BCS	1.377 ***		1.086 ***	
WGT_DOA		3.279 ***	-	
$TREAT_1$	-0.259	0.270	-0.494	0.038
$TREAT_2$	0.617	1.208 *	0.311	0.989
$TREAT_3$	-2.484 ***	-2.533 ***	-2.899 ***	-2.776 ***
$TREAT_4$	-0.344	-0.563	-0.480	-0.544
REA			0.765 ***	6.271 ***
REA^2				-0.322 ***
D_REA				-1.153 ***
GMD			8.476 *	
GMD^2			-0.762 **	
RF				7.344 *
RF^2				-4.775 *

Note: Single, double, and triple asterisks denote significance at the 10%, 5%, and 1% level, respectively. N = 138.

Table 3. Certainty Equivalents from Alternative Heifer Sorting Strategies Including Sorting Based on Real Time Ultrasound (RTU) Data Taken Prior to Backgrounding

Backgrounding Cost ($/head)	No Sort	No RTU Data	RTU Data	Total RTU Value	RTU Value per Head
		Risk aversion coefficient = 1			
185	30,392	31,100	31,616	515	3.73
225	25,631	28,386	28,666	280	2.03
260	19,975	24,481	24,552	71	0.52
		Risk aversion coefficient = 2			
185	29,225	30,415	30,873	458	3.32
225	23,674	26,892	27,114	223	1.61
260	18,037	23,317	23,298	-20	-0.14
		Risk aversion coefficient = 3			
185	27,003	28,673	29,068	395	2.86
225	21,665	25,545	25,688	143	1.04
260	16,160	21,928	21,851	-77	-0.56

Note: RTU value per head is based on 138 head of cattle.