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# Pricing Fed Cattle on a Grid: An Analysis of the Incentive Mechanism over Time

**By**

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**Abstract**

Empirical results suggest that the grid premium and discount structure is slowly adjusting carcass quality incentive/disincentive market signals to encourage marketing on a grid and discourage marketing by the pen. If this trend continues, grid market share of steer and heifer slaughter volume should increase in the future.

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**Introduction:**

The beef industry has experienced relatively weak demand and declining market share for its product over the last thirty years (Tonsor 2011). The beef industry, however, has not remained passive in the face of weak demand and the loss of market share to pork and poultry. The beef industry responded by suggesting production and marketing reforms along its entire supply chain. The stated goal of these suggested reforms is to transform the beef industry into a value-based industry. The blueprint of this initiative is outlined in an industry sponsored white paper: War on Fat released by the Value Based Marketing Task Force (VBMTF 1990).

A key component of the initiative is the call for the development of a value based pricing system. In the early 1990s the industry began the conversion from the traditional "Grade and Yield" pricing system for fed cattle into what is commonly referred to today as grid pricing. The goal of the beef industry's movement toward value based pricing is to improve the flow of information from the consumer to the producer so that the industry is producing the "right product at the right price to meet consumer demand" (Fausti et al. 2010a: p. 19).

The grid pricing literature (e.g., Schroeder and Graff 2000; Fausti and Qasmi 2002; McDonald and Schroeder 2003; Johnson and Ward 2005) has investigated and discussed in great detail the effectiveness of the grid pricing system to transmit market signals to producers with respect to carcass quality. This literature has also discussed potential barriers to the potential across-the-board producer adoption of grid pricing (e.g., Fausti et al. 1998; Belasco et al. 2010). Several studies have attempted to estimate grid market share of fed cattle slaughter volume (e.g., Schroeder et al. 2002; Muth et al. 2007; Fausti et.al 2010a) to determine the level of industry adoption of the grid pricing system. However, up to this point, empirical evidence on if the incentive structure of the grid pricing system (since its inception) has become a more effective signaling mechanism with respect to carcass quality has not appeared in the literature.

The objective of this paper is to investigate *if* the effectiveness of the grid pricing system to transmit informative price signals to producers has changed over time. In this study, we evaluate grid price signals by comparing carcass quality incentive/disincentive price structure of the grid system to selling fed cattle by the pen at an average price.

Specifically, we simulate per head weekly price (grid and dressed weight) and then derive the pen level average price (grid and dressed weight) and the price differential (gird minus dressed weight) for two pens of slaughter cattle (1500 head per pen) over a 381 week period. The two pens differ with respect to carcass quality but individual animal carcass attributes remained fixed over the timeframe of the study. We employ an EGARCH-in-Mean regression modeling procedure to analyze price differential variation over time. Our empirical results indicate that the incentive to market high (low) quality cattle on a grid (by the pen) has increased (decreased) during the timeframe covered in this study. This finding indicates that the grid pricing system's role as a value based pricing system is strengthening. Furthermore, we incorporated the model's conditional variance as an explanatory variable and found that market risk does affect the incentive structure associated with the decision to market on a grid or by the pen. The incorporation of price volatility modeling tools into the grid pricing literature reflects a contribution to the empirical literature on livestock markets.

**Literature Review:**

Agricultural economists have investigated a number of issues pertaining to the beef industry's value based marketing (VBM) initiative for slaughter cattle. A general discussion of this literature can be found in Fausti et al. (2010a). The success of the value based marketing initiative cannot be measured by a single metric. Consumer acceptance can be measured by changes in beef demand over time (Schroeder et al. 2000), or investigated using experimental methods (e.g., Umberger 2007). Production efficiency, with respect to carcass quality, has been investigated in the context of technological innovation to enhance value based beef production and marketing methods (e.g. Lusk 2007; Koontz et. al. 2008).

A white paper (War on Fat) published by the Value Based Marketing Task Force (VBMTF 1990) specifically discussed the need for an alternative pricing system to the traditional practice of selling fed cattle at an average price by the pen. Selling fed cattle at an average price by the pen is viewed by the beef industry (VBMTF: consensus point 7) as an inefficient pricing mechanism because it distorts market signals from the consumer to the producer (Feuz et al. 1993) with respect to carcass quality. The price signal issue arises because selling slaughter cattle by the pen at a negotiated price per hundred weight allows pricing error to enter into the transaction because carcass quality: a) is unknown at the time of the transaction, and b) is not uniform across all animals in a pen. Thus, animals with desirable carcass attributes are paid the same price per pound as animals with undesirable carcass attributes. Thus, low quality cattle are being paid a premium above their actual market value, and high quality cattle are being penalized by being paid a price per pound below their actual market value. The implication is that producers who sell by the pen do not receive a price signal on carcass quality differences for the animals they market within a pen.

The introduction of grid pricing mechanisms (GPM) as a value-based pricing system alternative to pen level sales (Fausti et al. 1998) reflects the beef industry's desire to improve carcass quality through the market mechanism. Grid pricing mechanisms have been touted by the beef industry and academic researchers as a key component in the development of a value based marketing system for fed cattle (Schroeder et al. 1998). The goal of a grid pricing system is to provide an incentive/disincentive mechanism that rewards desirable carcass attributes and discounts undesirable carcass attributes, thus providing a market signal that will encourage producers to improve carcass quality.

Agricultural economists have investigated effectiveness of GPM as a price transmission mechanism from consumers to producers (e.g., McDonald and Schroeder 2003; Johnson and Ward 2005 & 2006). The general consensus is that carcass weight rather than grid premiums and discounts assigned to carcass quality attributes is still a very important component of the GPM price signal. Johnson and Ward (2006) report that for cattle with the highest (lowest) carcass quality sold on a grid, weight accounted for 79% (50%) of the market signal. Furthermore, they report that grid discounts account for 20% and 49.5% of the market signal for high quality and the low quality cattle groups in their study, respectively. Their findings are consistent with earlier studies that have raised the issue that the GPM premium and discount structure may act as a "barrier to adoption" of grid pricing by producers (e.g., Fausti and Qasmi 2002).

The goal of the VBM initiative is to transform the beef industry's production and marketing system along the entire supply chain. To accomplish this goal, a VBM pricing system needs to capture a dominant share of fed cattle sales. While grid marketing has increased in importance as a pricing method for fed cattle over the last fifteen years, it has not replaced average pricing by the pen as the dominant marketing option selected by fed cattle producers. Fausti et al. (2010a) provides empirical estimates that grid market share of steer and heifer slaughter has increased from the low teens in the 1990s to approximately 45% in 2009. The inability of the grid pricing system to capture a dominant share of fed cattle slaughter implies a weakness in the incentive mechanism.

Conceptually, an important objective of GPM as an integral component of a value based marketing system is to induce fed cattle producers to sell their cattle on a grid. The benefits to producers who sell on a grid touted by the beef industry are: a) producers will be rewarded for the above average cattle they sell on a grid, and b) producers will be given detailed information on the quality of each individual carcass by the packer. Carcass information and the premiums represent the gird market signal to the producer that is absent when cattle are sold at an average price by the pen. In turn, the producer will make adjustments to his/her production system to improve the carcass quality of animals sold in the future. However, there is also risk the producer must accept. When a producer sells on a grid he/she faces uncertainty concerning the average quality of animals they are marketing. This uncertainty creates a financial risk that their cattle may be of lower quality than they expected. The reason why this financial risk exits is because; producers do have the option of selling their cattle by the pen at an average price. In this case, the buyer (packer) assumes the financial risk associated with carcass quality uncertainty (see Fausti and Feuz 1995 for additional discussion of this issue).

The key to accomplishing the beef industry's goal of having a dominant value based pricing system is dependent on how effective the grid pricing system's incentive mechanism is at transmitting market signals to producers. A key indicator of success would be if the incentive to market higher quality cattle on a grid strengthens and the disincentive to market lower quality cattle on a grid weakens. A weakening of the incentive to market lower quality cattle by the pen at an average price relative to selling on a grid will encourage producers to increase their use of a grid when marketing fed cattle. In turn, information of grid performance will encourage producers to adopt value based production practices. A key metric of success for the beef industry's value based initiative is a reduction in the "barriers to adoption" of its value based pricing system.

Thus, a logical approach for evaluating the effectiveness of GPM incentive mechanism is to compare its performance as a signaling mechanism relative to the alternative pricing methods available to producers. Evaluating market outcomes for cattle sold on a grid relative to cattle sold live or dressed weight has been a common practice in the grid pricing literature (e.g., Fausti et al. 1998; Schroeder and Graff 2000; Anderson and Zeuli 2001).

**Data**

Carcass data on 2590 slaughter steers was collected from a retained ownership study conducted by South Dakota State University. A random sampling procedure was employed to construct two data sets. The first dataset, labeled "Choice" data, consists of 2/3 choice grade steers and 1/3 select grade steers, whereas the second dataset (Select) includes 2/3 select grade steers and 1/3 choice grade steers.[1] Table 1 contains the summary statistics for the two data sets.

**Table 1**

The carcass data was used to simulate weekly per-head market value using both a grid pricing system and a dressed weight pricing system. The weekly market simulation was used to derive a weekly average for the pen level per-head revenue differential for both pens using a matched pairs process. Weekly grid price per-head was determined using a calculated a weekly base price and the weekly AMS additive grid as proposed by Fausti et al. (1998). Weekly grid premium and discount data was collected from USDA-AMS weekly report (LM_CT155): *National Carcass Premiums and Discounts for Slaughter Steers and Heifers*. The pen level dressed weight price (typically referred to as Hot Carcass Weight (HCW) price) is the Nebraska Weekly Direct Slaughter Cattle-Negotiated Purchases report (LM_CT158). The reported HCW price selected is for dressed delivered steers grading 35% to 65% choice. For each week from April 2001 to July 2008 (381 weeks) individual steer market values were estimated, matched pair differences were calculated ($GridRev_{it} - HCWRev_{it}$), and pen level averages were calculated to derived the variable of interest denoted $RevD_t$ for the high and low quality grade pens.[2] Summary statistics describing the data can be found in tables 2 and 3.

**Tables 2 and 3**

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[1] Additional information these data sets can be found in Fausti et al. (1998).

[2] We did not include AMS grid premium and discount data from October 1996 to April 2001 (pre mandatory livestock price reporting period) due a recent study by Fausti et al. (2010b). This study suggests that AMS publicly reported weekly grid premium and discount data may have been tainted by sample selection bias.

Explanatory variables were selected based on potential influence on $RevD_t$. Given that carcass quality is being held constant over time, reported weekly AMS grid premiums and discounts, a seasonality dummy variable, and a time trend variable were selected. Given that grid premium and discount prices within the quality grade and yield grade categories are highly correlated, we selected the choice/select discount, yield grade 1-2 premium, and the yield grade 5 discount as the proxies for the grid pricing system in our empirical model. Note, we converted the grid discounts to positive values to simplify interpretation.

**Methodology**

We employ an EGARCH-in-Mean regression model to examine the revenue differentials for the choice and select datasets. The revenue differential is defined as the pen average of the per-head matched pair revenue difference between the AMS grid and the HCW price. Following the price discovery literature (Ward 1987, Feuz et al., 1995, Fausti and Feuz, 1995), we consider informational disparity over cattle quality and risk aversion of cattle producers as primary factors explaining the revenue differentials between the two marketing alternatives. Other important factors are included, such as past revenue differentials, the potential trend in preference for the AMS grid marketing alternative and seasonal price pattern.

We propose the following regression for the revenue differential for the choice data:

$$RevD_t = const + \sum_{l=1}^{L} \phi_l RevD_{t-l} + \beta_1 selectp_t + \beta_2 yg2_t + \beta_3 yg5p_t + \beta_4 T_t + \beta_5 DS_t + \beta_6 ln(h_t) + \varepsilon_t \quad (1)$$

where $RevD_t$, $const$, $RevD_{t-l}$, $selectp_t$, $yg2_t$, $yg5p_t$, $T_t$, $DS_t$ and $h_t$ are the weekly revenue differential, intercept, lagged revenue differential, the choice-select premium, the premium of yield grade 2 relative to the benchmark grade, the discount of yield grade 5 relative to the benchmark grade, time trend, seasonal dummy and conditional variance (risk) associated with the regression residual $\varepsilon_t$ [3], respectively. In particular, $selectp_t$, $yg2_t$ and $yg5p_t$ capture the informational disparity over quality; the logarithm of $h_t$ is considered as a proxy for risk.

Durbin-Watson test statistics based on preliminary regression indicate that error terms $\varepsilon_t$ are auto-correlated. Q and LM test statistics show that a significant ARCH effect is present in the residuals of the regression. The following EGARCH(q,p) model is employed to account for the above effects.

$$\varepsilon_t = \sum_{n=1}^{N} \rho_n \varepsilon_{t-n} + \sqrt{h_t} e_t \quad (2)$$

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[3] Conditional variance $h_t$ is defined precisely by the EGARCH model in Equations (2) and (3).

$$ln(h_t) = \omega + \sum_{i=1}^{q} \alpha_i [\theta e_{t-i} + (| e_{t-i} | - E | e_{t-i} |)] + \sum_{j=1}^{p} \gamma_j ln(h_{t-j}) \quad (3)$$

where $e_t \sim i.i.d.N(0,1)$.

Additionally, the EGARCH model has two desirable features that are not available in the traditional GARCH model. First, the parameters in (3) are not restricted to be positive; Second, the item in parenthesis "$| e_{t-i} | - E | e_{t-i} |$" captures the asymmetric effect of residual shock on conditional variance. In particular, the asymmetry exists when the coefficient of $e_{t-i}$ is $\theta + 1$ for $e_{t-i} > 0$ and $\theta - 1$ for $e_{t-i} < 0$.

Lastly, we determine the appropriate order of lags in Equations (1) through (3). For the regression model (Equation 1), we choose three lags of $RevD_t$ with coefficients at least significant at the 5% level. For the model of auto-correlated errors (Equation 2), we first assume constant $h_t$ and then run the regression model with auto-correlated errors. We remove insignificant lags from a maximum length of 13 based on backward elimination. More specifically, we retain the first four lags for the choice dataset and the third and fourth orders for the select dataset. For the EGARCH model (Equation 3), we employ the minimum number of lags while ensuring the normality of the residual $e_t$. It amounts to the choice of q=9 and p=1 for the choice dataset and q=9 and p=4 for the select dataset.

Using the above settings, we verify the fitness of the EGARCH-in-Mean regression model, reported in table 4. The respective model fits the choice dataset better than the select dataset according to the substantially lower regression errors (SSE, MSE, MAE and MAPE) and higher R-square. The significance of Jacque-Berra normality test is 0.91 and 0.80 for the choice and select datasets, respectively. We cannot reject the null hypothesis of normality of residual $e_t$, which confirms the critical normality assumption of the EGARCH model.

**Table 4**

**Empirical Results**

The summary statistics presented in table 3 are consistent with the empirical literature on grid pricing. Summary statistics reflect long-run marketing outcomes for two pens of cattle holding carcass quality attributes constant over time. Empirical evidence indicates that higher quality cattle are rewarded on a grid and lower quality cattle are penalized relative to selling at an average price. Regardless of cattle quality revenue variability is higher when marketing on a grid.

The summary statistics also provide insight on the relationship between financial risk and carcass quality uncertainty. Assume the producer is uncertain about the carcass quality of his/her cattle and the producer owns both the choice and select pens. Summary statistics indicate that there is a \$23.77 per-head price differential between marketing above average cattle on a grid relative to selling below average cattle on a grid (table 3: \$963.31-939.54). This per-head price differential represents the mean of the statistical range in per-head average price per-pen. if the producer is uncertain about the carcass quality of the cattle he/she is selling, then this price differential represents the per-head financial risk the producer faces. On the other hand, comparing revenue from selling below and above average cattle at an average price resulted in only an 84 cent HCWP per-head differential between pens. In this case, the financial risk the producer faces is zero, because this differential is the result of the minimal weight difference across pens.

The EGARCH-in-Mean regression model is estimated using maximum likelihood. The results for the choice and select datasets are reported in the left and right panels of table 5, respectively. We analyze the regression results before presenting the EGARCH model. All results are compared between the two datasets.

**Table 5**

*Regression Results: Grid Premiums and Discounts*

In table 5, the estimated coefficient for the choice-select discount $selectp_t$ is 1.544 for the choice dataset vs. -0.540 for the select dataset. The choice-select discount essentially functions as a market signal on the current price differential between carcasses with a higher percentage in the level of intramuscular fat and carcasses with a low level. The grid pricing literature has documented that is quality grade price differential is the dominant carcass characteristic explaining per-head revenue variability (e.g. Johnson and Ward 2005 & 2006). The economic intuition for the empirical estimates for $selectp_t$ indicates for a one dollar increase in the choice premium (select discount); a) the per-head price differential (the incentive to market on a grid) for the choice pen increases by \$1.54, and b) the per-head price differential (the disincentive to market on a grid) for the select pen increases by \$0.54.

Our empirical estimates clearly indicate that change in the choice/select spread alters the financial risk producers' face when deciding to sell cattle on a grid or market by the pen. Assume current markets conditions are consistent with \$23.77 per-head price differential between marketing above average cattle on a grid relative to below average cattle. A one dollar increase (decrease) in the choice/select discount will increase (decrease) the per-head price differential to \$25.85 (\$21.69). We conclude that the incentive structure for marketing high (low) quality grade cattle on a grid relative to selling by the pen strengthens (weakens) as the choice/select discount increases.

Empirical estimates for the yield grade premium and discount variables indicate they do affect the per head price differential ( $RevD_t$ ) for the choice and select pens. The premium "*yg2*" for high yielding (boneless retail cuts) carcasses has a positive relationship with the per head revenue differential for both the choice and select pens. As in the case of the choice/select spread, our empirical estimates indicate that a change in "*yg2*" premium affects the incentive (disincentive) to sell cattle on a grid (by the pen). A one dollar increase "*yg2*" in the premium will decrease the per-head price differential for the select pen by $2.63. This reduces the incentive to market the select pen live weight to $2.70 (based on -$5.33 statistical mean grid discount). On the other hand, for the choice pen, the incentive to market on a grid increases by $1.46. Thus, an increase in the "*yg2*" premium by one dollar reduces the financial risk a producer faces if there is uncertainty concerning the level of carcass quality. Assuming uncertainty over carcass quality, the financial risk decreases (the grid price differential between the choice and select pens) when the yg2 premium increases. Financial risk declines from $23.77 per-head to $22.60. We conclude that the incentive structure for marketing on a grid relative to selling by the pen strengthens (weakens) as the "*yg2*" premium increases (decreases).

The final grid price variable included in the model is yield grade 5 (*yg5p)* and it is negative for both the choice and the select models. A one dollar increase in the "*yg5p*" discount will reduce the incentive to sell the choice pen on a grid by $0.52. Given the statistical mean for the grid premium for the choice pen is $17.27, an increase in this discount will only have a minimal effect of the incentive to market the choice pen on a grid. However, for the select pen, the disincentive increases by $0.85. For the select pen, there is a $5.33 incentive to sell by the pen. This increase to $6.18 for a one dollar increase in "*yg5p*", ceteris paribus. The financial risk (the grid price differential between the choice and select pens) of an increase in the yg5 discount increases when there is uncertainty over carcass quality by $1.37, from $23.77 per-head to $25.14. We conclude that the incentive structure for marketing on a grid relative to selling by the pen weakens (strengthens) as the "*yg5p*" discount increases (decreases).

One interesting results stands out; an increase in the choice carcass premium and yield grade 3 premium have the opposite effect on the producer's incentive to market on a grid. This inherent conflict in the structure of the grid pricing system appears to be a "barrier to adoption" that has not be identified in the previous literature.

*Regression Results: Time Trend and Seasonality*

The literature has yet to answer the question: is the incentive structure of the grid pricing system evolving over time? The time trend in the regression can help address such a question. From Table 5, we find that $T$ is a significant factor for both datasets. During the sample period (2001-2008), the positive (negative) revenue differential became larger (smaller) for the choice (select) quality cattle. This implies that the incentive for marketing high (low) quality cattle on the grid (pen) gains has strengthened over time. In a recent article by Fausti et al. (2010a), it is reported that grid market share of steer and heifer slaughter volume increased from 35.8% in 2004 to 38.8% in 2008. The increase in grid market share of slaughter volume is consistent with our empirical finding that the incentive mechanism for marketing on the grid has strengthened and the incentive to market by the pen has declined during the period covered in the data. Documentation of the evolving nature of the grid pricing system's incentive mechanism opens additional opportunities for additional research on this issue.

Peel and Meyer (2002) discuss the seasonal pattern in fed cattle prices; price is lower in the summer and higher otherwise. The revenue differential doesn't follow the same seasonal pattern and has been discussed in the gird pricing literature. In our model, the seasonal dummy *DS* is defined as 1 between June and December, and 0 otherwise. The *DS* coefficients for both datasets are statistically significant at the 2% level and negative. Therefore, the revenue differential does exhibit seasonality. The negative coefficient of *DS* implies that the revenue differential for choice pen is lower, i.e., a slight decline (-$0.59) in the incentive to market on a grid in the summer and fall. For the select pen the negative coefficient implies the incentive to market by the pen slightly increases between June and December. These results are consistent with previous seasonal patterns reported in the literature (e.g., Fausti and Qasmi 2002).

*EGARCH-in-Mean Model Results and Implications for Marketing Risk*

The EGARCH-in-Mean model can be decomposed into five effects: the ARCH effect $\alpha$, the GARCH effect $\gamma$, the sign effect $\theta e_t$, the size effect[4] $|e_t| - E|e_t|$ and risk premium $\delta ln(h_t)$. The majority of the nine ARCH coefficients are positive for both datasets, implying that the past shocks amplify the conditional variance $h_t$. The GARCH coefficient is (largely) negative for the choice (select) dataset, indicating that the conditional variance exhibits a mean-reverting pattern. The sign (or asymmetry) effect is different between the choice and select datasets: negative for the former and negative for the latter. The conditional variance of the residuals for the choice dataset increases in response to negative shocks. Conversely, the conditional variance of the residuals for the select dataset reacts more to positive shocks. Assuming that conditional variance is a proxy for the risk, the risk premium associated with logarithm of $h_t$ is significantly negative for the select dataset, although insignificant for the choice dataset. One view of this result is that sellers of select cattle are more willing to market their cattle by the pen in order to avoid an even larger penalty on the grid. The EGARCH model verifies the view in the literature that carcass quality uncertainty injects financial risk into the marketing decision and this risk disproportionally affects lower quality cattle. Thus, producer uncertainty over the quality of cattle they are marketing marks selling them on a grid inherently risky.

**Table 5**

Summary

There are three cash market pricing alternatives that producers have to select from when marketing their fed cattle (live weight, dressed weight, and grid). The coexistence of pen level

[4] Here we fix the magnitude of the size effect to be "1", instead of a multiplication (of $|e_t| - E|e_t|$) for simplicity.

pricing system with the individual animal gird pricing system is an obstacle in the path of the beef industry's goal of transforming itself into a value based production and marketing system. Selling cattle at an average price by the pen is still very appealing to producers who are risk averse, lack the financial capital to adopt value based production technology, or lack economies of scale to gain access to marketing outlets that offer a grid pricing alternative (See Fausti et al. 2010 for additional discussion on these issues). However, changes in the grid incentive structure can mitigate these barriers. The empirical evidence suggests that the grid pricing system incentive structure is evolving to overcome these barriers to adoption.

Empirical results suggest that the grid premium and discount structure is slowly adjusting its carcass quality incentive/disincentive to encourage marketing on a grid and discourage marketing by the pen at an average price. If this trend continues, grid market share of steer and heifer slaughter volume should increase in the future.

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Table 1. Summary Statistics: Cattle Carcass Attributes

| Data Set/ Variable | N | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| Select Data Set: | | | | | |
| HCW | 1500 | 718.57 | 74.61 | 478.00 | 964.00 |
| QG | 1500 | 2.70 | 0.53 | 1.00 | 4.00 |
| YG | 1500 | 2.66 | 0.64 | 0.64 | 5.06 |
| Choice Data Set: | | | | | |
| HCW | 1500 | 719.37 | 73.84 | 478.00 | 964.00 |
| QG | 1500 | 2.35 | 0.52 | 1.00 | 4.00 |
| YG | 1500 | 2.78 | 0.62 | 0.64 | 5.06 |

Table 2. Summary Statistics: National Carcass Premiums and Discounts for Slaughter Steers and Heifers ($ per hundred weight)

| Variable | N | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| Choice/Select | 381 | -9.81 | 4.44 | -24.87 | -2.84 |
| YG 1-2 | 381 | 2.88 | 0.29 | 1.89 | 4.30 |
| YG>5 | 381 | -18.47 | 0.73 | -22.71 | -16.55 |

Table 3. Summary Statistics

| Variable | Obs. | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| Select Data Set: | | | | | |
| GRIDREV | 381 | 939.54 | 115.22 | 698.71 | 1240.62 |
| SDGRIDRE | 381 | 106.65 | 13.58 | 79.56 | 155.48 |
| HCWREV | 381 | 944.87 | 114.91 | 702.75 | 1253.61 |
| SDHCW | 381 | 98.11 | 11.93 | 72.97 | 130.16 |
| DIFFREV* | 381 | -5.33 | 3.66 | -18.54 | 3.20 |
| Grid/HCW* | 381 | -0.01 | 0.00 | -0.02 | 0.00 |
| DIFFSD* | 381 | 8.54 | 5.12 | 3.30 | 48.40 |
| Choice Data Set: | | | | | |
| GRIDREV | 381 | 963.31 | 118.12 | 714.40 | 1291.02 |
| SDGRIDRE | 381 | 108.94 | 14.07 | 81.11 | 153.94 |
| HCWREV | 381 | 945.71 | 114.57 | 703.54 | 1192.50 |
| SDHCW | 381 | 97.11 | 11.82 | 72.21 | 128.81 |
| DIFFREV* | 381 | 17.27 | 8.37 | -3.64 | 42.36 |
| Grid/HCW* | 381 | 0.02 | 0.01 | 0.00 | 0.12 |
| DIFFSD* | 381 | 11.83 | 6.01 | 3.02 | 36.84 |

Table 4. Model Diagnostics

| | Choice | Select |
|---|---|---|
| OBS | 378.00 | 378.00 |
| LogLik | -504.94 | -541.47 |
| SSE | 411.31 | 636.29 |
| MSE | 1.09 | 1.68 |
| MAE | 0.76 | 0.89 |
| MAPE | 4.80 | 44.28 |
| R-Sq. | 0.98 | 0.88 |
| SBC | 1164.19 | 1243.18 |
| AIC | 1061.89 | 1136.93 |
| AICC | 1065.89 | 1141.25 |
| J-B Test | 0.19 | 0.45 |
| Pr > $\chi^2$ | 0.91 | 0.80 |

Table 5. EGARCH-in-Mean Regression Results

| | Choice | | | | Select | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Estimate | Std. Error. | t-value | prob. | Estimate | Std. Error. | t-value | prob. |
| Constant | 1.361 | 0.020 | 69.53 | <.0001 | 3.702 | 0.003 | 1160.34 | <.0001 |
| $RevD_{t-1}$ | 0.057 | 0.026 | 2.15 | 0.0300 | 0.433 | 0.001 | 331.98 | <.0001 |
| $RevD_{t-2}$ | -0.089 | 0.029 | -3.11 | 0.0020 | 0.059 | 0.004 | 15.02 | <.0001 |
| $RevD_{t-3}$ | 0.061 | 0.016 | 3.84 | 0.0001 | -0.208 | 0.002 | -89.06 | <.0001 |
| selectp | 1.544 | 0.039 | 39.94 | <.0001 | -0.540 | 0.005 | -105.03 | <.0001 |
| yg2 | 1.462 | 0.150 | 9.73 | <.0001 | 2.635 | 0.003 | 828.72 | <.0001 |
| yg5p | -0.520 | 0.065 | -8.01 | <.0001 | -0.849 | 0.002 | -397.76 | <.0001 |
| T | 0.016 | 0.003 | 5.65 | <.0001 | 0.013 | 0.000 | 65.70 | <.0001 |
| DS | -0.587 | 0.244 | -2.41 | 0.0160 | -0.237 | 0.003 | -77.72 | <.0001 |
| $\rho_1$ | -0.647 | 0.040 | -16.09 | <.0001 | - | - | - | - |
| $\rho_2$ | -0.250 | 0.043 | -5.81 | <.0001 | - | - | - | - |
| $\rho_3$ | 0.009 | 0.034 | 0.28 | 0.7800 | -0.436 | 0.002 | -255.92 | <.0001 |
| $\rho_4$ | -0.040 | 0.038 | -1.04 | 0.3000 | -0.387 | 0.002 | -190.78 | <.0001 |
| $\omega$ | -0.153 | 0.080 | -1.91 | 0.0600 | 0.002 | 0.003 | 0.47 | 0.6400 |
| $\alpha_1$ | 0.511 | 0.088 | 5.81 | <.0001 | 0.941 | 0.005 | 194.30 | <.0001 |
| $\alpha_2$ | 0.618 | 0.077 | 8.05 | <.0001 | 1.099 | 0.003 | 322.91 | <.0001 |
| $\alpha_3$ | 0.639 | 0.101 | 6.32 | <.0001 | 1.232 | 0.009 | 137.98 | <.0001 |
| $\alpha_4$ | 0.138 | 0.096 | 1.44 | 0.1500 | 0.841 | 0.003 | 310.61 | <.0001 |
| $\alpha_5$ | -0.029 | 0.062 | -0.46 | 0.6400 | 0.023 | 0.004 | 6.33 | <.0001 |
| $\alpha_6$ | 0.031 | 0.077 | 0.40 | 0.6900 | 0.000 | 0.005 | 0.02 | 0.9800 |
| $\alpha_7$ | 0.186 | 0.115 | 1.62 | 0.1100 | -0.334 | 0.004 | -82.37 | <.0001 |
| $\alpha_8$ | -0.079 | 0.099 | -0.80 | 0.4200 | -0.282 | 0.003 | -85.46 | <.0001 |
| $\alpha_9$ | 0.376 | 0.119 | 3.15 | 0.0000 | 0.074 | 0.004 | 18.90 | <.0001 |
| $\gamma_1$ | -0.041 | 0.074 | -0.55 | 0.5800 | -0.602 | 0.004 | -145.31 | <.0001 |
| $\gamma_2$ | - | - | - | - | -0.476 | 0.006 | -74.93 | <.0001 |
| $\gamma_3$ | - | - | - | - | -0.165 | 0.008 | -20.76 | <.0001 |
| $\gamma_4$ | - | - | - | - | 0.518 | 0.004 | 120.99 | <.0001 |
| $\theta$ | -0.136 | 0.058 | -2.34 | 0.0200 | 0.035 | 0.003 | 11.47 | <.0001 |
| $\delta$ | -0.043 | 0.056 | -0.76 | 0.4500 | -0.256 | 0.004 | -61.56 | <.0001 |