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

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This paper examines returns from holding 30- and 90-day call and put positions, and the forecasting performance of implied volatility in the live and feeder cattle options markets. Implied volatility is an upwardly biased and inefficient predictor of realized volatility, with bias most pronounced in live cattle. While significant returns exist from several positions, strategies are strongly affected by drifts in futures prices. However, returns from live cattle puts are persistent, and evidence from 30-day straddle returns indicates the live cattle market overprices volatility. Overpricing is consistent with volatility risk, the effect of which is magnified by extreme market conditions.

Key Words: feeder cattle, live cattle, options, returns, risk, volatility forecasting

Introduction

Beef production is an important segment of American agriculture, with an estimated $74 billion dollar retail equivalent in 2007, which amounts to almost one-fourth of farm sector cash receipts (USDA/Economic Research Service, 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. It is critical in this challenging environment 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. For instance, in a marketing context, higher expected volatility may increase a producer's willingness to pay a higher premium for price protection. If expectations are in error, the added premium can result in a loss to the producer.[1]

Agricultural options have become increasingly popular since 1984, when trading resumed for several commodities. Part of the reason for this increase in popularity is likely the greater flexibility of strategies and smaller cash-flow impacts offered by options compared to futures contracts. Despite their popularity, there is a widespread belief that option premiums are too expensive. If options are overpriced, then option buyers are purchasing insurance above actuarially fair levels. Indeed, studies have suggested significant option overpricing may exist

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[1] Antonovitz and Roe (1986) provide a comprehensive framework for evaluating information in risky markets. Adam, Garcia, and Hauser (1996) investigate the value of accurate forecast information on the mean and volatility in the presence of futures and options.

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 events compared to the actual historical distribution (Branger and Schlag, 2005).

Although most research on option pricing has focused on financial markets, several recent studies have assessed the efficiency of agricultural options, often with mixed results. Using 30- and 90-day returns data, Urcola and Irwin (2011) find that corn, soybean, wheat, and hog options are priced efficiently, with only a few exceptions such as puts in the hog market. McKenzie, Thomsen, and Phelan (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 to generate significant returns from short straddle positions. Egelkraut and Garcia (2006) construct implied forward volatilities for grains and hogs, and argue 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) report in live and feeder cattle that implied volatility is biased and does not encompass generalized autoregressive conditional heteroskedastic (GARCH) in-sample estimates, a result which contrasts with their findings for most other commodity markets. Using data from 1986 through 1999, Manfredo and Sanders (2004) also conclude that implied volatility is a biased, inefficient forecast of one-week realized volatility in live cattle futures, yet still encompasses GARCH out-of-sample forecasts.

The purpose of this paper is to assess the performance of live and feeder cattle options 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—which can provide a far-reaching reflection of market efficiency (Garcia and Leuthold, 2004)—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 which include extreme levels of volatility. Empirical returns are constructed through simulated buy-and-hold trading strategies executed 30 and 90 calendar days prior to option expiration. Returns are subdivided into call and put options for both holding periods. Empirical returns are also calculated from 30- and 90-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 options market's ability to incorporate information into the pricing process and signal whether the options used by participants 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—May 20, 2003, in Canada, and December 23, 2003, in Washington State. Jin, Power, and Elbakidze (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, it should be clear that

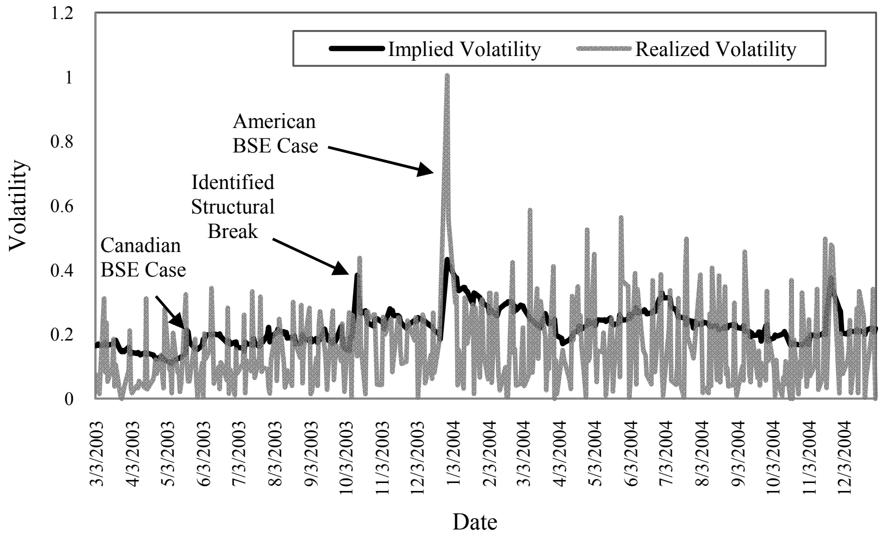

Figure 1. Live cattle daily implied and realized volatility, 3/2003–12/2004

volatility in cattle markets after the BSE outbreaks was also influenced by other related agricultural and nonagricultural market disruptions, including the emergence of the corn-ethanol-energy complex.

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 nonarbitrage restrictions as they are determined by pit committee members and by a computer software program. Additional data included live and feeder cattle futures prices and three-month T-bill rates from the St. Louis Federal Reserve.

Live cattle option data started on October 30, 1984, and ended on January 30, 2008. There were 543,430 individual option observations, with 4,646 unique options traded during this time frame. Live cattle options expire in six months: February, April, June, August, October, and December. Live cattle option volume averaged 654,824 contracts per year. 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 January 9, 1987 to January 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 higher commercial firm participation and geographical density of live cattle operations. Many feedlots run several hundred thousand head of cattle annually through their operations on a constant-flow basis, which requires price risk management. Also, many large firms such as R.J. O'Brien and ADM hedge their production to obtain more attractive lending arrangements. In contrast, the average American cow-calf herd is about 50 head, so many cow-calf ranchers have herds 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, and expressed as:

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

where r denotes 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 30 or 90 calendar days prior to option expiration and holding until the option expires. Short-term (30-day) holding periods increase the number of available observations, 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 as:

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

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 $(T - t)$ denotes the number of days the option is held. Option dollar returns are then calculated by subtracting the forward premium from the premium at expiration:

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

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

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

If positive or negative returns are found for an option subset, accurate confidence intervals are needed to determine whether 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 percentage returns. Jarque-Bera tests are calculated using:

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

where n represents the number of observations, S is sample skewness, and K is sample kurtosis. If Jarque-Bera statistics indicate nonnormality, 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 percentage return confidence interval calculated from bootstrapping, the subset of options is 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. Options are traded for various exercise or strike prices, and the deviation between the strike price and the current price of the underlying futures contract is used to classify an option in terms of its moneyness. For instance, a put option is in- (out-of-) the-money if the strike price is greater (less) than the futures price. If the strike and futures prices are equal, the option is referred to as at-the-money. Here, 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—an observed pattern in which at-the-money options have lower implied volatilities than deeply out-of- or in-the-money options—which can lead to overestimation of subsequent realized volatility. Five moneyness categories are created, with the first 94% category 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.[2]

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 (figures 2 and 3). If significant positive returns from short straddles are found, evidence exists that options premiums are overpriced relative to risk in the 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 30 and 90 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 the value of the option remains. This allows for returns if market expectations differ from realized volatility.

Volatility Forecasting

Weekly implied volatility, realized volatility, and GARCH forecast volatility series are constructed to assess the forecasting performance of implied volatility in predicting subsequent

[2] A market's tick size is the exchange-determined minimum amount that a price can change. For live cattle options, the tick or minimum price change is \$.025/cwt or \$10 per contract.

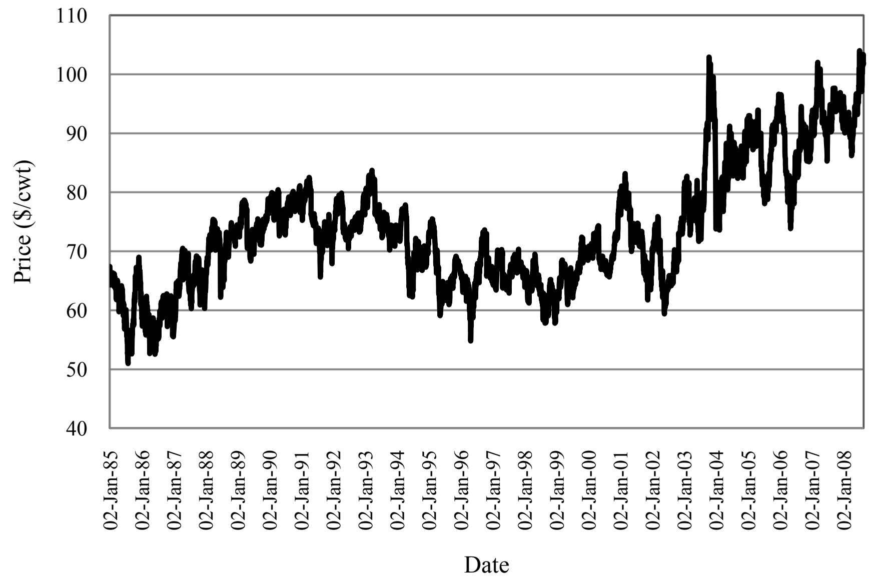

Figure 2. Live cattle nearby futures, 1/1985–1/2008

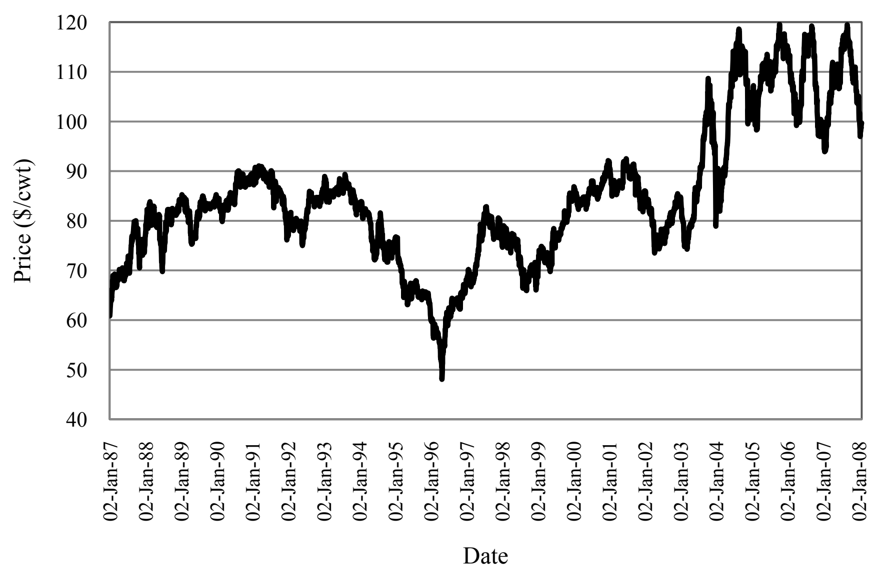

Figure 3. Feeder cattle nearby futures, 1/1987–1/2008

one-week realized volatility. The use of weekly forecasts follows Manfredo and Sanders (2004), who argued 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 (Hull, 2008). Calls and puts are priced in the Black-Scholes-Merton model as:

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

where

$$d_1 = \frac{\ln(S/K) + (\sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}, \quad d_2 = d_1 - \sigma\sqrt{T-t} \ ,$$

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. As noted earlier, this is done to avoid the problems of the volatility smile, when options that are deeply in- or out-of-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. Since the focus is on a one-week horizon, this can be written as:

$$(7) \qquad \sigma_{realized,t} = \sqrt{R_{t+1}^2} \ ,$$

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 the following equation:

$$(8) \qquad \sigma_{realized,t} = \sqrt{R_{t+1}^2 * 52} \ .$$

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 is expressed as:

$$(9) \qquad h_t^2 = \delta + \gamma\varepsilon_{t-1}^2 + \theta h_{t-1}^2,$$

where h_t^2 is the conditional variance, ε_{t-1}^2 is the lagged error squared, and h_{t-1}^2 is the lagged conditional variance. The volatility is converted to an annualized basis as follows:

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

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 nonnormality 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 criterion (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 reassessed, 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 reestimating 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 (Harvey, Leybourne, and Newbold, 1997). MDM values are calculated using:

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

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 $\bar{d}$ 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 presence of nonnormally 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:

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

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

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

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):

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

and the residuals are independent. In equation (14), the initial forecast is viewed as implied volatility. A nonsignificant 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. The Newey-West (1987) procedure is used on all regression-type models where it is needed to generate a consistent variance-covariance matrix for testing.

Results

Empirical Returns

Summary statistics of dollar and percentage returns from holding live and feeder cattle call and put options for 30 and 90 days until expiration are reported in tables 1 and 2. As expected, more observations were present for 30-day options than 90-day and more for 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 70% of options were traded prior to October 2003. Standard deviations in both dollar and percentage 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 underpricing 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 percentage returns are examined.[3] For instance, over the entire sample, 90-day calls averaged returns of $53.33 and 7.27%, both statistically insignificant. In contrast, 30-day puts averaged returns of −$143.21 and −41.54%, both significant at the 5% level. Put overpricing is more severe in 90-day horizons if dollar returns are considered, but more severe in 30-day horizons on a percentage basis. Ninety-day put returns were −$226.43, while percentage returns were −26.95%, less than the −41.54% found in 30-day puts. Since most 90-day options have higher option premiums than 30-day options when a position is established, percentage returns provide a more valid comparison.

In the later period, it appears that losses in live cattle put options increased considerably (table 2). In 30-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 regress back to previous market levels. In live cattle calls, patterns in returns between periods are not as apparent. Thirty-day call returns decreased while 90-day call returns improved in the later period.

[3] Based on equation (3), $/cwt measures also can be generated by dividing the live cattle and feeder cattle dollar returns by their respective 400 cwt and 500 cwt contract specifications.

Table 1. Live and Feeder Cattle Empirical Returns

Commodity, Holding Period, and Option	Dollar Returns ($)		Percent Returns (%)	
	Mean	Std. Dev.	Mean	Std. Dev.
Live Cattle:				
30-Day Calls	26.16	722.31	−3.27	222.75
90-Day Calls	53.33	1,207.90	7.27	211.35
30-Day Puts	−143.21*	579.26	−41.54*	137.29
90-Day Puts	−226.43*	972.24	−26.95*	222.81
Feeder Cattle:				
30-Day Calls	244.82*	1,009.14	34.92*	289.96
90-Day Calls	246.90*	1,662.54	30.50*	282.65
30-Day Puts	−89.44*	853.40	−27.91*	185.26
90-Day Puts	−202.89*	1,268.39	−19.97*	222.08

Notes: An asterisk (*) indicates returns differ from zero at the 5% level. Live cattle data range from January 1985 to January 2008; feeder cattle range from March 1987 to January 2008. Confidence intervals are generated using a bootstrapping procedure.

Table 2. Live and Feeder Cattle Empirical Returns by Period

Commodity, Holding Period, and Option	Dollar Returns ($)		Percent Returns (%)		No. of Observations	
	Early Period	Later Period	Early Period	Later Period	Early Period	Later Period
Live Cattle:						
30-Day Calls	56.54*	−48.98	3.89	−21.01*	691	278
90-Day Calls	20.91	158.73	−1.19	34.77	554	156
30-Day Puts	−112.79*	−228.56*	−36.44*	−55.85*	721	256
90-Day Puts	−214.58*	−271.95*	−27.98*	−23.01	561	146
Feeder Cattle:						
30-Day Calls	94.85*	562.05*	7.38	93.15*	550	260
90-Day Calls	78.81	786.37*	10.03	96.18*	475	148
30-Day Puts	−105.56*	−51.96	−24.42*	−36.03*	621	267
90-Day Puts	−248.19*	−64.57	−33.01*	−23.52	514	167

Notes: An asterisk (*) indicates returns differ from zero at the 5% level. Live cattle data range from January 1985 to January 2008; feeder cattle range from March 1987 to January 2008. Early period data range from start of data to September 2003; later period data range from October 2003 to January 2008.

For the feeder cattle market, call options were significantly underpriced, but significant overpricing of feeder cattle puts was evident. Once again, findings on pricing efficiency are consistent in both dollar and percentage returns (table 1). For instance, 30-day calls achieved significant returns of $244.82 and 34.92%, while significant losses of −$89.44 and −27.91% occurred in 30-day puts. Dollar and percentage returns to put options appear to follow patterns in live cattle options, where percentage returns were larger in magnitude for 30-day holding periods and dollar returns were larger in 90-day periods. However, dollar and percentage returns to feeder cattle calls were very similar, regardless of length of holding period. For example, 30-day calls returned $244.82 and 90-day calls returned $246.90. In the later period, returns to holding both 30- and 90-day calls increased sharply (table 2) and, as reflected in figure 5, 30-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.

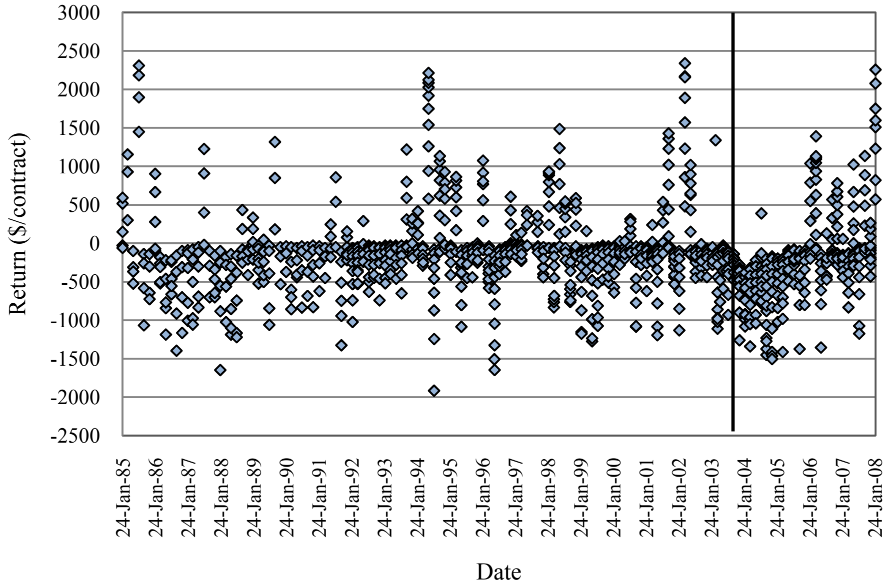

Figure 4. Live cattle 30-day put returns, 1/1985–1/2008

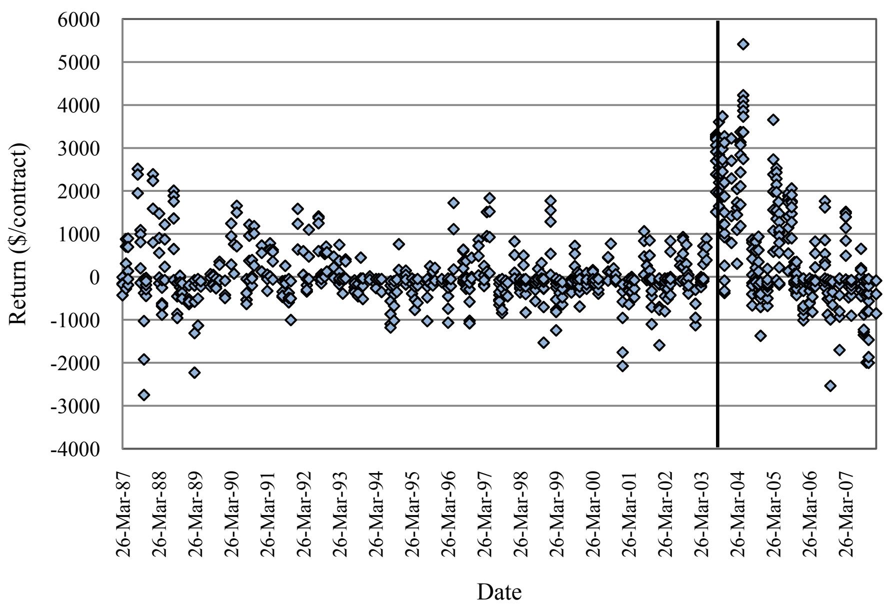

Figure 5. Feeder cattle 30-day call returns, 3/1987–1/2008

Table 3. Short Straddle Returns

Period and Return	Live Cattle 30-Day	Live Cattle 90-Day	Feeder Cattle 30-Day	Feeder Cattle 90-Day
All Years:				
Dollar Return ($)	160.07	3.23	−40.57	−46.02
	(0.01)	(0.98)	(0.52)	(0.77)
Percent Return (%)	14.21	−3.42	−2.83	−3.32
	(0.01)	(0.59)	(0.64)	(0.68)
Early Period:				
Dollar Return ($)	100.44	−29.81	5.09	150.45
	(0.09)	(0.77)	(0.93)	(0.26)
Percent Return (%)	11.89	−4.15	0.74	6.03
	(0.06)	(0.56)	(0.91)	(0.41)
Later Period:				
Dollar Return ($)	438.33	134.76	−255.37	−859.05
	(0.02)	(0.74)	(0.20)	(0.11)
Percent Return (%)	24.98	0.37	−19.64	−42.05
	(0.05)	(0.98)	(0.18)	(0.03)

Notes: Numbers in parentheses are *p*-values of straddle returns. The early period contains all observations from the start of the data until October 2003; the later period runs from October 2003 to the end of the data.

Results from short straddle positions reported in table 3 show positive and significant returns from 30-day live cattle straddles and insignificant returns from 90-day live cattle and 30- and 90-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 90-day live cattle puts and 30- and 90-day feeder cattle calls appear to have been caused predominantly by movements in underlying futures prices, and not by inefficiency.[4] However, the straddle results suggest that 30-day live cattle options were overpriced. In recent years, a time of higher market volatility, the level of overpricing for the 30-day cattle short straddles increased markedly as dollar returns rose from $100.44 in the early period to $438.33 in the later period.[5] Examination of the returns for the live cattle straddle positions over time identifies the immediate influence of the BSE outbreaks on returns (figure 6). Returns immediately following the outbreak were large and positive. Subsequently, it appears 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 if the market overestimates the probability of additional catastrophic events. This is similar to the peso problem identified by Branger and Schlag (2005).

Transaction costs are not explicitly included in the previous analysis. On standardized exchanges, transaction costs primarily consist of brokerage fees and any change in price to establish or liquidate a market position—the liquidity costs. In recent years, option brokerage fees have decreased to around $25 per contract (Jackson, 2005). These costs were higher in

[4] Some evidence of significant underpricing in 90-day straddle returns appears in feeder cattle for the later period, which is likely a reflection of the high degree of volatility (figure 3) that was difficult to predict at this more distant horizon.

[5] On a $/cwt basis, the magnitude increases sharply from $0.25/cwt in the early period to $1.10/cwt in the later period. In terms of a typical truckload of cattle (500 cwt), the increase is from $125.55 to $547.91, which at $85/cwt is an increase from 0.3% to 1.3% of the value of the truckload.

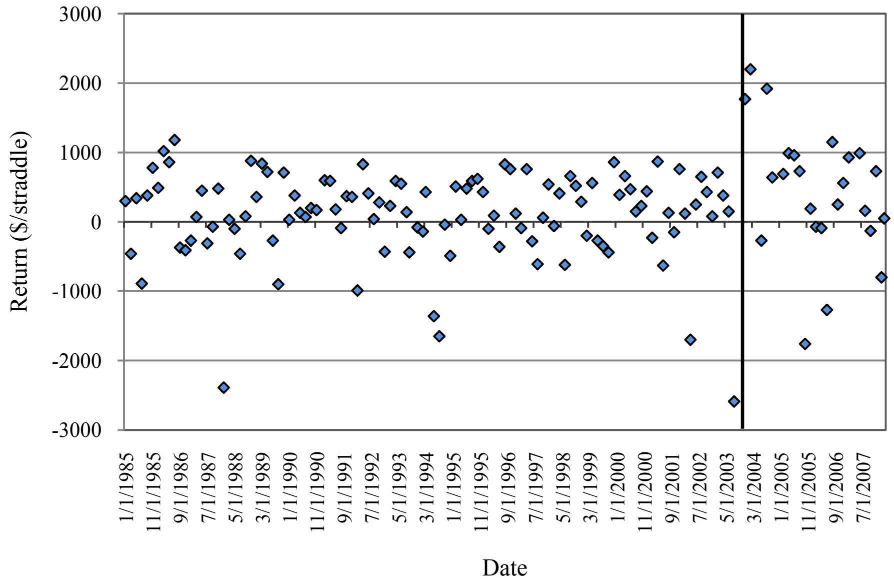

Figure 6. Live cattle 30-day straddle dollar returns

earlier periods of the data set, so average brokerage costs of $35 to $40 per option contract are likely suitable. Liquidity costs are more difficult to measure, but are more likely larger in feeder cattle markets due to lower volume.[6] Nonetheless, transaction costs of more than $100, several times larger than market 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 brokerage costs are around $70 to $80. Live cattle 30-day straddles averaged returns of $160; thus, liquidity costs would have to exceed eight ticks (i.e., $80 per contract—see footnote 2) to erase profits found in these straddles.

Volatility Forecasting

Summary statistics for volatility measures are presented in table 4. There were 996 weekly observations in live cattle and 887 in feeder cattle, with 226 in the later period. For brevity, the discussion focuses on the volatility forecasts generated by the GARCH(1,1) with a t-distribution which allows for nonnormality. The other formulations failed to produce out-of-sample forecasts that improved accuracy. Allowing for different mean and (p, q) structures permitted flexibility in live and feeder cattle markets, but failed to reduce forecast errors. The TGARCH(1,1) with deterministic contract seasonality did not converge 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.[7]

[6] Frank and Garcia (2011) provide a discussion of liquidity costs and estimates for the live cattle futures market. Shah, Brorsen, and Anderson (2009) estimate liquidity costs for the Kansas City wheat options markets. For July 2007, they identify liquidity costs in wheat options two to three times higher than in futures.

[7] The results from the alternate models change the quantitative findings marginally, but do not change the qualitative findings. The results are available from the authors upon request.

Table 4. Live and Feeder Cattle Average Volatilities by Period

Commodity and Volatility Measure	Early Period	Later Period	Change Between Periods	No. of Observations Early Period	No. of Observations 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	+0.040		
Implied Volatility	0.097	0.133	+0.036		
GARCH (1,1) *t*	0.103	0.142	+0.039		

Notes: 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; the later period runs from October 2003 to the end of the data.

Table 5. 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*	−0.011
GARCH (1,1) *t*	−0.032*	−0.030*	−0.039*	−0.009
Feeder Cattle:				
Implied Volatility	−0.018*	−0.019*	−0.016*	+0.003
GARCH (1,1) *t*	−0.026*	−0.026*	−0.025*	+0.001

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

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

Feeder cattle volatility measures were smaller in magnitude than respective live cattle measures. For instance, during the early period, feeder cattle implied volatility averaged 0.097 while live cattle averaged 0.135. In the later period, all volatility measures increased markedly. For example, live cattle realized volatility increased from 0.094 in the early period to 0.132 afterwards. The jump in live cattle implied volatility was even larger, with an increase from 0.135 to 0.185. Interestingly, the changes in forecasted volatilities are quite similar between periods, particularly for the feeder cattle market.

Examination of forecast errors using equation (12) identifies similar patterns (table 5). 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 increased in the later period, but the change in the systemic bias was virtually identical in each market.

Figures 7 and 8 provide annual averages of weekly forecast errors for live and feeder cattle markets, respectively. For live cattle, GARCH errors appear to be at least as accurate and at

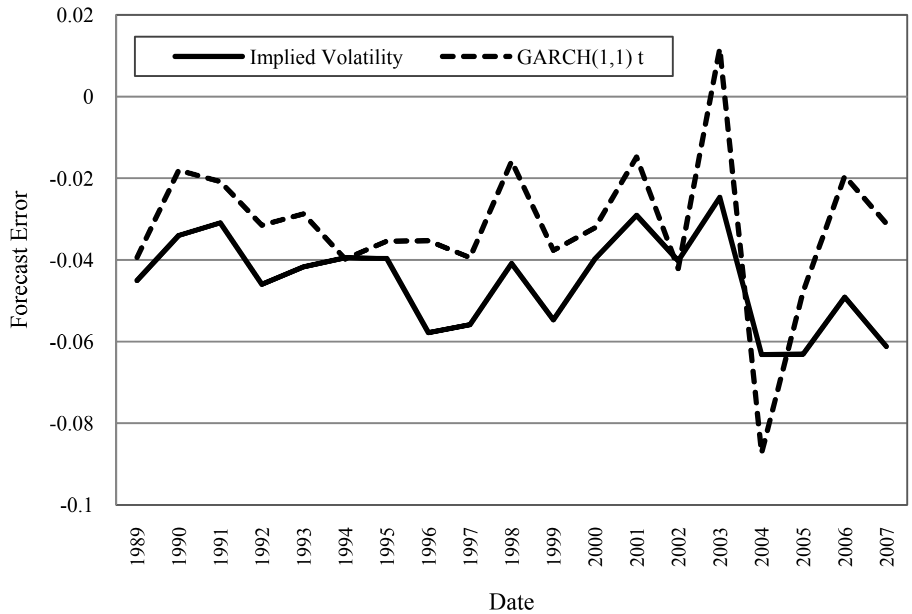

Figure 7. Live cattle average annual weekly forecast error, 1/1989–1/2008

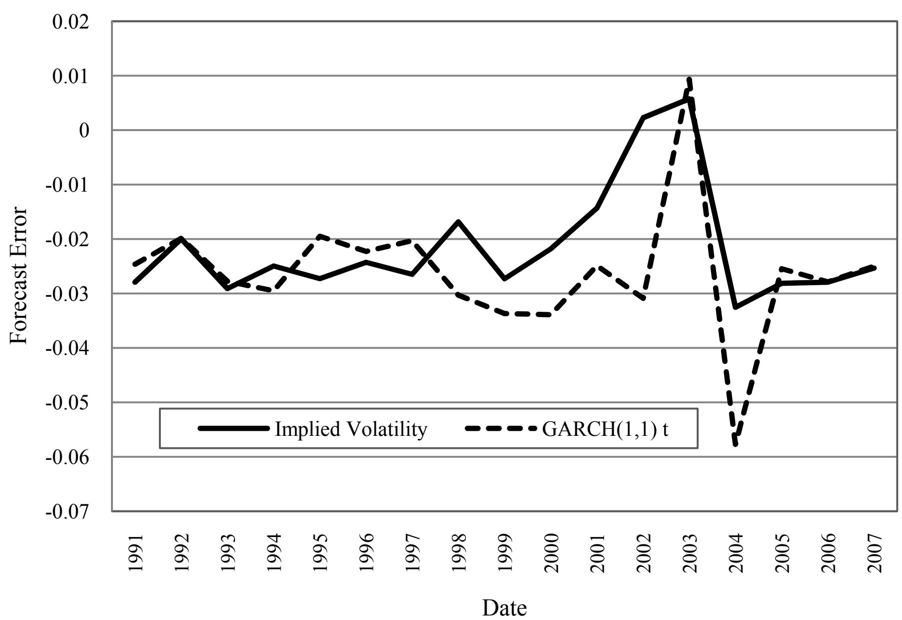

Figure 8. Feeder cattle average annual weekly forecast error, 3/1991–1/2008

Table 6. Results of MDM Test Between Volatility Forecasts

Period and Commodity	Mean Absolute Error	Mean Squared Error
All Years:		
Live Cattle	2.00*	−0.94
Feeder Cattle	−6.37*	−1.74
Early Period:		
Live Cattle	0.91	0.01
Feeder Cattle	−1.95*	−0.06
Later Period:		
Live Cattle	0.42	−1.03
Feeder Cattle	−2.49*	−1.25

Notes: An asterisk (*) indicates MDM values are significant at the 5% level. A negative sign indicates the implied volatility forecast error is less than the GARCH alternative.

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. After 2002, forecast errors are similar except for 2004, when implied volatility is more accurate.

Table 6 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 to the feeder cattle market, average implied volatility errors appear systematically smaller throughout, reaching significance under the mean absolute error criterion.

Results of bias and efficiency tests are presented in table 7. 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^2 increases from 0.08 to 0.232 when implied volatility rather than GARCH is used as the sole forecast. However, live cattle options are biased and inefficient throughout, as the null hypotheses from models (1) and (3) are rejected. Also, in the early period when both forecasts are used, the GARCH coefficient is significant and the constant moves 40% 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 pronounced. 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 the presence of a larger amount of stochastic volatility that forecasts were unable to predict.[8]

[8] Similar to the findings presented, encompassing tests based on forecast errors support the notion that GARCH forecasts provide little information to the implied volatility.

Table 7. Forecast Bias and Efficiency Regressions

Period, Commodity, and Regression	α	β_1	β_2	R^2	*p*-Values: Joint *F*-Test	*p*-Values: Portmanteau Test (15 lags)
All Years:						
Live Cattle						
[1]	−0.045	1.012		0.232	0.00	0.00
[2]	0.029*		0.548	0.080	0.00	0.00
[3]	−0.040*	1.361	−0.419	0.250	0.00	0.04
Feeder Cattle						
[1]	−0.024	1.049		0.286	0.00	0.13
[2]	0.029*		0.513	0.080	0.00	0.08
[3]	−0.021	1.097	−0.075	0.286	0.00	0.15
Early Period:						
Live Cattle						
[1]	−0.023	0.871		0.116	0.00	0.20
[2]	0.028*		0.537	0.039	0.00	0.09
[3]	−0.013	1.143	−0.378*	0.123	0.00	0.36
Feeder Cattle						
[1]	0.000	0.795		0.137	0.00	0.01
[2]	0.023*		0.529	0.059	0.00	0.01
[3]	−0.003	0.752	0.068	0.135	0.00	0.01
Later Period:						
Live Cattle						
[1]	−0.100*	1.254		0.351	0.00	0.04
[2]	0.039*		0.540	0.077	0.00	0.00
[3]	−0.086*	1.607	−0.459	0.379	0.00	0.26
Feeder Cattle						
[1]	−0.051	1.255		0.406	0.00	0.90
[2]	0.055*		0.426	0.052	0.00	0.87
[3]	−0.042	1.320	−0.129	0.408	0.00	0.94

Regressions:
[1] $\sigma_{realized,t} = \alpha + \beta_1 \sigma_{IV,t} + \varepsilon_t$, H_1: $\alpha = 0$, $\beta_1 = 1$
[2] $\sigma_{realized,t} = \alpha + \beta_2 \sigma_{GARCH,t} + \varepsilon_t$, H_2: $\alpha = 0$, $\beta_2 = 1$
[3] $\sigma_{realized,t} = \alpha + \beta_1 \sigma_{IV,t} + \beta_2 \sigma_{GARCH,t} + \varepsilon_t$, H_3: $\alpha = 0$, $\beta_1 = 1$, $\beta_2 = 0$

Notes: An asterisk (*) indicates significance at the 5% level. Tests on significance are based on Newey-West variances. R^2 is the adjusted coefficient of determination.

Conclusion

This study has investigated 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 the live cattle market, the overstatement of realized volatility was more than twice as large as in the feeder cattle market, which is consistent with returns findings. While some evidence of marginal information added by GARCH out-of-sample forecasts was found, implied volatility encompassed GARCH forecasts in both markets.

Analysis of the 30- and 90-day returns from holding live and feeder cattle call and put options, and from short straddle positions, provides further insight on market behavior and performance. Significant positive returns were found in feeder cattle calls, and negative returns in live and feeder cattle puts. Returns on short straddle positions—which can be profitable when future volatility is lower than market expectations—were significantly positive only for the 30-day live cattle positions. Combined, these findings suggest that the positive returns in feeder cattle calls and the negative returns in feeder cattle puts were primarily influenced by the increase in feeder cattle futures market prices, and not by overpricing in the options markets. However, significant short straddle returns support the notion that 30-day live cattle options were overpriced relative to market transaction costs.

Our results are fairly consistent with prior studies on cattle volatility forecasting, but deviate somewhat from analysis of empirical returns for other agricultural options markets. Using daily data and realized volatility measured over different horizons, Szakmary et al. (2003) find evidence that live and feeder cattle implied volatility forecasts are biased and do not encompass in-sample GARCH alternatives, which differs from their findings for other agricultural commodities. For a similar time period, Manfredo and Sanders (2004) conclude 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. Urcola and Irwin (2011) report widespread efficiency when examining estimated returns for holding options, which is consistent with our short straddle results—a more accurate measure of options efficiency in trending markets. 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. However, their results differ from the findings of persistent returns in excess of market costs in live cattle options at shorter horizons and its biased volatility forecasting.

What might explain the apparent overpricing in the short-term live cattle market? Overpriced options can arise due to lack of arbitrage, risk premiums, path-peso problems, and biased beliefs. Path-peso problems emerge when a market overestimates the probability of catastrophic events compared to the actual historical distribution, and biased beliefs emerge from either misinterpretation or insufficient information. Here, high levels of market activity (trading volume) in the live cattle market suggest that sufficient liquidity exists to provide effective arbitrage. This is supported by the feeder cattle findings in which straddle returns are not significant and implied volatility is a less biased forecast despite having 80% less volume trading. In a similar vein, the lack of information or its systematic misinterpretation in a highly traded market for the 24-year period of the analysis seems rather unlikely. An explanation that is more consistent with the pattern of results in the live cattle market centers on the presence of a risk premium which has been magnified by the market's overestimation of the probability of catastrophic events and added uncertainty that emerged in the more recent period. In a hedging context, this implies that writers of put options must be compensated by their buyers for the added risk and uncertainty associated with changing market volatility. This interpretation is consistent with recent research which has investigated the discrepancies between implied volatilities generated by the Black-Sholes-Merton (BSM) model and realized volatility.

While the BSM model is widely used, its implied volatilities have been recently criticized because they fail to account for volatility risk (Doran and Ronn, 2008). Implied volatilities provide a risk-neutral estimate of volatility because they are derived from the BSM model, which assumes the variance in returns is constant over time or deterministically changing through time. If realized volatility is changing stochastically (which appears to be the case, particularly in the live cattle market in recent years), BSM premiums may have an added volatility risk premium imbedded in price, and implied volatility will be a poor representation of subsequent volatility. For energy markets, Doran and Ronn identify the existence of the market price of volatility risk which results in an upward bias in implied volatility. In the context of volatility risk, the straddle returns greater than transaction costs in the live cattle market can be viewed as a reflection of the added price—the market price of volatility risk—imbedded in market premiums.

Several other points emerge from our findings. First, while we find evidence for a short-run volatility risk premium in the live cattle options market, the factors that explain its existence in the live cattle but not in the feeder cattle market are not completely clear and call for further research to identify its primary sources and implications for cattle producers and market participants. One explanation for the difference may arise from the business environment producers face. Commercial feedlot operations are heavy users of live cattle puts. Large investments in facilities and livestock, limited flexibility in their production process, and a desire to obtain attractive financing may make these producers willing to pay an additional premium to manage output price risk. In contrast, feeder cattle producers are much smaller in size (often producing less than one contract's worth of feeder cattle) and frequently raise feeder cattle as part of a more diversified farm portfolio. Observable risk premiums also may be less likely to emerge in this context, and more difficult to measure in returns and straddle positions.

Second, large shocks such as BSE outbreaks can significantly change the volatility and the market's assessment of the likely recurrence of catastrophic events. Here, we find evidence in both the empirical returns and in volatility 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 effect was most pronounced in the 30- as opposed to the 90-day horizon, which is consistent with Jin, Power, and Elbakidze's (2008) findings of futures price behavior in nearby and more distant contracts.

Third, in times of change, as evidenced by the attractiveness of the straddle returns, market participants and traders may find value in correctly identifying the structure of changing volatility and assuming appropriate strategies. The value of identifying changing volatility in the cattle markets becomes more important as these markets are more closely linked to the highly volatile corn-ethanol-energy complex.

Finally, when using empirical returns from buy-and-hold strategies to assess options markets, trends or patterns in futures prices should be investigated. Failure to do so can lead to flawed conclusions about market performance.

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