FED CATTLE MARKETING:
A FIELD EXPERIMENT

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association 2017 Annual Meeting, Mobile, Alabama, February 4-7.

ABSTRACT

To improve meat quality and consistency, cattle feeders have moved towards implementing marketing strategies based on visual estimates of physiological characteristics (e.g. 0.5 inches backfat). Recognizing that physiological targets will not necessarily result in profit maximization; this research aims to develop a market timing method accounting for animal growth, output price and cost dynamics to enhance the likelihood of maximizing profit on an individual basis. A natural field experiment in Iowa is utilized to evaluate the potential for the new methodology. One hundred twenty three cattle are randomly assigned into each treatment. The first treatment consists of marketing an individual *when* it attains a visual estimate of 0.5 inches of backfat (EPM). The second treatment consists of marketing an individual *when* its value of the marginal product equals marginal factor costs (PMR). Profit between treatments is compared utilizing three methods: realized, uniform carcass base price, and uniform cash prices.

KEYWORDS: Fed Cattle, Dynamic Growth, Marketing, Experiment

Introduction

Profitability has long been a concern of cattle producers. Due to continual changes in cattle genetic composition, consumer meat demand, pricing mechanisms, and major market shocks caused by drought and government intervention in grain markets results in constant adjustment by cattle feeders to maximize profits. For instance, the transition from a cash based market to carcass based pricing has been apparent over the years, noting that 16% of cattle were being sold on the grid in 1996 compared to 45% in 2001 (McDonald et al., 2001). This change has been a result of efforts to improve meat quality and consistency in order to meet consumer demand (Value Based Marketing Task Force, 1990; Fausti et al., 1998) but also transfers value risk from the buyer to the seller (feedlot). Typically, "rules of thumb" have been used to meet this demand and attempt to minimize value risk. Utilizing basic observed information (such as visual appraisals of back fat, days on feed contingent upon delivery, etc.) may have led to some marginal improvements of profit. However, marketing strategies based on profit maximization may yield more profits (Maples et al., 2015).

Recognizing that marketing based on physiological characteristics will not necessarily result in profit maximization; Maples et al. (2015) developed a simple methodology to market cattle based on a dynamic profit maximization rule. The authors recognize that cattle are independent utility maximizers and that feeders have little to no control over input prices, output prices, feed consumption, cattle genetics or nature. However, the producer has control with regards to input type and market timing. The authors utilized live weight observations to estimate the dynamic value of the marginal products in conjunction with estimated marginal factor costs, largely determined from feed consumption, to solve for a dynamic *ex-post* profit maximization market timing rule (PMR). Their analysis found that End-Point Marketing (EPM) strategies based on physiological characteristics resulted in reduced average per head profitability of $7.67 to $21.09, depending on the growth function estimated and assumed realized prices.

Given that *ex-post* analyses are informative but lack application for cattle feeders, this research extends Maples et al. (2015) by incorporating a continually updated ex-ante prediction methodology. To determine the applicability and efficacy of a more forward looking application of their theoretical evaluation, this research tests the validity of their PMR approach on both profits and carcass merit by conducting a natural field experiment comparing the EPM and PMR marketing strategies. Results indicate that, for this replication, carcass characteristics are not significantly impacted by implementing the PMR approach. Not accounting for price movement significantly and negatively impacts profitability for this methodology. However, profitability results also indicate that when price movement is accounted for, the PMR method still outperforms the EPM strategy.

Literature Review

The use of dynamic nonlinear growth functions to predict the growth of living things is a well-established practice in the biological and scientific literature. There have been numerous recent applications in the livestock and poultry industries, such as, cattle (e.g. Forni et al. 2007, 2009), swine (e.g. Strathe et al., 2010; Craig and Schinckel, 2001), lamb (e.g. Topal et al., 2004), chicken (e.g. Zuidhof, 2005; Kuhni et al, 2003), and turkey (e.g. Porter et al. 2010).

Langemeier et al., (1992), Lawrence et al., (1999) Mark et al., (2000) among others have identified factors that influence cattle feeding profitability, focusing primarily on input and output prices. Cattle slaughter weight is often noted in the literature as significantly impacting profitability, regardless of the marketing method. For instance, Feuz (1999) found that weight explains 96% to 100% of the variation in revenue when cattle are sold on the cash market. Furthermore, Johnson and Ward (2005) found that weight explains 61% to %71 of the variation in revenue when cattle are sold under carcass merit (formula) pricing. Johnson and Ward (2006) found in their study of formula pricing, that carcass weight sends a stronger signal to producers than carcass quality characteristics.

Other research has focused on the profitability differences between different pricing methods including formula (based on the value of various carcass characteristics), carcass weight, and live weight pricing (Fuez et al., 1993; Johnson and Ward, 2005, 2006; McDonald and Schroeder, 2003). While, at times, each strategy can result in an optimal outcome based on market conditions and animal profiles, profit variability is lowest for live weight pricing and highest for formula pricing (Koontz et al., 2008). As such, formula pricing shifts the risk of the animal's true value from the processor to the feeder. Additionally, analyses of using ultrasound and genetic testing technologies to improve carcass estimates of a live animal have been conducted (Lusk et al., 2003; DeVuyst et al., 2007). Such research follows the rationale that additional information improves pricing method choice and returns to the seller. For instance, Schroeder and Graff (2000) found that average revenues could be improved from \$15 to \$35 per head if producers had perfect foresight as to animal's quality and yield grade prior to slaughter. Similar analyses have been conducted by DeVuyst et al. (2007) using animal genotyping and by Walburger and Crews (2004) using animal parentage.

Lusk et al. (2003) used ultrasound technology to predict carcass qualities and estimated the value of the information over the three main marketing methods: live weight, carcass weight, and formula pricing. They analyzed data from 163 animals from Mississippi State University's

Mississippi Farm to Feedlot Program. The authors found that using ultrasound information increased revenue by approximately $5 per head for cattle priced on a formula basis and between $25 and $33 for cattle marketed on a live or carcass weight basis.

Previous studies have also shown increases in profitability based on a variety of different market timing approaches (Koontz et al. 2000; Lusk et al. 2003; Koontz et al. 2008). Koontz et al. (2008) estimated the value of sorting cattle utilizing ultrasound technology in combination with three animal growth and carcass development curves to predict slaughter weight, USDA quality grade and USDA yield grade. To predict carcass weight at any point in time, they utilize a linear standard growth curve and assume cattle gain 3.2 pounds per day. Koontz et al. (2008) found a $15 to $30 increase in profitability per head from sorting cattle multiple times in the final 80 days prior to slaughter while they estimated the marginal increase in fixed cost from sorting to be $5.70 per head. They also found that the opportunity cost of overfeeding cattle is much greater than underfeeding due to the additional feed cost.

Maples et al. (2015) analyzed the potential loss of profit due to the implementation of the EPM marketing strategy of 0.5 inches of back fat. The authors considered two potential growth functions; one based on the classic Verhulst Logistic life-cycle growth function and an alteration to the life-cycle model which does not require information of the animals age. Regardless of the assumed underlying growth function estimated, the authors found that nearly all cattle were either harvested too early or too late in accordance to profit maximization.

Experimental design

One hundred twenty three beef cattle were used in the experiment. The cattle in study were primarily born and raised at Mississippi Agricultural and Forestry Experiment Station- White

Sands Unit in Poplarville, MS, January, 2015. The remainder of the cattle were born at Mississippi Agriculture and Forestry Experiment Station- Brown Loam Unit in Raymond, MS the previous fall. Cattle were randomly sorted into two treatments (EPM and PMR) based on sex and weight. The cattle ranged in live weight from 5 cwt to 10 cwt, consisting of 80 percent steers. Cattle were then fed at Gregory feedlots in Tabor, Iowa beginning in April 2016 with the last load harvested October 2016. The cattle were finally harvested by Tyson Foods, Inc. in Dakota City, Iowa and were sold on a carcass merit basis. All pertinent carcass information was collect.

The first treatment of cattle were marketed using the EPM marketing strategy. The strategy consisted of being visually evaluated for frame score upon arrival, then given projected weights for what each individual head would weigh with 0.5 inches of back fat. They are then visually evaluated again as they reach the projected weight. When the cattle reach 0.5 inches of back fat via this visual evaluation they are then marketed. In this treatment, two full loads of cattle were marketed (62 head of cattle).

The second treatment of cattle was marketed based on the PMR strategy. This treatment consisted of four half loads of cattle (61 total head of cattle). Cattle were marketed once the estimated marginal value product equaled marginal factor costs. Estimated marginal physical products were updated every 28 days with realized weights. The estimated marginal value product was updated on a weekly basis as cash prices were realized. Estimated marginal factor costs were updated as feed consumption was updated (every 28 days). A marketing weight constraint was placed on this treatment by only allowing cattle to be harvested between 1,000 to 1,700 pounds live in order to avoid heavy discounts.

Data

Data began being collected from Gregory Feedlots beginning on April 15th when the cattle were delivered. Data collection processes began prior to delivery in 2014. Thus, the data spans from 2014 until the last pen of cattle were harvested on November 1st, 2016. Cattle were weighed every 28 days until harvest.

The final price at harvest is the actual price received from a pen. The price of fed cattle is based on the cash price of cattle in the Iowa/Minnesota area as reported by the USDA. Feed prices are formulated by Gregory feedlots. Feed consumption is calculated by the Cornell Value Discovery System which is based on what an animal currently weighs and what that animal gained in the previous period. Interest and yardage are calculated by Gregory feedlots. Once consumption is assigned to an individual head, then it is prorated back based on the actual feed consumed by the pen. Body Condition Score, Frame Score, and Muscle Score were all evaluated by a USDA market reporter for the area.

PMR Methodology

Estimated Growth Model

Research that estimates growth functions for cattle is long standing. Brown et al., (1976) compare the effectiveness of five different growth functions when modeling weight-age relationships for female cattle. They estimate the Logistic, Gompertz, Richards, and Brody growth functions and found the Brody function to be the best predictor of weight for their application. Goonewardene et al., (1981) developed a similar approach using the Logistic, Richards, Brody, and Von Bertalanffy functions to analyze the growth of cattle females. Forni et al. (2009) is another example where these growth functions are used to model the growth of Nelore female cattle. Each of these studies analyzes the growth of cattle over multiple years (life-cycle) of data as these females are tracked from birth till removal from the breeding herd.

There are several functions to consider when estimating biological growth (Tsoularis and Wallace, 2002). Estimates of growth in animals are obtained by tracking live animal weight over time (or age) and the functional form is often chosen by i) how well it fits the data, and ii) its computational ease (Lopez et al., 2000; Brown et al., 1976). Growth functions can be estimated for either individual or groups of animals by estimating nonlinear biological parameters, such as the intrinsic rate of growth over time (e.g. Brown, et al., 1976; Perotto et al., 1992; Menchaca et al., 1996). Furthermore, it has been shown that growth and nutrient requirements are interrelated, and feed sources necessarily impact growth rates (Perry and Fox, 1997; Pereda-Solis et al., 2011).

Therefore, a three-stage approach was taken in order to formulate an appropriate growth model for ex-ante analysis. The beginning of formulating a realistic growth function starts with understanding how this function may look and the functional form of the corresponding weight function. This is the first stage as we follow the theoretical framework outlined by (Maples et al.), which compared two logistic growth models for use in a profit maximization rule in the feedlot. One model assumed birth weight is known as cattle arrive in the feedlot (Verhulst Life-Cycle Growth Model) while the other assumed birth weight is unknown (Days-On-Feed Growth Model). Considering the current data that is being used follows cattle from birth to harvest we will use the model that includes birth weight into its estimate of growth. This model starts with the Verhulst life-cycle growth model (the most common life-cycle growth model), imposes an initial condition, and then integrates the differential of this equation as derived by Maples et al. (2015). This equation is represented by

$y_i(t;\Omega_i) = \frac{m_i}{1+\gamma_i e^{-k_i m_i t}}$ (1), where k_i denotes an efficiency parameter, γ_i denotes a phenotypic adjustment factor (birthweight model restriction), and m_i is maturity weight as time goes to infinity.

Each parameter is considered to be a function of both genotype and environmental influences which were estimated using a basic OLS model. Environmental influences are considered to be representative of the various feedlots and management practices within these multiple feedlots. Stage two consists of regressing those exogenous variables on m and k in order to form an appropriate model for ex-ante analysis.

Stages

As stated previously, projecting individual growth curves for these cattle consists of three stages. The first stage consists of estimating the growth parameters using historic data from the Tri-County Steer Carcass Futurity (TCSCF). Parameters *m* and *k* were estimated by nonlinear least squares estimation using known (true) weights.

In the second stage, parameter *k* is estimated using a basic OLS regression formulated as a function of delivery age, hide color, delivery weight, body condition score, frame score, muscling score, sex, sire breed, dam breed, whether the animal is purebred or not, delivery month, origin, and feedlot location. Parameter *m* is estimated as a function of these same regressors with a bound restricting cattle to a maturity weight of 1800 (pounds). The parameters were estimated holding gamma constant at t_0 (birth weight) as discussed earlier. This will then yield the predictive ex-ante model for growth. In this stage *marginal factor* cost is estimated using the same variables.

Experimental design in the third stage consisted of specific data collection procedures outlined as follows. Upon entering the feedlot, cattle were weighed every 28 days. Body condition score, frame score and muscling score were evaluated by USDA market reporters. Once the first set of data is collected, the growth parameters were estimated using the OLS models derived earlier.

Parameters *m*, *k* and *marginal factor* cost were continually be updated as new information is acquired via an Ad Hoc updating procedure explained as follows. Once the growth parameters (*m* and *k*) have been estimated, estimated weights for each weighing period (every 28 days) are given. Once new (true) weights have been acquired, these true weights then replaced the estimated weights and new growth parameters were calculated using nonlinear least squares. *Marginal factor* cost were estimated using average aggregated closeout data provided by the feedlot using feed cost, interest, and yardage. Any costs occurred only once will not be considered in the equation for marginal factor cost (only cost that can change over time will be considered).

Profit maximization for each individual head begins with estimating the marginal physical product of the growth function. Marginal physical product (MPP) is then multiplied by price to get the value of the marginal product (VMP). The corresponding time period when VMP=MFC is the projected profit maximizing time period to sell.

Updating procedure for cattle that are failing/exceeding predictions

Cattle that are ten percent away from the most recent weighing in current predictions are updated to more rapidly put weight on true weights cattle have received. The updating process uses the simple rule of ten percent in order to reduce furthering inaccuracy. A Macro Do-loop in SAS uses an iterative process to continually take true weights along with predictions to reduce error in between known weights and the associated projected weights. This process first takes these true weights and the most recent projections and updates the m and k variables normally as outlined previously. Following that, these new projections are taken along with the truth and projects new m and k variables. This process is then continues until total weight error is minimized for the weighing periods that have already occurred. It should be noted that m and k variables are inevitably a function of the first projections made when cattle arrive in the feedlot. This can make it difficult to overcome these first impressions if cattle are not projected right from the beginning.

Method of Treatment Comparison

Once all cattle have been harvested, the next step is to compare profitability among treatments. The first procedure to compare profits is to look at realized marginal profits. Considering time independent costs are not decision making variables, it would be realistic to only look at marginal profits. Marginal profits are estimated as the income received from harvest minus feed cost, yardage, and interest. Realized profits, which will also be used as a method of comparison, are simply based on the carcass value received at harvest. A weakness of this approach, though, is that stochastic prices and carcass traits are a function of the marketing methodology. The second procedure is to compare normalized marginal profits. Normalized profits are based on the cash price associated with predicted harvest dates. A weakness of this method is that it could potentially bias results due to unknown realizable carcass characteristics. Considering the elements of this marketing procedure, estimated weights will be used for cattle that were not able to be sold on time.

Results

Initial results using realized profitability between treatments indicates that the EPM treatment outperformed the PMR treatment by an average of $48.76 per head. Once marginal profits were calculated, the EPM treatment made an additional $59.10 per head more than the PMR treatment. Considering that most cattle in the PMR treatment were not marketed on time according to each relative growth function, the associated growth function with each individual head was used to calculate was these cattle would have weighed had they been marketed optimally. In order to formulate realistic prices associated with this date, cash price during the optimal marketing time period was used. An adjustment for weight error was also made. It was formulated as the actual harvest weight divided by the predicted weight at harvest. That weight error adjustment is then multiplied by predicted weight associated with the optimal harvest date to give a more realistic prediction of what the cattle would have weighed at that point in time. Given that method of comparing treatments, the EPM treatment outperformed the PMR treatment by $42.23 per head. Using uniform prices (i.e. the same constant price for all cattle) is was found that the PMR treatment outperformed the EPM treatment by $11.75 per head.

Once comparing profits among treatments is done, further analysis must still be done. Considering that cattle were sorted into treatments based solely on sex and weight alone, this may still lead to an inherent profitability bias among treatments. Ex-post analysis was used in order to compare true profit potential between the two groups. True, known weights for the cattle were taken and a growth curve was fitted for all cattle in both treatments. Then the optimal selling point was derived given the equations relative to each animal and individual cost data, using a constant price. The constant price that is used for this part of the analysis is the average price received by the EPM group. Upon completion, it was discovered that the EPM group had a $24.40 advantage. Taking this into consideration, the EPM treatment still outperformed the PMR treatment for most analysis but not nearly as significantly. These results can be found in Table 1. Carcass characteristic differences are not surprising. Marbling score for cattle marketed with the PMR approach had a higher average but also a higher standard deviation as can be found in Table 2.

Conclusion

Discussion

As discussed previously, the EPM treatment did outperform the PMR treatment. This may be due to a few reasons. Considering the relative price volatility (as can be seen in Figure 1) that occurred within this market at the time the trial was conducted (price had decreased as much as $38.87/cwt at one point in this time period), using myopic prices may have failed to truly predict an optimal time period to sell. As you can see from Maples et al. (2015) and from the current analysis using constant prices, in fairly stable market conditions this methodology will outperform the EPM strategy. Within this specific extreme, though, we did not see profitability improvements using the PMR methodology.

This area of research (within regards to optimal timing in a feedlot) needs continued analysis. We know from previous literature (Maples et al., 2015) that profit maximization can be applied to a feedlot setting. Considering the logistical constraints encountered within this experiment, another trial should be ran with a larger number of cattle. Price forecasting is another area that needs further consideration when applying a profit maximizing approach, especially when dealing with extreme price declines within a market. As well, understanding how cattle can be better fitted to a growth curve using an ex-ante approach should be explored. Overall, this methodology has been proven to work prior to this study but further research and analysis should be conducted before applying it to private industry.

Implications for Future Research

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The first area of improvement is in regards to feed consumption. As outlined earlier, feed is charged based on how much the animal already weighs and how much the animal has gained since the last weighing. Then that number is prorated back to what a pen consumed in aggregate. The problem inherently associated with this process is that some cattle convert feed to muscling easily and others do not, leaving the feed consumption estimate inaccurate on an individual head basis. For example, those cattle that do convert feed well may not eat as much as the average animal in that pen but also perform very well and may gain more than the average gained in the pen. However, they will get charged more feed than they actually consumed because they gained weight and converted feed well. With the cattle that do not convert feed well, they may be eating more feed relative to other cattle in the same pen but get charged very little feed because they are not growing very well. Thus, costs may be estimated inaccurately which effects optimal timing and profitability.

Genetic diversity is another area where more information may be useful. Thompson et al. (2016), note that additional genetic information may gain producers \$1-\$13/head. However, genetic testing cost roughly \$40/head. Thus, the cost does not justify the additional information gained. This does, though, allow one to consider that benefit of additional information.

Considering the ex-post estimations of profitability bias, sorting cattle into treatments should take further consideration. One potential way to sort cattle is utilizing the ex-ante predictions. Using the predictions, sorting cattle based on expected profitability may alleviate some bias. If a larger sample size were obtained, though, then this bias is of less concern. However, sorting cattle solely on sex and weight should not be considered sufficient for future studies regarding profitability.

The logistic growth model does have a few short-comings. This model tends to lack flexibility for individual animals that may exceed (or fall short of) the efficiencies of a group of cattle. As discussed previously, a method was put in place to deal with cattle that do not fit their individual growth curve well. However, individual growth curves still rely heavily on the ex-ante predictive model as a baseline. As well, the data that was used to formulate this model (since this is an ex-ante evaluation, we must have estimates we are ready to apply in the feedlot) only has cattle that are higher in delivery weight when arriving in the feedlot than what was seen in the cattle that are used in this analysis. Therefore, further analysis should be conducted to determine how the Ex-Ante predictive model can further be improved through estimation of the parameters as well as other utilizing other growth functions. As well, updating processes such as Bayesian updating or machine learning should be explored.

As discussed previously, price expectancy is an issue that should be further explored. Producers not accounting for steep price declines or inclines may lead to regret when using this model. However, attempting to account for future trends when the market in actuality stabilizes may also lead to regret. Essentially, this methodology has the potential to account for price movement and still produce an optimal decision but is still contingent on the accuracy of price forecasting. Furthermore, it should be noted (as before) that when incorporating the price movements the value of the marginal product takes a different functional form that when assuming constant prices.

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Table 1. Profitability differences among treatments

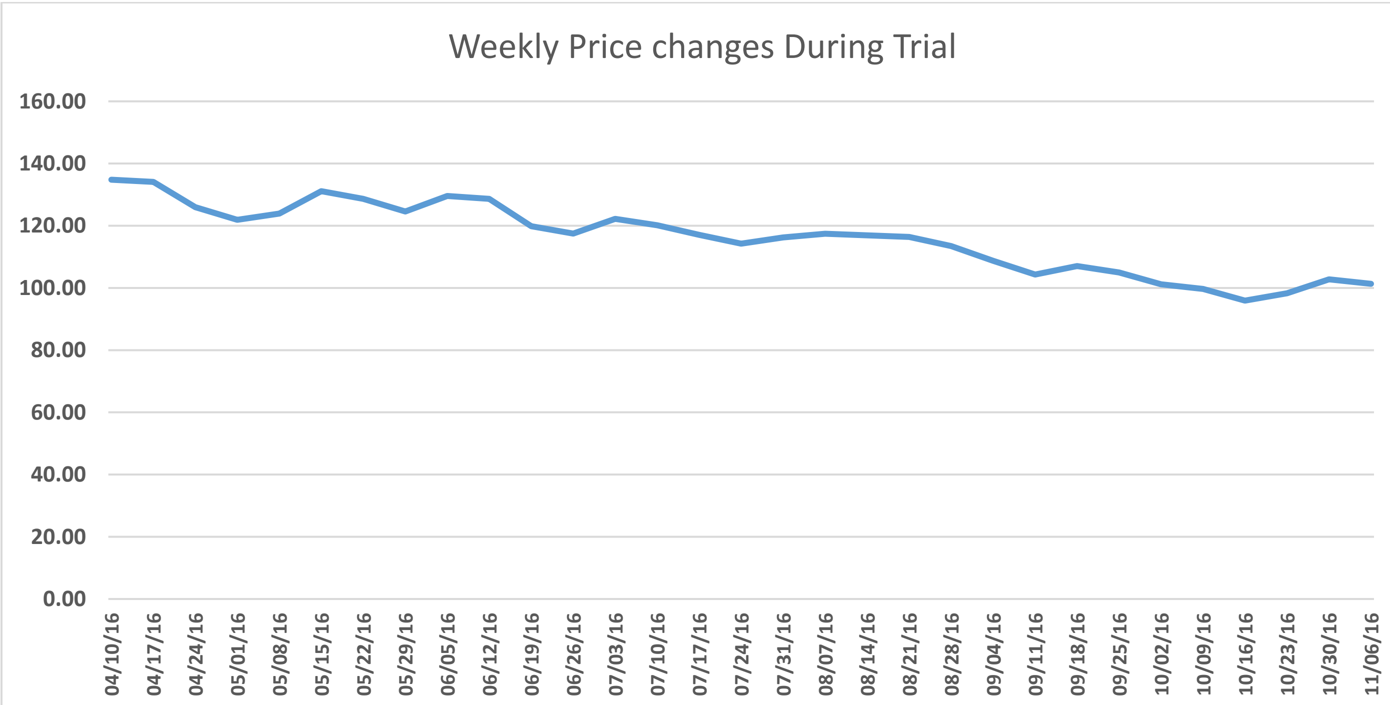
	PMR	EPM	difference	True difference
Realized Profit	-41.3259	7.437515	-48.7633871	-24.36338713
Profits without risk management	-73.5557	-24.8028	-48.7529006	-24.35290061
marginal profit	999.3638	1058.468	-59.1042758	-34.70427581
marginal profit with weight correction	1046.996	1089.229	-42.2332813	-17.83328131
marginal profit using a Constant cash price	1096.431	1084.681	11.75022774	36.15022774

Note: True difference denotes the profitability difference when it is corrected for treatment bias

Table 2. Carcass Characteristic Summary Statistics

	Marbling Score	Marbling Score
	PMR	**EPM**
Average	1050.114754	1044.483871
Min	899	880
Max	1362	1197
S.D.	85.20449814	73.52215859

Figure 1.



Weekly Price changes During Trial
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
04/10/16
04/17/16
04/24/16
05/01/16
05/08/16
05/15/16
05/22/16
05/29/16
06/05/16
06/12/16
06/19/16
06/26/16
07/03/16
07/10/16
07/17/16
07/24/16
07/31/16
08/07/16
08/14/16
08/21/16
08/28/16
09/04/16
09/11/16
09/18/16
09/25/16
10/02/16
10/09/16
10/16/16
10/23/16
10/30/16
11/06/16