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Live and Feeder Cattle Options Markets: Returns, Risk, and Volatility Forecasting

by

Lee Brittain, Philip Garcia,
and Scott H. Irwin

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Lee Brittain
Philip Garcia
Scott H. Irwin

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Lee Brittain (lbritta2@illinois.edu) is a research assistant, Philip Garcia is the T.A. Hieronymus Distinguished Chair in Futures Markets at the Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, and Scott H. Irwin is the Laurence J. Norton Chair of Agricultural Marketing at the Department of Agricultural and Consumers Economics, University of Illinois at Urbana-Champaign. Funding support from the Office for Futures and Options Research at the University of Illinois at Urbana-Champaign is gratefully acknowledged.

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The paper examines empirical returns from holding thirty- and ninety-day call and put positions, and the forecasting performance of implied volatility in the live and feeder cattle options markets. In both markets, implied volatility is an upwardly biased and inefficient predictor of realized volatility, with bias most prominent in live cattle. While significant returns exist holding several market positions, most strategies are strongly affected by a drift in futures market prices. However, the returns from selling live cattle puts are persistent, and evidence from straddle returns identifies that the market overprices volatility. This overpricing is consistent with a short-term risk premium whose effect is magnified by extreme changes in market conditions.

Keywords: live cattle, feeder cattle, options, returns, risk, volatility forecasting

Introduction

Beef production is an important segment of American agriculture, with an estimated seventy-four billion dollar retail equivalent in 2007 which amounts to almost one-fourth of farm sector cash receipts (ERS 2009). In the past few years, cattle producers have faced a difficult production environment, with historically high grain prices and severe demand shocks from outbreaks in North America of Bovine Spongiform Encephalopathy (BSE), or mad-cow disease. High grain prices have forced some feedlot managers to shut down operations, and mad-cow outbreaks have resulted in the closing of many export markets to American beef. In this challenging environment, it is critical for risk managers in cattle markets to have accurate information on expected price volatility in live and feeder cattle prices, and to know that options used in risk management activities are accurately priced.

Agricultural options have become increasingly popular since trading resumed in 1984 for several commodities. Despite their popularity, widespread beliefs are held that option premiums are too expensive. If options are overpriced, then option buyers are purchasing insurance above actuarially fair levels. Studies have suggested significant option overpricing may exist in some financial futures options markets (Coval and Shumway 2000; Bondarenko 2003). Possible explanations for overpriced options include lack of arbitrage, risk premiums, path-peso problems, and biased beliefs. Path-peso problems arise when the market overestimates the probability of catastrophic market events compared to the actual historical distribution (Branger and Schlag 2005).

Although most research on option efficiency has focused on financial markets, some studies in recent years have assessed the efficiency of agricultural options. Using thirty and ninety-day returns data, Urcola (2007) finds that corn, soybean, wheat, and hog options are priced efficiently, with only a few exceptions such as puts in the hog market. Mckenzie et al (2007) conclude that long hog straddle positions exited on Hogs and Pigs report days are profitable if transaction costs are under certain levels. Simon (2002) finds that corn implied volatility overstates realized volatility, but this overstatement is not sufficient enough to generate significant returns from short straddle positions. Egelkraut and Garcia (2006) constructed implied forward volatilities for grains and hogs, and find that they perform well. Two studies provide evidence on the forecasting ability of implied volatility in cattle options markets. Using daily data from 1989 to 2001, Szakmary et al (2003) find in live and feeder cattle that implied volatility was biased and did not encompass GARCH in-sample estimates. Using data from 1986 through 1999, Manfredo and Sanders (2004) find that implied volatility was a biased, inefficient forecast of one-week realized volatility in live cattle futures, yet still encompassed GARCH out-of-sample forecasts.

The purpose of this paper is to assess the performance of live and feeder cattle option markets using empirical returns from holding options and the ability of implied volatility to predict realized volatility. Prior research has not focused on empirical returns from live and feeder cattle options, and possible biases and inefficiencies of feeder cattle implied volatility have not been studied. Additionally, this study augments past studies on live cattle implied volatility by adding data from recent years that includes extreme levels of volatility. Empirical returns are constructed through simulated buy-and-hold trading strategies executed thirty- and ninety-calendar days prior to option expiration. Returns are subdivided into call and put options for both holding periods. Additionally, empirical returns are also calculated from thirty- and ninety-day straddle positions, to determine if returns are caused by drifts in underlying futures prices or are manifestations of a risk premium in these markets. Weekly implied volatility, realized volatility, and GARCH forecast volatility series are constructed to test the weekly forecasting performance of implied volatility and GARCH forecasts. The use of different procedures and horizons permits a more complete assessment of the option market's ability to incorporate information into the pricing process and signal whether the options participants use to manage risk are effectively priced.

Particular attention is given to differences in market behavior before and after abnormally volatile periods in cattle markets during two significant BSE outbreaks on May 20th, 2003 in Canada and December 23rd, 2003 in Washington. Jin et al (2008) identified October 2003 as a structural break in the live cattle market, which serves as the dividing line between time periods in our study. Figure 1 illustrates the sharp increases in realized and implied volatility precipitated by BSE outbreaks in 2003. There appears to be a higher level of realized volatility and implied volatility after the BSE spike in December 2003. While we use October 2003 as a dividing line to separate the data, the volatility in cattle and related markets afterwards was influenced by numerous other agricultural and non-agricultural market disruptions.

Data

The options database, consisting of daily live and feeder cattle option settlement prices, volume, and open interest, was provided by the Chicago Mercantile Exchange (CME). Settlement prices are used instead of closing prices because settlement prices are less likely to have rounding errors or violate non-arbitrage restrictions, since they are determined by pit committee members and by a computer software program. Additional data included live and feeder cattle futures prices and interest rates, based on the three-month T-bill rate reported by the St. Louis Federal Reserve.

Live cattle option data started on 10/30/1984 and ended on 1/30/2008. There were 543,430 individual option observations, with 4,646 unique options traded during this timeframe. Live cattle options expire in six months: February, April, June, August, October, and December. Live cattle annual option volume averaged 654,824 contracts. Prior to 1991, live cattle options expired on the last business Friday of the contract month. After 1991, they expired on the first business Friday of the contract month. Live cattle futures contracts are traded on 40,000 pound specifications.

Feeder cattle data ranged from 1/9/1987 to 1/30/2008. There were 493,103 individual feeder cattle option observations, with 5,094 unique options traded. Feeder cattle options expire in eight months: January, March, April, May, August, September, October, and November. Feeder cattle annual option volume averaged 139,974 contracts. Feeder cattle options expire on the last business Thursday of the contract month. Feeder cattle futures contracts are traded on 50,000 pound specifications.

Live cattle options are clearly the more heavily traded market, with average annual volume almost five times as large as feeder cattle. The heavier use of live cattle options and futures is not surprising, due to the larger commercial firm participation and geographical density of live cattle operations. Many large firms like RJ O'Brien, ADM, etc., hedge their production to obtain more attractive lending arrangements. Also, many feedlots run several thousand head of cattle annually through their operations on a constant-flow basis, which requires consideration to price risk. In contrast, the average cow-calf herd size in America is about fifty, so many cow-calf ranchers have herds that are too small to justify the use of options on 40,000 pound feeder cattle contracts.

Theoretical Framework and Procedures

Empirical Returns

Empirical returns are calculated using the Efficient Market Hypothesis (EMH) as the underlying benchmark for evaluating pricing efficiency. The EMH states that current prices reflect known information and function as an unbiased expectation of future prices. As a result, the economic profits to holding a financial asset should be zero, expressed as:

$$E(r_{j,T} \mid \Phi_T) = 0 \quad , \tag{1}$$

where r is the asset return, j is the financial instrument and Φ_T is the information set.

The general trading strategies used to simulate empirical returns involve buying call or put options thirty or ninety calendar days prior to option expiration, and holding until the option expires. Short-term (thirty-day) holding periods increase the amount of observations available, while longer-term holding periods may mimic hedging strategies used by producers. Option premiums are converted to forward premiums when the position is set to account for the time value of money. Forward premiums are calculated such that:

$$P_f = P_i e^{r_f (T-t)} \tag{2}$$

where P_f is the forward option premium, P_i is the initial option premium, r_f is the risk free rate of interest, and (T-t) is the number of days the option is held. Option dollar returns are then calculated by subtracting the forward premium from the premium at expiration,

$$R=(P_{exp}-P_f)*\mathrm{CW}, \tag{3}$$

where R is the option return, P_{exp} is the option premium at expiration, P_f is the forward option premium, and CW is the contract weight. Percent returns from holding options are calculated as:

$$R=\left(\frac{P_{\exp}-P_f}{P_f}\right)*100 \quad . \tag{4}$$

If positive or negative returns are found for an option subset, accurate confidence intervals are needed to determine if returns are statistically significant. If returns are normally distributed, t-tests are used to determine significance. However, most option returns tend to be skewed. Consequently, a Jarque-Bera test of normality is applied to option dollar and percent returns. Jarque-Bera tests are calculated such that:

$$JB=\frac{n}{6}(S^2+\frac{(K-3)^2}{4}) \quad , \tag{5}$$

where n is the number of observations, S is sample skewness, and K is sample kurtosis. If Jarque-Bera statistics indicate non-normality, confidence intervals are constructed using a bootstrapping procedure. Bootstrapping with replacement is performed using 2,000 trials to establish 95% confidence intervals. If zero is contained in the dollar or percent return confidence interval calculated from bootstrapping, then that subset of options could be considered efficiently priced.

Several filters are applied to observations such as volume requirements, strike moneyness, and minimum option premiums. When the option position is set, at least one contract must have traded on that day. Options that are actively traded usually contain more accurate information than illiquid ones. Option observations are kept only when the option strike has a moneyness range between 92.5-107.5% of the underlying futures prices. This was done to avoid problems such as volatility smiles that are inherent with deeply out- or in-the-money options. Five moneyness bins are created, with the first 94% bin containing options whose strike was between 92.5% and 95.5% of the underlying futures price when the position was set. Option premiums when the position is set must be at least three times the minimum tick size to avoid skewing percentage returns from very small premiums.

Additionally, empirical returns from short straddle positions are simulated. Short straddles, which consist of selling a call and a put option of the same strike, will generate returns when future realized volatility differs from market expectations. Live and feeder cattle prices have been increasing over time, particularly in recent years, which means that independent of the efficiency of the options market put (call) holders could experience negative (positive) returns (Figure 2 and 3). If significant positive returns from short straddles are found, evidence exists that options premiums are overpriced relative to risk in market. In the absence of significant returns from short straddles, significant returns from buying and holding a call or put option are being influenced by futures price movements.

Short straddle returns are simulated as buy-and-hold trading strategies both thirty- and ninety-days prior to expiration. If straddle positions are exited prior to expiration, any persistent bias in options prices would nullify returns since premiums when the position is exited would reflect the same bias. However, when straddles are held until expiration, only intrinsic value of the options remains. This allows for returns if market expectations differ from realized volatility.

Volatility Forecasting

Weekly implied volatility, realized volatility, and General Autoregressive Conditional Heteroskedasticity (GARCH) forecast volatility series are constructed to assess the forecasting performance of implied volatility in predicting subsequent one-week realized volatility. The use of weekly forecasts follows Sanders and Manfredo (2004), who argued that this horizon provides meaningful market information for cattle market participants.

The implied volatility of an option is the volatility that will yield a theoretical option price equal to the current option premium. Implied volatilities have become so widely used that many option traders make decisions based on the implied volatility of the option, not its premium. The most popular model to estimate implied volatility was developed by Black, Scholes, and Merton. Calls and puts are priced in the Black-Scholes-Merton model as follows:

$$c(S,t) = SN(d_1) - Ke^{-r(T-t)}N(d_2) \qquad (6)$$

$$p(S,t) = Ke^{-r(T-t)}N(-d_2) - SN(-d_1)$$

where $d_1 = \dfrac{\ln(S/K) + (\sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}$, $d_2 = d_1 - \sigma\sqrt{T-t}$, N is the normal cumulative distribution function, r is the risk-free interest rate, and T-t is the time remaining until option expiration. From these formulas, the implied volatility of an option can be calculated if the option premium, underlying asset price, strike price, interest rate, and time-to-maturity are known.

The weekly series are calculated using Wednesday prices. The nearby contract is used to determine volatilities up until eight days prior to expiration, at which point the rollover to the next contract occurs. Implied volatilities are calculated based on the average of implied volatilities of the four options, two calls and two puts, which were closest to the money. This is done to avoid the problems of the volatility smile, when options that are deeply in- or out-the-money have implied volatilities higher than at-the-money options. All volatility measures are converted to an annualized basis.

While the true realized volatility on the underlying asset is not directly observable, several measures of realized volatility exist. In one of the most widely-used formulations which assumes efficiency in the underlying futures market, realized volatility is defined as the square root of squared returns over the time horizon. Here since the focus is on a one-week horizon, this can be written as:

$$\sigma_{realized,t} = \sqrt{R^2_{t+1}} \tag{7}$$

where $R_t = \ln(P_t) - \ln(P_{t-1})$, and P_t and P_{t-1} are prices of the underlying futures contract. Realized volatility calculations are converted to an annualized basis using (8):

$$\sigma_{realized,t} = \sqrt{R^2_{t+1} * 52} \quad . \tag{8}$$

While implied volatility is often used as a forecast by market participants, GARCH models may add information to implied volatility forecasts of realized volatility. Consider a zero-mean GARCH (1,1) model in which past prices and residuals are used to construct one-step ahead forecasts of conditional volatility. The conditional volatility can be expressed as:

$$h_t^2 = \delta + \gamma\varepsilon^2_{t-1} + \theta h^2_{t-1} \ , \tag{9}$$

where h^2_t is the conditional variance, ε^2_{t-1} is the lagged error squared and h^2_{t-1} is the lagged conditional variance. The volatility can be converted to an annualized basis where:

$$_t\sigma_{GARCH,t+1} = \sqrt{h_t^2 * 52} \quad . \tag{10}$$

Despite evidence that GARCH(1,1) with a zero-mean specification performs effectively in forecasting realized volatility (Szakmary et al, 2003), several alternative GARCH models are examined. To begin, a GARCH(1,1) with a t-distribution to allow for non-normality is evaluated. Models with varying (p,q) structures for the GARCH model and mean specification are also considered. Using the first four years of observations to identify initial specifications and parameters, a more flexible specification is explored in which the GARCH and mean specification structure can vary, based on minimizing the Bayesian Information Criteria (BIC). Here, the mean (max = AR(4)) and (p,q) (max=p=q=2) structure is identified and estimated yearly, and then used to forecast the weekly observations for that year, updating the parameter estimates after each observation. At the end of the year, the mean and (p,q) structure is re-assessed, and the process continues. A third procedure, a Threshold GARCH, is also explored. Focus is put on a TGARCH(1,1) model that allows deterministic seasonal contract volatility and asymmetric behavior triggered by whether error in the returns equation is less than zero, which has been shown to perform well in agricultural commodities (Simon, 2002; Isengildina, Irwin, and Good, 2006). Here again, the process of estimating, forecasting one-step ahead, adding a new observation, and re-estimating is followed.

Forecast Evaluation

Several procedures are used to evaluate and characterize volatilities and their forecast errors. A Modified Diebold Mariano (MDM) test is applied to both mean absolute and mean squared errors to assess whether differences exist among forecast volatilities. MDM values are calculated using:

$$MDM = \sqrt{\frac{T-1}{\frac{1}{t}\sum_{t=1}^{T}(d_t-\bar{d})^2}}\,\bar{d} \qquad H_o : E(d_t = 0) \quad , \qquad (11)$$

where $d_t = g(e_{t,1}) - g(e_{t,2})$, $(e_{t,1})$ is the error of the IV forecast, $(e_{t,2})$ is the error of the GARCH forecast, and d bar is the average difference over the time series. MDM values found are then compared with the critical values found in the Student's t distribution to test the null hypothesis of equal forecast performance. MDM tests work well even in the presences of non-normally distributed data, autocorrelation in successive errors, and biased forecasts. (Egelkraut and Garcia 2006). In addition, systematic bias in the individual forecast errors is examined by running the following regressions:

$$e_t = (\sigma_{realized,t} - \sigma_{forecast,t}) = \gamma_1 + \mu_t \qquad H_o : \gamma_1 = 0 \quad . \qquad (12)$$

Several regression-type procedures are performed on the forecasts and their forecast errors to further to assess the bias, efficiency, and encompassing ability. Using equation (13),

$$\sigma_{realized,t} = \alpha + \beta_1 \sigma_{forecast,t} + \varepsilon_t \qquad H_o : \alpha = 0, \beta_1 = 1 \quad , \qquad (13)$$

a forecast is unbiased if we fail to reject the null hypothesis. A forecast is efficient if we fail to reject the null hypothesis in equation (14),

$$\sigma_{realized,t} = \alpha + \beta_1 \sigma_{forecast,t} + \beta_2 \sigma_{alternate\ forecast,t} + \varepsilon_t \qquad H_o : \alpha = 0, \beta_1 = 1, \beta_2 = 0 \quad , \qquad (14)$$

and the residuals are independent. In (14), the initial forecast is viewed as implied volatility. A non-significant parameter for the alternate forecasts means the information provided by the alternative is already contained in the implied volatility. In contrast, if the coefficient is significant, then the alternative forecast does provide information about realized volatility not contained in the implied volatility. Finally, another procedure to examine the relative information contained in forecasts is based on assessment of the relative predictive power of the forecast errors. Forecast encompassing is tested using equation (15):

$$e_{1t} = \alpha + \lambda(e_{1t} - e_{2t}) + \varepsilon_t \qquad H_o : \lambda = 0 \quad , \qquad (15)$$

where e_{1t} is the error of the preferred forecast, and e_{2t} is the error of the competing forecast. A significant lambda rejects the null hypothesis of an encompassing forecast, indicating that the alternative contains information reduces error.

Results

Empirical Returns

Summary statistics of dollar and percent returns from holding live and feeder cattle call and put options for thirty and ninety-days till expiration are shown in Tables 1 and 2. As expected, more observations were present for thirty-day options than ninety-day and more in live cattle options than feeder cattle. In the live cattle market, similar numbers of call and put observations were present, while in feeder cattle more puts than calls were traded. About seventy percent of options were traded prior to October 2003. Standard deviations in both dollar and percent returns for call options were usually higher than put options, and standard deviations for feeder cattle options were larger than live cattle. Bootstrapping procedures were used to calculate confidence intervals for returns, since all series failed the Jarque-Bera normality test. Discussion of option overpricing or under-pricing is viewed from the perspective of option buyers. Thus, overpriced options have initial premiums that were too large to achieve efficient pricing.

For the live cattle market, calls appear to be efficiently priced, while significant overpricing of puts exists regardless of holding period or time horizon examined. These results are relatively consistent regardless of whether dollar or percent returns are examined. For instance, over the entire sample, ninety-day calls averaged returns of $53.33 and 7.27%, both statistically insignificant. In contrast, thirty-day puts averaged returns of -$143.21 and -41.54%, both significant at the 5% level. Put overpricing is more severe in ninety-day horizons if dollar returns are considered, but more severe in thirty-day horizons on a percentage basis. Ninety-day put returns were -$226.43, while percent returns were -26.95%, less than the -41.54% found in thirty-day puts. Since most ninety-day options have higher option premiums than thirty-day options when a position is established, percent returns provide a more valid comparison.

In the later period, it appears that losses in live cattle put options increased considerably (Table 2). In thirty-day puts, losses increased from -$112.79 to -$228.56 and -36.44% to -55.85%. Figure 4 displays the noticeable decline in individual put returns beginning in late 2003 which seems to slowly move back to previous market levels. In live cattle calls, patterns in returns between periods are not as apparent. Thirty-day call returns decreased while ninety-day call returns improved in the later period.

For the feeder cattle market, call options were significantly underpriced, while significant overpricing of feeder cattle puts was evident. Once again, findings on pricing efficiency are consistent in both dollar and percent returns (Table 1). For instance, thirty-day calls achieved significant returns of $244.82 and 34.92%, while significant losses of -$89.44 and -27.91% existed in thirty-day puts. Dollar and percent returns to put options appear to follow patterns in live cattle options, where percent returns were larger in magnitude for thirty-day holding periods and dollar returns are larger in ninety-day. However, dollar and percent returns to feeder cattle calls were very similar, regardless of length of holding period. For example, thirty-day calls returned $244.82 and ninety-day calls returned $246.90. In the later period, returns to holding both thirty- and ninety-day calls increase sharply (Table 2), and as reflected in Figure 5, thirty-day call returns have only in recent years moderated back to previous levels. Returns to holding puts increased modestly in the later period and are not significant.

Results from short straddle positions in Table 3 show positive and significant returns from thirty-day live cattle straddles, and insignificant returns from ninety-day live cattle and thirty- and ninety-day feeder cattle straddles. When straddles are simulated, the influence of futures price level and movements on returns is basically removed and the extent to which options price the risk in the market is more apparent. In this context, significant returns from ninety-day live cattle puts and thirty- and ninety-day feeder cattle calls appear to have been caused predominantly by movements in underlying futures prices. However, the straddle results suggest that thirty-day live cattle options were overpriced which is consistent with the presence of a risk premium. In recent years, a time of higher market volatility, the level of overpricing for the thirty-day cattle short straddles increased markedly as dollar returns rose from $100.44 in the early period to $438.33 in the later period. Examination of the returns for the live cattle straddle positions over time identifies the influence of the BSE outbreaks on returns (Figure 6). Returns immediately following the outbreak were large and positive. Subsequently, it appears that the returns distribution shifted upward slightly suggesting a lingering effect. In the presence of added volatility during this period, positive returns using a short straddle strategy can emerge when the market overestimates the probability of additional catastrophic events. This is similar to the peso problem identified by Branger and Schlag (2005).

In short, positive returns were generated from buying feeder cattle calls, selling live and feeder cattle puts, and buying thirty-day live cattle short straddles. Most of the returns can be attributed to changes in the price of the underlying futures contract, but evidence for the live cattle options market differs, suggesting the presence of a risk premium whose effect was magnified by the BSE outbreak.

Transaction costs are not explicitly included in the previous analysis. In recent years, option transaction costs have decreased to around twenty-five dollars per contract (Jackson 2005). Transaction costs were higher in earlier periods of the dataset, so average transaction costs of $35 to $40 per option contract are likely suitable. Liquidity costs are more difficult to measure, but are larger in feeder cattle markets due to lower volume. Nonetheless, transaction costs more than $100, several times larger than realistic levels, are necessary to eliminate significant profits found from selling live and feeder cattle puts and buying feeder cattle calls reported here. For short straddles two options are traded, so average transaction costs are around $70 to $80. Live cattle thirty-day straddles averaged returns of $160, so liquidity costs would have to exceed eight ticks to erase profits found in these straddles.

Volatility Forecasting

Summary statistics for volatility measures are shown in Table 4 and 5. There were 996 weekly observations in live cattle and 887 in feeder cattle, with 226 in the later period. Efforts to generate GARCH formulations were somewhat problematic, and failed to produce out-of-sample forecasts appreciably different from a GARCH(1,1) with a t-distribution. Allowing for different mean and (p,q) structures permitted flexibility in live and feeder cattle markets, but failed to reduce forecast errors. Use of the TGARCH(1,1) with deterministic contract seasonality was ineffective in the live cattle market for long stretches of the data, indicating the model's incompatibility with the data. TGARCH(1,1) worked better in the feeder cattle market, but again did not produce improved forecasts. As a result, discussion is focused on the volatility measures generated by the GARCH(1,1) with a t-distribution.[1]

Both forecasts, implied volatility and GARCH forecast volatility, had larger means but smaller standard deviations than one-week realized volatility. Standard deviations for realized volatilities were almost twice as large as both implied volatility and GARCH standard deviations. This may suggest that both volatility forecasts have difficulty capturing the tails of the realized volatility distribution.[2] Feeder cattle volatility measures were smaller in magnitude than respective live cattle measures. For instance, feeder cattle implied volatility averaged .106 while live cattle averaged .146.

In the later period, all volatility measures increased markedly (Table 5). For example, live cattle realized volatility increased from .094 in the early period to .132 afterwards. The jump in live cattle implied volatility was even larger, with an increase from .135 to .185. Interestingly, the changes in forecasted volatilities are quite similar between the periods, particularly for the feeder cattle market. Figures 7 and 8, which plot and feeder cattle volatility measures over time, depict the enormous spike in volatility that occurred in December 2003, with the American BSE case in Washington.

Examination of forecast errors using equation (12) identifies similar patterns (Table 6).[3] Negative forecast errors indicate that both implied volatility and GARCH forecast volatility overstated subsequent realized volatility. Forecast errors were larger in live cattle than feeder cattle. GARCH forecast errors were slightly smaller than implied volatility in live cattle, but this was reversed in the feeder cattle market. Regardless of the method, live cattle forecast errors increase in the later period, but the change in the systemic bias was virtually identical in each market.[4]

Figures 9 and 10 provide annual averages of weekly forecast errors for live and feeder cattle markets. For live cattle, GARCH errors appear to be at least as accurate and at times smaller than implied volatility errors, except in 2004 when GARCH errors increase dramatically in magnitude. For feeder cattle, GARCH and implied volatilities initially perform in a similar manner, but implied volatility registers smaller average errors from 1998 through 2002. Except for 2004, during which average forecast errors are quite similar.

Table 7 displays MDM test results. For live cattle, there is little evidence to support differences in forecast accuracy between the implied volatility and GARCH alternative except for the entire period under the mean absolute error criterion. In contrast for the feeder cattle market, average implied volatility errors appear systematically smaller throughout, reaching significance under the mean absolute error criterion.

The results of bias, efficiency, and encompassing tests are presented in Tables 8 and 9. For both markets and periods, it is clear that the implied volatilities have higher predictive power than GARCH alternatives. For instance, in live cattle for the entire forecast period, the adjusted R-squared increase from .08 to .232 when implied volatility instead of GARCH is used as the sole forecast. However, live cattle options are biased and inefficient throughout as the null hypotheses from model (1) and (3) are rejected (Table 8). Also, in the early period when both forecasts are used, the GARCH coefficient is significant and the constant moves forty percent closer to zero than when implied volatility is the sole forecast used. In the later period, autocorrelation in live cattle residuals emerges. Feeder cattle options are also biased and inefficient, but the evidence is less dramatic. The GARCH alternative is not significant and autocorrelation in the residuals is not pronounced. The increased significance of alpha coefficients in the later period may indicate that there was a larger amount of stochastic volatility that forecasts were unable to predict. Results from the encompassing tests based on forecast errors (Table 9, equation (15)) are supportive of the notion that GARCH forecasts provide little information to the implied volatilities.[5] Despite the relatively large lambda weights for live cattle, large standard errors mute the effect of the GARCH forecasts.

Concluding Remarks

This paper investigates empirical returns and volatility forecasting in live and feeder cattle options markets. The findings indicate that live and feeder cattle implied volatilities were consistently upwardly biased and inefficient forecasts of subsequent one-week realized volatility. In live cattle, the overstatement of realized volatility was more than twice as severe, and some evidence of marginal information added by GARCH out-of-sample forecasts was found. Despite this performance, implied volatility encompassed GARCH forecasts in both markets. Significant positive returns were found in feeder cattle calls, and negative returns in live and feeder cattle puts. However, short straddle returns—which can be profitable when future volatility is lower than market expectations—were significantly positive only for the thirty-day live cattle positions. Combined, these findings indicate that the positive returns in feeder cattle calls, and the negative returns in feeder cattle puts were primarily influenced by the increase in live and feeder cattle futures market prices. However, significant short straddle returns support the notion that thirty-day live cattle options were overpriced. In recent years, a period of higher market volatility, the level of overpricing reflected in the thirty-day cattle straddle returns increased markedly. This pattern of behavior is highly consistent with the presence of a risk premium in thirty-day live cattle puts whose effect may have been magnified by the market's overestimation of the probability of additional catastrophic events following the BSE outbreaks. Based on the combined analysis of the returns and volatility forecasting, systematic overpricing is most persistent in the live cattle put market at shorter horizons (weekly as opposed to ninety-day horizon).

Our results are fairly consistent with prior studies on cattle option volatility forecasting, but deviate somewhat from analysis of empirical returns for other agricultural options markets. Szakmary et al (2003) using daily data and realized volatility measured over different horizons present evidence that live and feeder cattle implied volatility forecasts are biased and do not encompass in-sample GARCH alternatives. For a similar time period, Manfredo and Sanders (2004) find that out-of-sample live cattle implied volatility is an upwardly biased and inefficient forecast of one-week realized volatility that still encompassed a GARCH alternative. In contrast, Urcola (2007) finds widespread efficiency when examining estimated returns for holding options which differ from our results. Closer examination of the findings here suggests positive returns in feeder cattle calls, and negative returns in feeder cattle puts were affected by upward trends in live cattle and feeder cattle market prices. Persistent returns in live cattle puts appear consistent with the presence of a risk premium that was magnified by response to BSE outbreak and subsequent volatility shocks.

Several points emerge. First, it is frequently conjectured that more highly traded markets contain more information which should lead to greater efficiency. Yet, we find that live cattle options, which exhibit almost five times the traded volume as feeder cattle, perform considerably worse both in efficient pricing and volatility forecasting. An explanation for the difference in performance is the presence of a risk premium which appears to exist in live cattle option market. Second, while we find evidence for a risk premium, the factors that explain its existence in live cattle but not in feeder cattle market are not completely clear. Commercial feedlot operations are heavy users of live cattle puts. Perhaps, their large investments in facilities and livestock, and limited flexibility in their production process makes them willing to pay an additional premium to manage their output price risk. In contrast, feeder cattle producers are much smaller in size, often less than contract weight specifications, and frequently raise feeder cattle as a part of a more diversified farm portfolio. Observable systematic risk premiums may be less likely to emerge in this context, and more difficult to measure in returns and straddle positions. Third, large shocks such as BSE outbreaks can significantly change the volatility and the market's assessment of the likely reoccurrence of catastrophic events. Here, we find evidence in both the empirical returns and in volatility forecasting that the effect of the major BSE outbreaks was more pronounced in live cattle than in feeder cattle options markets. The primary BSE effect in the live cattle options market was relatively short term in nature, but slight residual effects from the outbreak lingered. We also see from the straddle returns evidence that the BSE effect was most pronounced in the thirty- as opposed to the ninety-day horizon which is consistent with Jin et al's (2008) findings of futures price behavior in nearby and more distant contracts. Finally, when using empirical returns from buy and hold strategies to assess efficiency of options markets, trends or patterns in futures prices should be investigated. Failure to do so can lead to flawed conclusions about option market performance.

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Table 1. Live and Feeder Cattle Empirical Returns

	Dollar Returns			Percent Returns		
Commodity, Holding Period, and Option	Mean	SD	Confidence Interval	Mean	SD	Confidence Interval
Live Cattle						
Thirty-day Calls	26.16	722.31	(-18,71)	-3.27	222.75	(-17,11)
Ninety-day Calls	53.33	1207.90	(-37,143)	7.27	211.35	(-9,23)
Thirty-day Puts	-143.21*	579.26	(-180,-106)	-41.54*	137.29	(-50,-33)
Ninety-day Puts	-226.43*	972.24	(-351,-183)	-26.95*	222.81	(-44,-12)
Feeder Cattle						
Thirty-day Calls	244.82*	1009.14	(175,314)	34.92*	289.96	(15,55)
Ninety-day Calls	246.90*	1662.54	(115,379)	30.50*	282.65	(9,52)
Thirty-day Puts	-89.44*	853.40	(-146,-32)	-27.91*	185.26	(-40,-16)
Ninety-day Puts	-202.89*	1268.39	(-297,-109)	-19.97*	222.08	(-36,-2)

Live Cattle data range from 1/1985 to 1/2008 and Feeder Cattle from 3/1987 to 1/2008. An asterisk (*) indicates returns differ from zero at 5% level. Confidence intervals are generated using a bootstrapping procedure.

Table 2. Live and Feeder Cattle Empirical Returns by Period

	Dollar Returns		Percent Returns		Observations	
Commodity, Holding Period, and Option	Early Period	Later Period	Early Period	Later Period	Early Period	Later Period
Live Cattle						
Thirty-day Calls	56.54*	-48.98	3.89	-21.01*	691	278
Ninety-day Calls	20.91	158.73	-1.19	34.77	554	156
Thirty-day Puts	-112.79*	-228.56*	-36.44*	-55.85*	721	256
Ninety-day Puts	-214.58*	-271.95*	-27.98*	-23.01	561	146
Feeder Cattle						
Thirty-day Calls	94.85*	562.05*	7.38	93.15*	550	260
Ninety-day Calls	78.81	786.37*	10.03	96.18*	475	148
Thirty-day Puts	-105.56*	-51.96	-24.42*	-36.03*	621	267
Ninety-day Puts	-248.19*	-64.57	-33.01*	-23.52	514	167

Live Cattle data range from 1/1985 to 1/2008 and Feeder Cattle from 3/1987 to 1/2008. Early period data range from start of data to September 2003. Later period data range from October 2003 to January 2008. An asterisk (*) indicates returns differ from zero at 5% level.

Table 3. Short Straddle Returns

Period and Return	Live Cattle Thirty-Day	Live Cattle Ninety-Day	Feeder Cattle Thirty-Day	Feeder Cattle Ninety-Day
All Years				
Dollar Return	160.07 (.01)	3.23 (.98)	-40.57 (.52)	-46.02 (.77)
Percent Return	14.21 (.01)	-3.42 (.59)	-2.83 (.64)	-3.32 (.68)
Early Period				
Dollar Return	100.44 (.09)	-29.81 (.77)	5.09 (.93)	150.45 (.26)
Percent Return	11.89 (.06)	-4.15 (.56)	.74 (.91)	6.03 (.41)
Later Period				
Dollar Return	438.33 (.02)	134.76 (.74)	-255.37 (.20)	-859.05 (.11)
Percent Return	24.98 (.05)	.37 (.98)	-19.64 (.18)	-42.05 (.03)

Note: p-values of straddle returns are shown in parantheses. The early period contains all observations from the start of the data until October 2003, while the later period runs from October 2003 to the end of the data.

Table 4. Live and Feeder Cattle Volatility Measures

Commodity and Volatility Measure	Mean	SD	CV	Observations
Live Cattle				996
Realized Volatility	0.103	0.096	0.932	
Implied Volatility	0.146	0.046	0.315	
GARCH (1,1) t	0.135	0.047	0.348	
Feeder Cattle				887
Realized Volatility	0.087	0.086	0.989	
Implied Volatility	0.106	0.044	0.415	
GARCH (1,1) t	0.113	0.046	0.407	

Live Cattle data range: 1/1989- 1/2008. Feeder Cattle data range: 3/1991- 1/2008. The coefficient of variation (CV) is equal to standard deviation divided by mean. All volatility measures are annualized.

Table 5. Live and Feeder Cattle Average Volatilities by Period

Commodity and Volatility Measure		Early Period	Later Period	Change Between Periods	Observations in Early Period	Observations in Later Period
Live Cattle					770	226
	Realized Volatility	0.094	0.132	+0.038		
	Implied Volatility	0.135	0.185	+0.050		
	GARCH (1,1) t	0.124	0.171	+0.047		
Feeder Cattle					661	226
	Realized Volatility	0.077	0.117	+0.04		
	Implied Volatility	0.097	0.133	+0.036		
	GARCH (1,1) t	0.103	0.142	+0.039		

Note: All volatility measures are weekly volatilities converted to an annualized basis. The early period contains all observations from the start of the data until October 2003, while the later period runs from October 2003 to the end of the data.

Table 6. Live and Feeder Cattle Forecast Errors

Commodity and Forecast		All Years	Early Period	Later Period	Change Between Periods
Live Cattle					
	Implied Volatility	-0.044*	-0.041*	-0.052*	-.011
	GARCH (1,1) t	-0.032*	-0.030*	-0.039*	-.009
Feeder Cattle					
	Implied Volatility	-0.018*	-0.019*	-0.016*	+.003
	GARCH (1,1) t	-0.026*	-0.026*	-0.025*	+.001

Regression: $e_t = (\sigma_{realized,t} - \sigma_{forecast,t}) = \gamma_1 + \mu_t \qquad H_1 : \gamma_1 = 0$

Note: Forecast error is defined as realized volatility minus forecast volatility.
An asterisk (*) indicates forecast error differs from zero at 5% level.

Table 7. MDM Test Between Volatility Forecasts

Period and Commodity		MAE	MSE
All years			
	Live Cattle	2.00*	-.94
	Feeder Cattle	-6.37*	-1.74
Early Period			
	Live Cattle	.91	.01
	Feeder Cattle	-1.95*	-.063
Later Period			
	Live Cattle	.42	-1.03
	Feeder Cattle	-2.49*	-1.25

Note: An asterisk (*) indicates MDM values significant at 5% level. MAE and MSE are mean absolute error and mean squared error. A negative sign indicates the implied volatility forecast error is less than the GARCH alternative.

Table 8. Forecast Bias and Efficiency Regressions

Period, Commodity and Regression	α	β_1	β_2	R^2	Joint F test	Portmanteau Test (15 lags)
All Years						
Live Cattle						
1	-.045	1.012		.232	0.00	0.00
2	.029*		.548	.080	0.00	0.00
3	-.040*	1.361	-.419	.250	0.00	0.04
Feeder Cattle						
1	-.024	1.049		.286	0.00	0.13
2	.029*		.513	.080	0.00	0.08
3	-.021	1.097	-.075	.286	0.00	0.15
Early Period						
Live Cattle						
1	-.023	.871		.116	0.00	0.20
2	.028*		.537	.039	0.00	0.09
3	-.013	1.143	-.378*	.123	0.00	0.36
Feeder Cattle						
1	.000	.795		.137	0.00	0.01
2	.023*		.529	.059	0.00	0.01
3	-.003	.752	.068	.135	0.00	0.01
Later Period						
Live Cattle						
1	-.100*	1.254		.351	0.00	0.04
2	.039*		.540	.077	0.00	0.00
3	-.086*	1.607	-.459	.379	0.00	0.26
Feeder Cattle						
1	-.051	1.255		.406	0.00	0.90
2	.055*		.426	.052	0.00	0.87
3	-.042	1.320	-.129	.408	0.00	0.94

Regressions:

1) $\sigma_{realized,t} = \alpha + \beta_1 \sigma_{IV,t} + \varepsilon_t \quad H_1 : \alpha = 0, \beta_1 = 1$

2) $\sigma_{realized,t} = \alpha + \beta_2 \sigma_{GARCH,t} + \varepsilon_t \quad H_2 : \alpha = 0, \beta_2 = 1$

3) $\sigma_{realized,t} = \alpha + \beta_1 \sigma_{IV,t} + \beta_2 \sigma_{GARCH,t} + \varepsilon_t \quad H_3 : \alpha = 0, \beta_1 = 1, \beta_2 = 0$

Note: Tests on significance are based on Newey-West variances. An asterisk (*) indicates significance at 5% level. p-values for Joint F and Portmanteau tests are shown. R-squared is the adjusted coefficient of determination.

Table 9. Forecast Encompassing Regressions

Period and Commodity	α	λ
All Years		
Live Cattle	-.049	-.408 (.13)
Feeder Cattle	-.018	-.081 (.67)
Early Period		
Live Cattle	-.044	-.235 (.10)
Feeder Cattle	-.021	.160 (.36)
Later Period		
Live Cattle	-.060	-.508 (.18)
Feeder Cattle	-.015	-.210 (.42)

Regression: $1) e_{1t} = \alpha + \lambda(e_{1t} - e_{2t}) + \varepsilon_t \quad H_1 : \lambda = 0$

Note: An asterisk (*) indicates coefficient differs from zero at 5% significance level. Implied volatility is the preferred forecast in the regression. p-values for lambda coefficients are shown in parentheses.

Figure 1. Live Cattle Daily Implied and Realized Volatility, 3/2003-12/2004

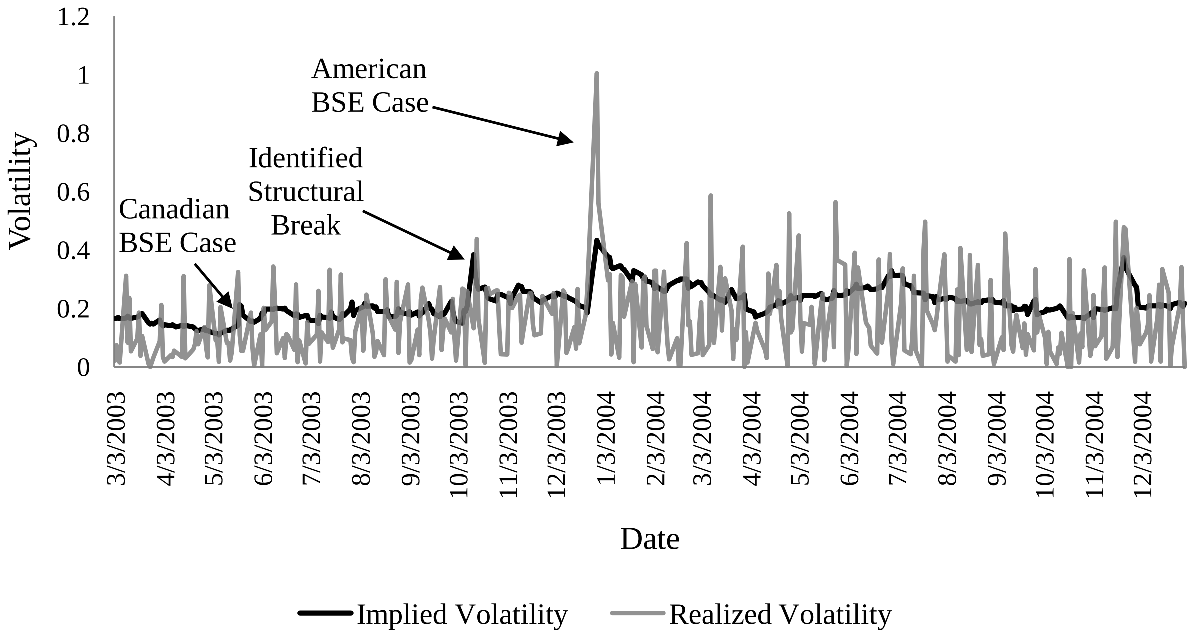


Figure 2. Live Cattle Nearby Futures, 1/1985-1/2008

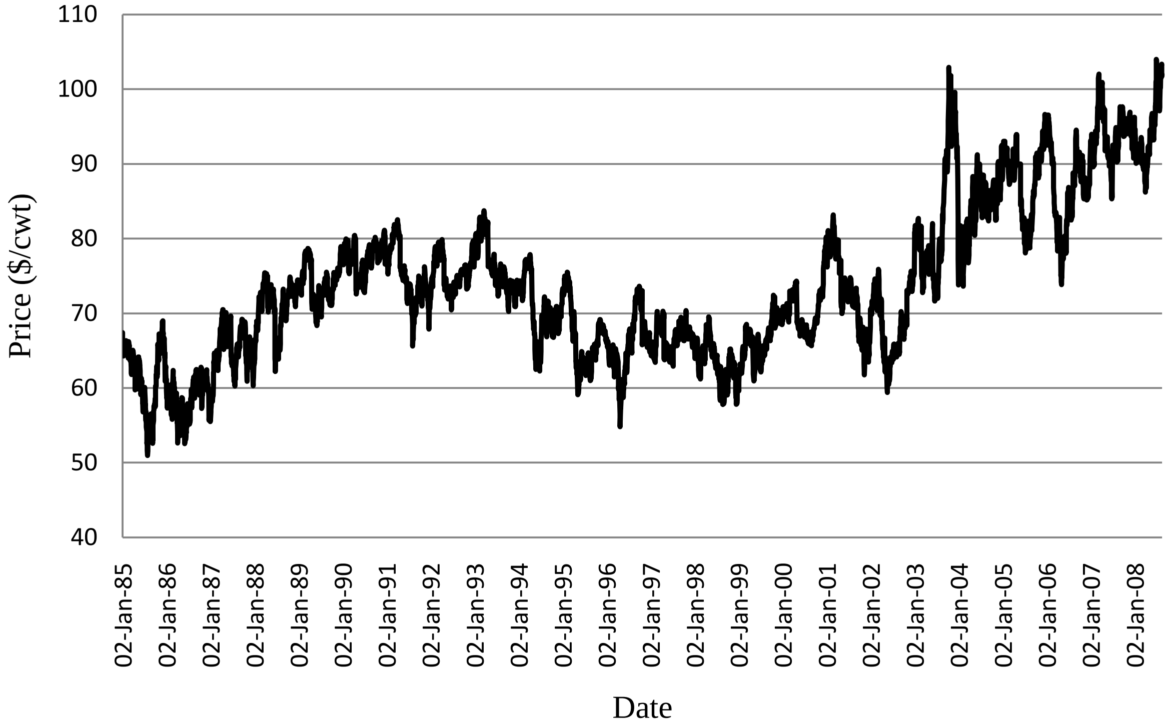


Figure 3. Feeder Cattle Nearby Futures, 1/1987-1/2008

Figure 4. Live Cattle Thirty-Day Put Returns, 1/1985-1/2008

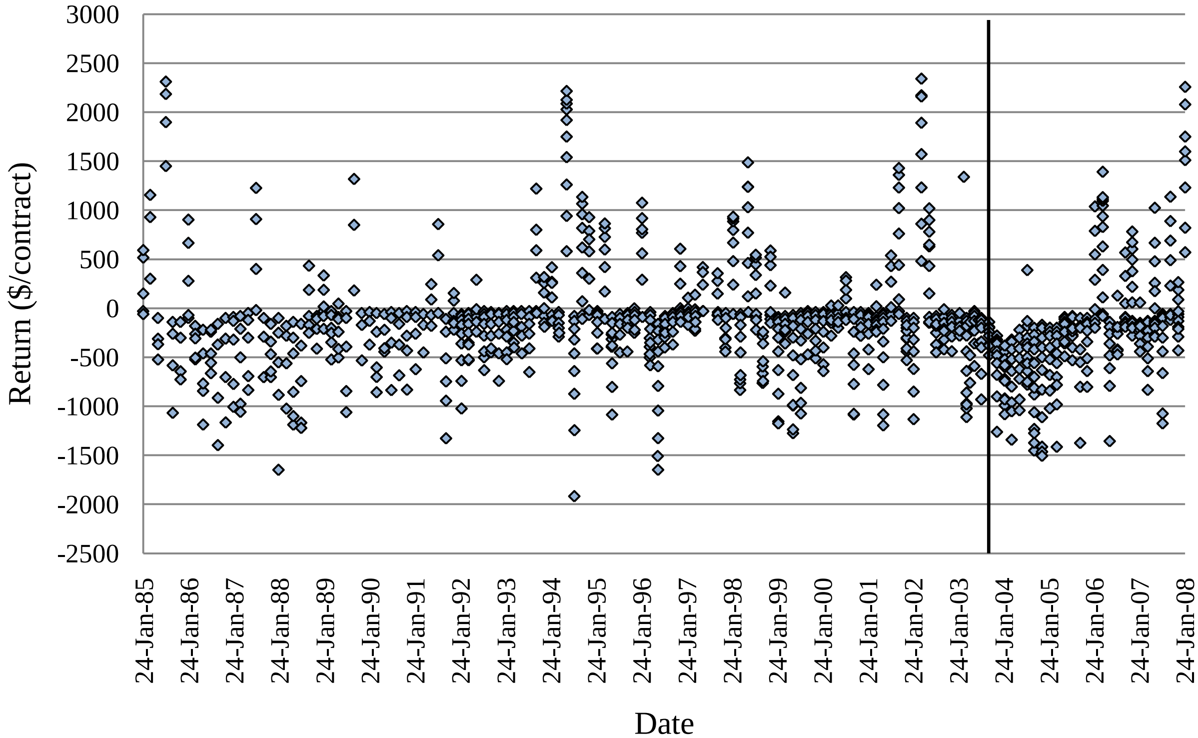


Figure 5. Feeder Cattle Thirty-Day Call Returns, 3/1987-1/2008

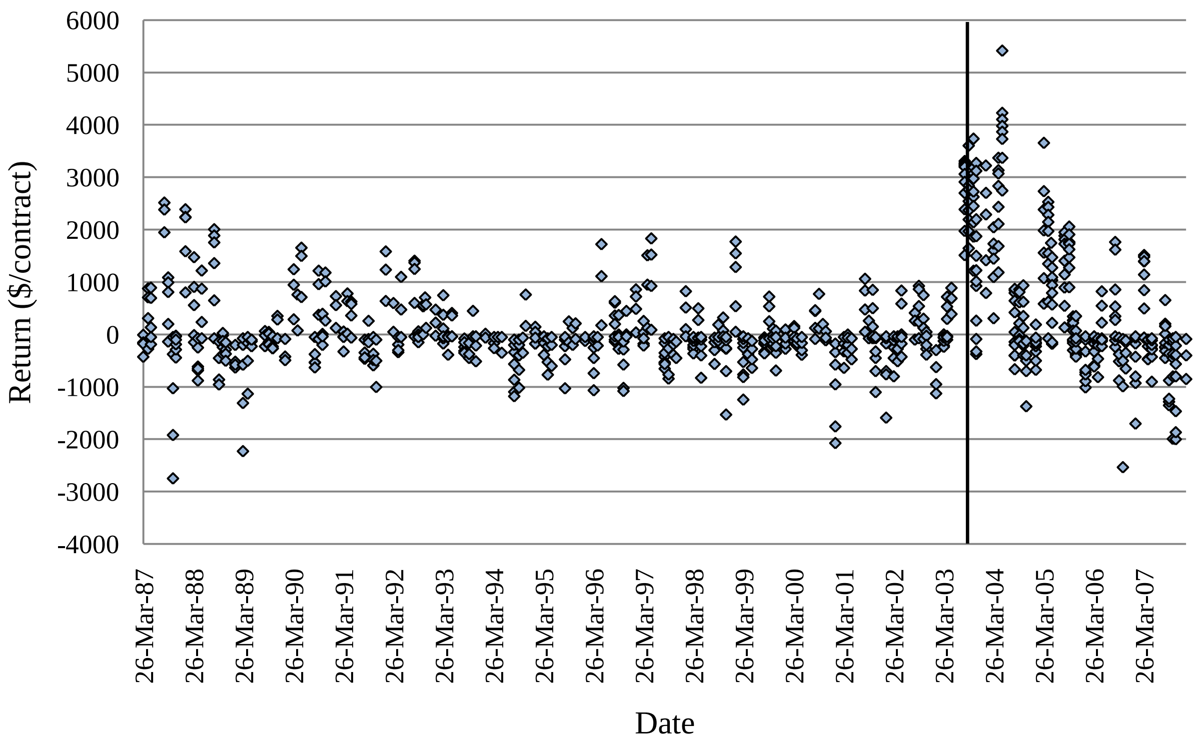


Figure 6: Live Cattle Thirty-Day Straddle Dollar Returns

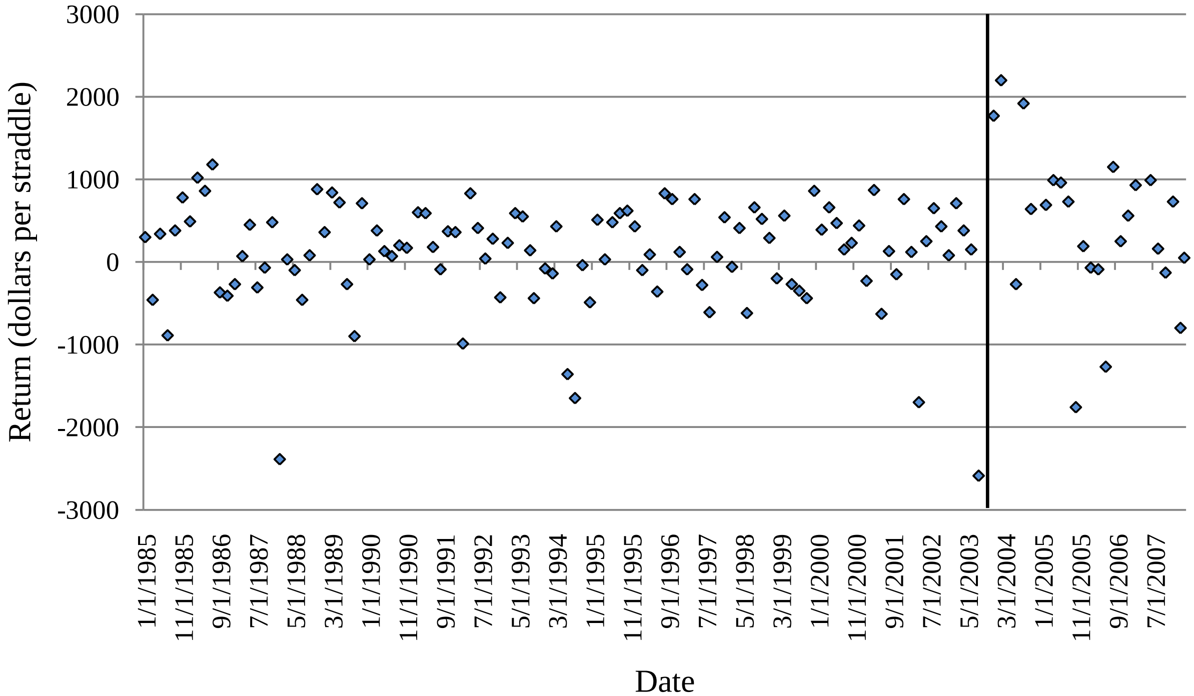


Figure 7. Live Cattle Weekly Realized Volatility and Implied Volatility, 1/1989-1/2008

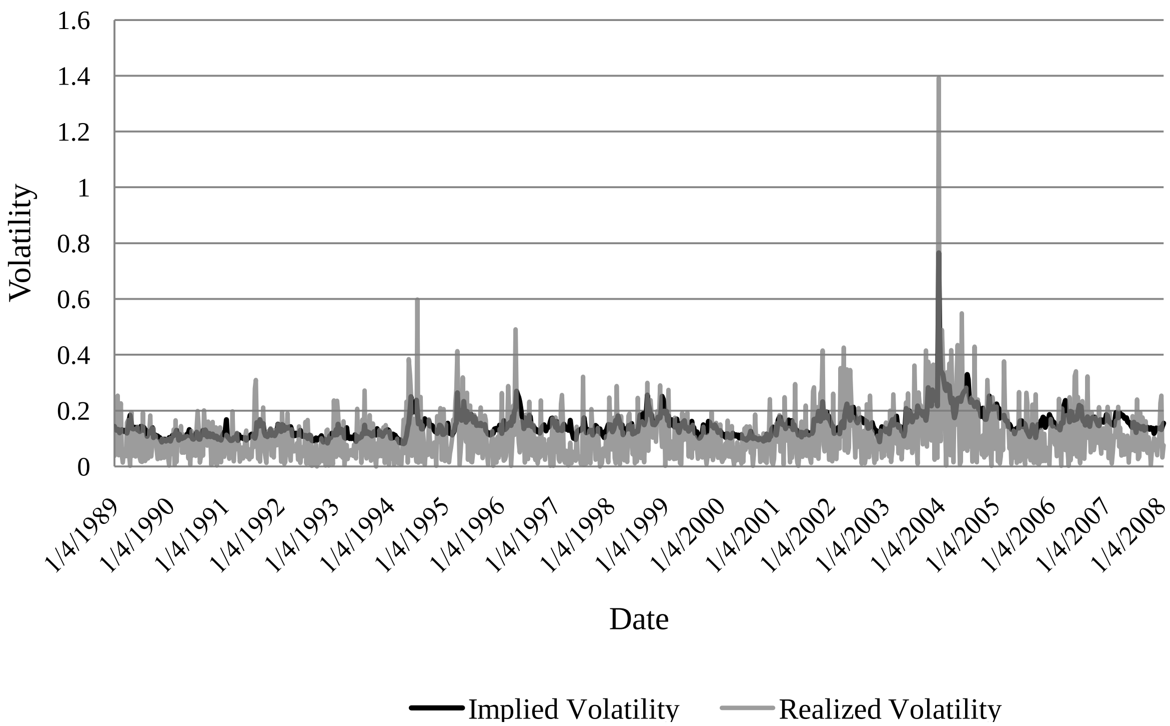


Figure 8. Feeder Cattle Weekly Realized Volatility and Implied Volatility, 1/1991-1/2008

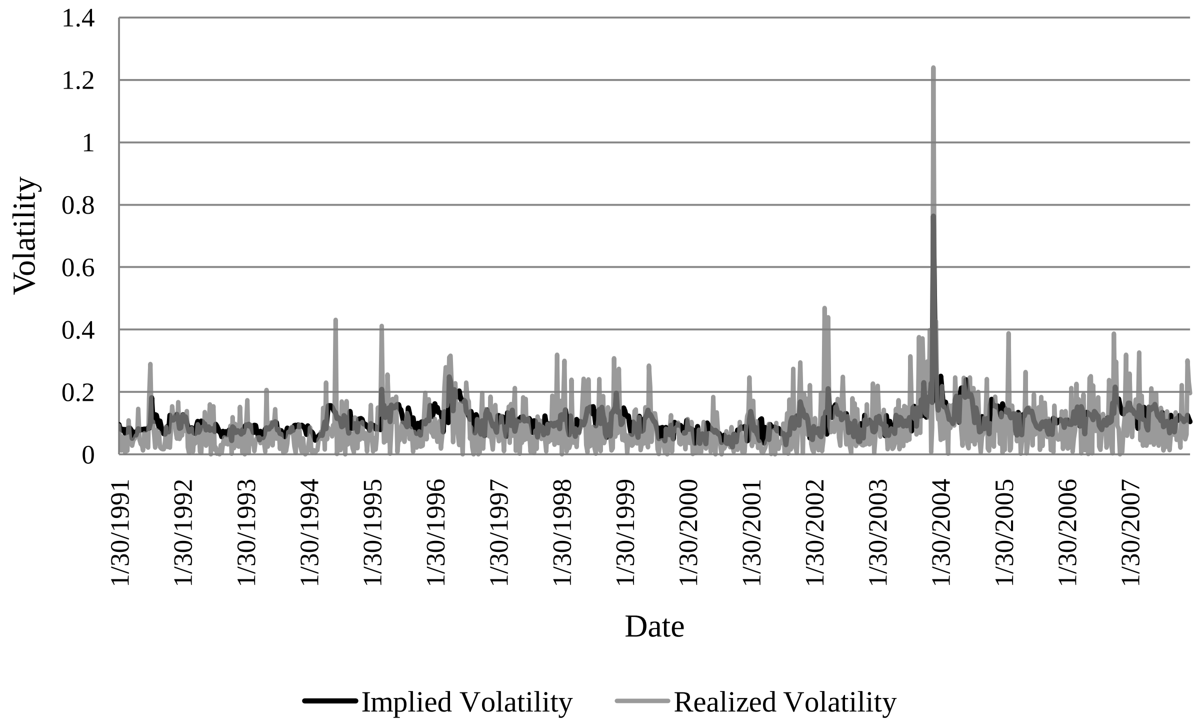


Figure 9. Live Cattle Average Annual Weekly Forecast Error, 1/1989-1/2008

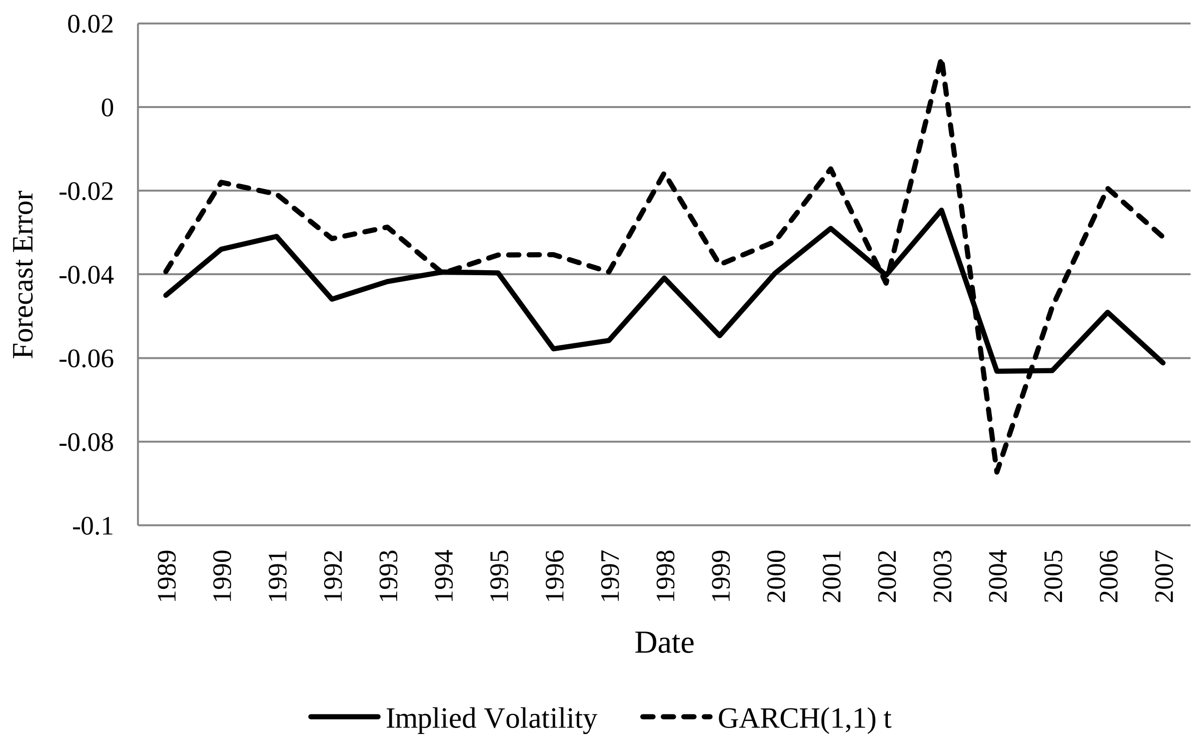
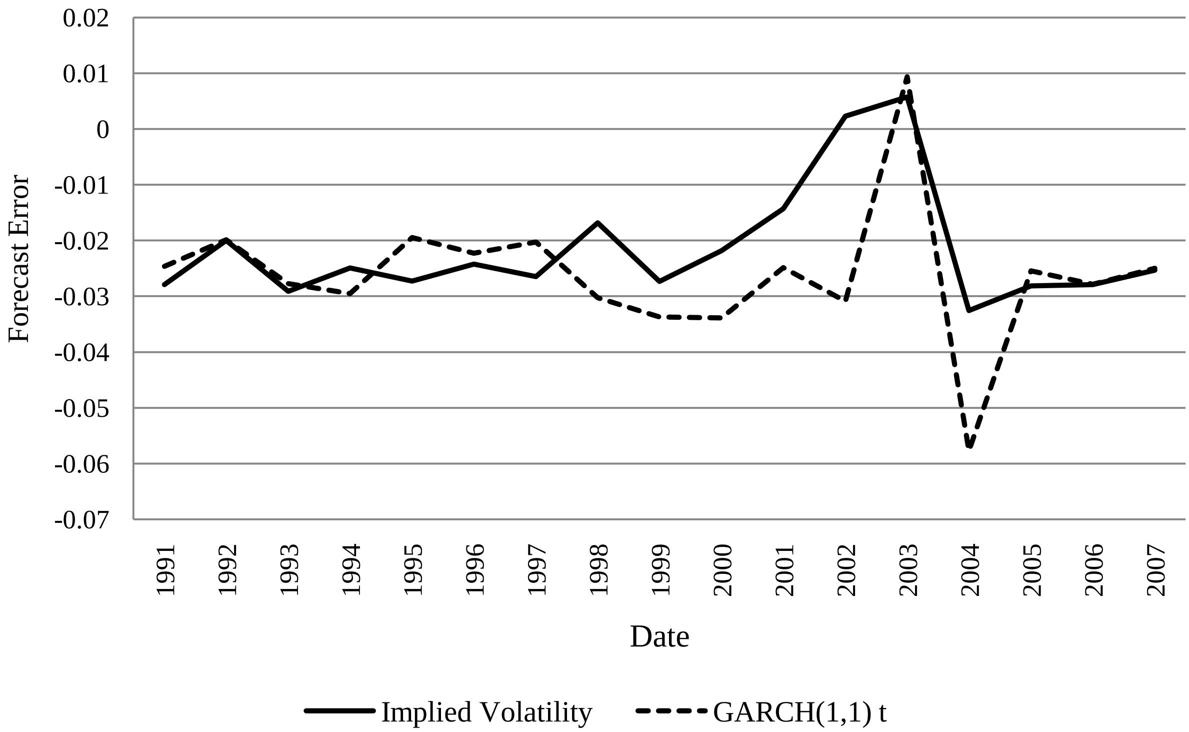


Figure 10. Feeder Cattle Average Annual Weekly Forecast Error, 3/1991-1/2008



Endnotes

1. Results for the other models are available from the authors.
2. GARCH models were also estimated with a GED distribution. While in some cases it provided better fits, this specification failed to change the forecast volatility to any degree.
3. Newy-West procedures were used on all regression-type models where needed to generate robust estimates of the standard errors.
4. A regression of the absolute values of forecast errors on trend confirms that the error has been increasing with the passage of time in a similar manner for the forecasts within a market.
5. When the GARCH is used as the preferred forecast, implied volatility always adds significant information.