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Efficiency of Market Price Signals for Feeder Cattle Frame Size and Muscling

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Two important beef cattle production traits that affect performance are frame size and muscle thickness. Both are components of official U.S. Department of Agriculture (USDA) feeder cattle grades. Considerable research has confirmed that both frame size and muscle score affect several aspects of feedlot and carcass performance (Adams et al.; Camfield et al.; Dolezal, Tatum, and Williams). Performance measures affected include growth rates, average daily gain (ADG), slaughter weight, muscle-to-bone ratio, quality grade, marbling score, and fat thickness. Dolezal, Tatum, and Williams found that both frame size and muscle score affected time-on-feed, which in turn affects the cost of production in the feedlot. Thus, feeder cattle grades affect both production costs and value-influencing attributes.

Since feeder cattle with different frame sizes and muscle scores perform differently and are valued differently in carcass form, buyers pay premiums or discounts for feeder cattle with differing frame size and muscle thickness (Buccola; Mintert et al.; Sartwelle et al.; Schroeder et al.; Smith et al.; Troxel et al.; Turner, McKissick, and Dykes). Conceptually, price differences should reflect expected performance and end-value differences. Smith et al. found price differences related to frame size amounted to as much as $18.86 per cwt. for feeder steers and

$20.99 per cwt. for heifers. Price differences related to muscle score were as much as $8.10 per cwt. for feeder heifers and $26.48 per cwt. for steers. Do these premiums and discounts accurately reflect the performance and end-value differences that are caused by a particular frame size and muscle thickness? What effect do frame size and muscling in feeder cattle have on profitability in stocker and feeding programs?

If the market values feeder cattle efficiently for frame size and muscle thickness, there should be no excess profit from buying an animal with one frame size and muscle thickness over another. Expected performance and end-value differences caused by frame size and muscle score will be reflected in purchase prices for feeder cattle of different grades, causing no significant differences in profits from the cattle. For example, if larger-framed cattle gain faster with better feed conversion, they should be worth more as feeder cattle. Then smaller-framed feeder cattle should be discounted sufficiently to be equally profitable as the better performing, but more expensive larger-framed cattle.

The expected marginal revenue from buying a certain frame size and muscle score for stocker and feeder programs should equal the expected marginal cost associated with the same frame size and muscle score. Each marginal revenue minus marginal cost (for stocker program, feeding program, and retained ownership program) should be equal zero and should equal the marginal revenue minus marginal cost for different frame sizes and muscling levels. If profits due to differences in frame size and muscling level are not equal, then it could be argued that the feeder cattle market does not efficiently value frame size and muscle score. If profits are equal, then it supports the argument that the market is efficient in valuing frame size and muscle score.

As noted, there is considerable research on cattle performance for feeder cattle with different frame sizes and muscling scores. Likewise, there is considerable research on price difference of feeder cattle with different frame sizes and muscling scores. However, little research has addressed the comparative profitability for feeder cattle with different frame sizes and muscle scores. This paper reports results of an experiment to assess performance and profitability differences of feeder cattle through the stocker, feeding, and combined stocker-feeding stages for different frame sizes and muscling scores of feeder cattle. Results are interpreted from the standpoint of assessing market efficiency for pricing feeder cattle of varying grades.

Experimental Design and Data

USDA has three feeder cattle frame scores (Large, Medium, and Small) and four muscle thickness scores (1, 2, 3, 4). This project focused on beef cattle, so only large, medium, and small frame feeder cattle and #1 and #2 muscle feeder cattle were considered, i.e., six combinations of feeder cattle frame size and muscling score; large frame #1 and #2 muscling; medium frame #1 and #2 muscling; and small frame #1 and #2 muscling.

A 3x2 factorial experimental design was utilized in this project. Independent variables were frame size and muscle thickness, along with commonly accepted variables that affect performance and profitability. Dependent variables were commonly used performance and profitability measures such as average daily gain (ADG), feed efficiency (conversion), hot carcass weight, yield grade, quality grade, stocker-level profit, feedlot-level profit, and retained ownership profit (stocker-level plus feedlot-level).

An experienced cattle buyer purchased roughly 20 feeder cattle for each of the six feeder cattle grade classes from November 6, 2000 until January 23, 2001. Cattle purchased were predominately of Angus genetics and were bought individually or in small lots. Feeder cattle were uniformly processed the day after being bought, backgrounded on hay and feed until small-grain pasture was ready, and then officially graded by current and former market reporters from the Oklahoma Department of Agriculture and the USDA. All cattle were implanted once, at the beginning of the small-grain pasture phase. Sick or unhealthy cattle were treated as needed. Data were kept on individual animals, including purchase price and feeder cattle traits such as flesh, color, sex, horn status, purchase location, date, and weight. Production data included ADG during backgrounding, feed and hay cost during backgrounding, vaccination costs, and medicine costs.

Cattle were moved to small-grain pasture on the Noble Foundation's Red River Research and Demonstration Farm in Burneyville, OK on February 12, 2001 and were taken off pasture on May 1, 2001 for a total of 77 days on small-grain pasture. Cattle were weighed, re-graded, priced by four independent order/buyers, and sent to the Colorado State University research feedlot in Fort Collins, CO. As the cattle were moved off pasture and into the feedlot, they were priced by original treatment group as if they were being sold in the field directly to the order buyer.

Data collected at the feedlot included feed intake, morbidity, mortality, feed cost, feedlot processing cost, and ADG. Cattle were fed in treatment groups to find feed efficiency. Fifteen pens of cattle were fed with 7 to 12 head per pen. The cattle were sorted to pens of similar weight and anticipated finishing time within treatments. When the average of the pen of cattle had an estimated 0.4 inches of backfat, the pen was harvested. Cattle were harvested in three groups. The first group was harvested on September 9, 2001; the second group on October 24, 2001; and the last group on November 13, 2001.

Carcass data, including harvest weight, hot carcass weight, dressing percentage, overall maturity, rib-eye area, quality grade, and yield grade, were obtained by meat scientists at

Colorado State University. The price of cattle was assessed by live-weight but cattle were actually sold on the Gelbvieh Alliance's muscle grid. The muscle grid emphasizes yield grade, but pays premiums for quality grade so it can be used for cattle that fit both grade strengths. The liveweight price used for comparison was the Cattle-Fax US average fed cattle price for the slaughter dates. Three other grids were also used to calculate the simulated profit had the cattle been sold differently. The USDA national average of reported grid prices on the slaughter dates was used as one alternative. This grid was intended to be an average grid that emphasized both quality and yield grade. Two simulated grids were also used; one emphasizing quality grade, the other yield grade. The simulated grid premiums and discounts resemble those of commonly used industry grids.

Estimated profit, i.e., returns to unpaid death loss, labor, transportation, selling, and management costs, was calculated for individual animals at each production phase, i.e., small-grain pasture (stocker) phase, feedlot phase, and combined stocker and feedlot phase (retained ownership). Profit was

$$\pi_i = P_i Y_i - R_i X_i - C_i Z_i \tag{1}$$

where π_i is profit for the i^th production stage. P_i is the output price of cattle in the i^th production stage, which depends on frame size and muscling level. Y_i is the output weight of cattle in the i^th production stage. R_i is the input price of cattle in the i^th production stage and X_i is input weight of cattle in the i^th production stage, both of which depend on frame size and muscling level. C_i is cost of production inputs in the i^th production stage and Z_i is amount of production inputs (non-livestock) in the i^th production stage.

Purchase price was adjusted to remove some of the bias associated with an order buyer specifically trying to buy certain types of cattle at a given sale. The auction barns where cattle were purchased are small and the order buyer could have influenced the price at which the cattle normally would have been purchased. The actual purchase price was regressed on independent variables that describe the cattle bought, such as frame size, muscle score, degree of flesh, hide color, horns, sex, weight, sale date and sale location. Predicted values from this model were then used as the adjusted purchase price in the adjusted profit models.

If the cattle market efficiently values frame size and muscle score, there should be no excess profit from buying a certain frame size and muscle score instead of another. The performance differences caused by frame size and muscle score will cause the profit of cattle to be the same no matter what the degree of frame size and muscle score. Thus, the profit from different levels of frame size and muscling will be equal when the market is efficient

$$\pi_i(F_i, M_i) = \pi_i(F_j, M_j) \tag{2}$$

$\pi_i(F_i, M_i)$ is profit in the ith production stage from a certain frame size and a certain muscle score, and is equal to $\pi_i(F_j, M_j)$, profit in the ith production stage from a different frame size and a different muscle score.

Ordinary least squares (OLS) regression was also used to analyze production and profit data. Performance models were estimated for stocker ADG, feedlot ADG, feedlot efficiency, carcass weight, quality grade, and yield grade. Profit models were estimated for adjusted profit from the stocker enterprise, actual profit from the feedlot enterprise when cattle were sold on a liveweight basis, actual profit from the feedlot enterprise when cattle were sold on the Gelbvieh grid, adjusted profit from all enterprises when cattle were sold on a liveweight basis, and adjusted profit from all enterprises when cattle were sold on the Gelbvieh grid. Models were checked for multicollinearity using the variance inflation factor (VIF). One variable, days on feed, caused significant multicollinearity in some models so was dropped from those models. Models were checked for heteroskedasticity using the Breusch-Pagan test. Models that were found to reject the null hypothesis of homoskedasticity were re-estimated using estimated generalized least squares regression (EGLS) (Greene).

Empirical Results

Performance Models – The models for pasture and feedlot ADG explained only a small portion of the variation in the dependent variable (12% and 8%, respectively). Frame size and muscle score had no significant relationship with ADG of cattle either on small-grain pasture or in the feedlot.

The feed conversion (efficiency) model explained 64% of the variation in feed conversion. This model was corrected for heteroskedasticity using EGLS. Small-framed cattle had significantly lower feed conversion or increased efficiency than medium-framed cattle, while large-framed cattle had significantly higher feed conversion or lower efficiency than medium-framed cattle. Number 1 muscled cattle also had significantly lower feed conversion than # 2 muscled cattle. Cattle that performed well during preconditioning and pasture continued to perform well in the feedlot. Backgrounding ADG, pasture ADG, and feedlot ADG all had negative coefficients, contributing to improved feed conversion in the feedlot. However, medicine costs had an unexpected negative relationship with feed efficiency.

Much of the variation in carcass weight was explained by the model (82%). Frame size and muscle score significantly impacted the harvest weight of cattle. This result also verifies the use of frame size and muscle score in estimating the future harvest weight of cattle. As expected, large frame cattle has significantly higher carcass weights and small frame cattle had lower carcass weights compared with medium frame cattle. Muscling also was significant.

Thin-fleshed animals (#1 muscle score) had lower harvest weights. Other variables significantly affecting carcass weight were days fed and feedlot ADG.

The quality grade model explained little of the variation in quality grade (17%). These results are largely as expected since even experts have difficulty identifying animals that grade well just by visual inspection and production records. Frame size and muscle score had no significant effect on quality grade. Days fed was the most significant management variable in explaining quality grade.

More variation in yield grade was explained by the model (65%) than quality grade. Frame size had no significant effect on yield grade, as expected. However, # 1 muscled cattle had significantly better yield grades (i.e., closer to 1.0) than # 2 muscled cattle. This supports USDA's use of muscle scores in estimating future yield grades of cattle. Adjusted fat thickness played an important role in yield grade because yield grade is calculated based on fat thickness of the carcass. Dressing percentage, as expected, also explained much of the variation in expert yield grade.

Profit Models – The adjusted stocker profit model was tested and corrected for heteroskedasticity using EGLS. Recall stocker profit was adjusted to remove bias that may have entered the experiment because the cattle buyer was buying certain types of cattle. The model explained 90% of the variability in individual animal stocker profits. Small and large frame feeder cattle were significantly related to the adjusted profit for the stocker enterprise. However, muscle score was not significant. Small-framed cattle were $21.13 per head more profitable than medium-framed cattle and large-framed cattle were $12.93 less profitable than medium-framed cattle. Note the adjusted purchase price was significant in explaining variability in stocker profit. Not surprisingly, feeder cattle bought at a lower price were more profitable, emphasizing the importance of buying wisely. The coefficient for pasture ADG was negative in the model because small-grain pasture costs were calculated on a per pound of gain basis. Every pound of gain added $0.30 of cost to the animal. Ending (off-pasture) weight had a significant positive effect, medicine cost a negative effect, and feeder cattle sale price a positive effect on stocker profits. Thus, procurement, performance, and marketing all are important parts of stocker enterprise profitability.

Both feedlot profit models explained nearly all (99%) of the variation in cattle feeding profits. Small frame size and muscle thickness were significant in explaining variability of profits for individual animals when cattle were sold on a liveweight basis. Small-framed cattle were $25.52 per head more profitable than either medium or large framed cattle. Number 1 muscled cattle were $20.62 less profitable than # 2 muscled cattle. Feeder cattle purchase price (adjusted), beginning (feedlot placement) weight, feed efficiency, feedlot ADG, harvest weight, liveweight sale price, yield grade, dressing percentage, overall maturity, and adjusted fat thickness were all statistically significant in explaining feeder enterprise profit variability. However, feeder cattle purchase price, yield grade and maturity had unexpected signs. Coefficient signs on other significant variables were as expected. Feed efficiency and feedlot ADG were important to feedlot profits. In general, the lower the beginning weight, the greater the profit. Profit also increased as slaughter weight increased since carcasses were not discounted unless they were excessively heavy (e.g., >950 lbs.). Liveweight price, dressing percentage, and adjusted fat thickness were significant with the expected signs.

Small and large frame cattle were associated with significantly different feedlot profits, as was muscle score, in the model explaining profit from the feeder enterprise when the cattle were sold on the Gelbvieh muscle grid. Small-framed cattle were $36.03 per head more profitable and large-framed cattle were $19.49 less profitable than medium-framed cattle. Number 1 muscled cattle were $48.31 less profitable than # 2 muscled cattle. The coefficients for frame size and muscle score were considerably greater in the muscle grid model than in the liveweight price model. Feeder cattle purchase price (adjusted), beginning (feedlot placement) weight, feed efficiency, harvest weight, sale price, yield grade, and dressing percentage were all statistically significant in explaining variation in profits when selling on a grid, just as they were when selling on a liveweight price. Quality grade was significant in the grid model but not the liveweight price model. As quality and yield grades improved, profit also improved. Quality and yield grade coefficients were negative in the model, but can be explained by the way quality and yield grades were recorded (prime=1, choice=2, select=3, standard=4, utility=5; and YG 1=1, YG 2=2, YG 3=3, YG 4=4, YG 5=5). The grid price model had more variables with expected signs, perhaps suggesting that grid pricing is associated with more accurate price and profit signals than liveweight pricing, i.e., grid pricing better reflects the value of the beef produced.

The adjusted profit model for all enterprises when cattle were sold on a liveweight basis explained 94% of the profit variation. Small-frame cattle were $37.85 per head more profitable than medium-frame cattle while large-frame cattle were $17.13 less profitable. There was no significant difference associated with muscle score. The adjusted purchase price significantly explained variation in profit for all enterprises. *Ceteris paribus*, the lower the input price, the higher the profit potential. Beginning (stocker) weight, pasture ADG, feedlot efficiency, and harvest weight were all significant in explaining profit variation. Results here verify use of these production performance variables in predicting retained ownership profitability. Medicine cost was also statistically significant. Cattle that get sick are not as profitable as those that stay healthy. Dressing percentage was significant at the 5% level, but quality grade and yield grade were not significant. Also important, as expected, was the sale price.

The principal difference between the adjusted profit model for all enterprises using the Gelbvieh muscle grid and using liveweight price was the importance of carcass characteristics that cannot be ascertained prior to slaughter. Some of these characteristics included quality grade, yield grade, and dressing percentage. The model explained 93% of the variation in profitability. Frame size was significant but muscle score was not. Small-frame cattle were $38.11 per head more profitable than medium-frame cattle while large-frame cattle were $27.61 less profitable. These coefficients were very similar to those in the liveweight price model. Adjusted purchase price was significant as well as production variables such as beginning (stocker) weight, pasture ADG, feedlot ADG, feed efficiency, and harvest weight.

Implications and Conclusion

Research suggested that the 1979 USDA feeder cattle grades were ineffective in predicting harvest weight and yield grade at which a carcass will quality grade Choice (Grona et al.). Thus, in 2000, new USDA feeder cattle grades were instituted. Results from this study indicate that the new grades are effective in predicting harvest weight and yield grade at Choice quality grade.

Performance characteristics of the cattle with varying frame sizes and muscle scores were not always notably different. Backgrounding, stocker, and feedlot ADG of the different groups of cattle differed little, while feed efficiency, days fed, and harvest weight varied more. Small-framed cattle were more feed efficient than medium-framed cattle, which were more feed efficient than large-framed cattle. Likewise, # 1 muscled cattle were more feed efficient than # 2 muscled cattle. Large-framed cattle were fed longer and were heavier at harvest than medium-framed cattle, which were fed longer and were heavier at harvest than small-framed cattle. Number 2 muscled cattle were heavier at harvest than # 1 muscled cattle, but were not fed significantly longer. These results are consistent with the objectives of the USDA feeder cattle grades.

There were many differences in carcass characteristics due to frame size and muscle score. Dressing percentage, hot carcass weight, adjusted fat thickness, and rib-eye area differed significantly among frame sizes, while yield grade and hot carcass weight differed significantly between muscle scores. There were no differences in carcass quality grades for either frame size or muscle score. Quality grade is probably caused more by management and genetics, i.e., performance potential, than by frame size and muscle score *per se*.

One question about which this research was concerned was the efficiency of the stocker and feeder cattle market. If prices are efficient, profit from producing cattle with different traits would be the same. Expected profit differences would be adjusted by price differences to erase actual profit differences. However, this was not found to be the case. Instead, regression results might lead one to believe the stocker and feeder cattle markets are inefficient.

Small-framed cattle had an adjusted actual stocker enterprise profit of $21.13 more than medium-framed cattle and large-framed cattle had an adjusted actual stocker enterprise profit of $12.93 less than medium-framed cattle. Frame size and muscle score variables were also significant in explaining profit differences for feedlot models. Small-framed cattle had higher profits than medium-framed cattle and large-framed cattle had lower profits than medium-framed cattle. Also, # 2 muscled cattle had higher profits than # 1 muscled cattle. Likewise for stocker and feedlot enterprises combined, profits differed for cattle with varying frame size. Small-framed cattle had higher profits than medium-framed cattle and medium-framed cattle had higher profits than large-framed cattle. Though not significant, # 1 muscled cattle had higher profits than # 2 muscled cattle.

Therefore, results from this study indicated greater profits were realized for small # 1 muscled cattle than other grades of feeder cattle. And as a result, there is evidence from this one study that stocker and feedlot prices are economically inefficient since a greater profit can be made producing one type of calf instead of another. An important caveat is appropriate however. This was a single experiment in time and was not large enough to conclude stocker and feeder cattle markets are inefficient. More research would be required to arrive at such a definitive conclusion.

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