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Efficiency Characteristics of the Live Cattle Options Market

Robert J. Hauser and Yue Liu*

A considerable amount of work involving the valuation of options on agricultural futures has been conducted by academicians during the past six years. These studies have focused on forecasting variance (e.g., Hauser and Andersen), explaining variance behavior (e.g., Kenyon et al.), measuring biases in implied volatility and premiums (e.g., Wilson, Fung, and Ricks), and identifying alternative valuation models (e.g., Choi and Longstaff).

Consider two fundamental questions: (1) Why are we concerned about how options are priced? (2) How should we evaluate the pricing models and/or results which have implications related to the models? There are many good answers to question #1 and, of course, the "best" answer depends on the purpose of the study. However, a short and incomplete list of reasons for studying valuation models and their premium or IV characteristics may include:

(a) Since a well known "externality" of an options market is an estimate of the market's variance forecast, then it behooves us to understand the derivation of the forecast and the factors affecting it.

(b) Risk management strategies for producers and merchandisers can perhaps be evaluated better in both explanatory and prescriptive terms if we understand the valuation process.

(c) Evaluation of pricing or market "efficiency" is of interest to regulators as well as industry participants.

(d) Given that the option market is now a fairly large and viable part of the commodity marketing sector, knowledge and information about the market is in itself of value to teachers, researchers, and extension personnel.

Methods of evaluation (question #2) have taken various forms. Regression models have been developed to explain IV behavior (e.g., Hauser and Neff), historical variance behavior (e.g., Kenyon et al.), and differences between a model premium and the market premium (e.g., Wilson, Fung and Ricks). Variance forecasts and IV's have been compared to realized variances (e.g., Eales et al.), and some studies have focused on forecasting IV's or premiums (e.g., Jordon et al.). Finally, analyses of price distributions have often been used to make inferences about the appropriateness of traditional option pricing models (e.g., Gordon and Heifner).

To our knowledge, however, very little work involving <u>agricultural futures options</u> has assessed valuation models, underlying assumptions, or

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markets in terms of empirical arbitrage opportunities. Though this has certainly not been the case in past studies on security or stock options. (A few examples among numerous studies include Chiras and Manaster, Galai, Trippi, and Whaley.) The justification and methodology for this type of evaluation is usually derived from the theoretical foundation on which most valuation models are based. In theory, the option and underlying commodity can be continuously and simultaneously traded in a manner which creates a risk-free portfolio. The equilibrium price of this portfolio is the risk-free rate of return, and since the portfolio can be priced, the equilibrium value of the option can also be found. If this option price is "correct" and if the market uses it then, by definition, the process of riskless hedging should make it possible either to buy or sell a portfolio yielding the risk-free rate of return.

Riskless hedging simulations have been used often in the finance literature to test the "efficiency" of an options market. Theoretically, if a market is efficient, then the appropriate rate of return will be generated from the simulation. However, an underlying assumption of the test is that the valuation model used to determine hedging ratios is the "best" model. Assume, for instance, that the market makes adjustments to the Black-Scholes model which improves its pricing performance and consequently changes the true arbitrage opportunities. The hedging simulations based on signals from the Black-Scholes model may imply that the market is yielding a return which is below equilibrium. Perhaps, however, the use of the correctly adjusted model would yield the equilibrium return. Thus, a test of this type can be thought of as a joint test which considers both the efficiency of a market as well as the performance of a valuation model.

There are three objectives of the present analysis. The first objective is simply to illustrate an application of the simulation process described above. As mentioned earlier, this type of analysis is commonly used in the finance literature, but has been ignored for the most part in studies involving options on agricultural futures. It is hoped that the present illustration will provide insights to some of the benefits as well as drawbacks of the methodology. The second objective is to evaluate the performance of alternative valuation techniques for live cattle options. The techniques are all based on the Black pricing model, but differ in terms of the variance forecast used in the model. The final objective is to identify efficiency characteristics of the live-cattle options market.

Procedures and Data

The simulation period was November 1984 through September 1987. Seven live-cattle option contracts were examined, expiring in 6/85, 2/86, 6/86, 10/86, 2/87, 6/87, and 10/87. One option per contract per day was considered when searching for a mispriced option that could be used to initiate the riskless-hedge portfolio. The potential mispriced options were calls with strikes nearest to the underlying futures price. The use of near-the-money calls helps ensure that option pricing errors are due to volatility forecasts as opposed to the underlying pricing model, moneyness, etc.

A portfolio is initiated if the implied volatility (IV) under Black's model is different than our volatility forecast by at least 5%. If the IV is greater (less) than our volatility estimate by 5%, then the option is assumed to be over- (under-) priced. If over- (under-) priced, a short (long) position in one option contract is established, and a long (short) position in h contracts of the underlying futures is taken, where h is Black's hedge ratio, or delta, defined by:

$$h = \delta C/\delta F = e^{-rt}\, N(d_1)$$
$$d_1 = [\ln (F/X) + \sigma^2 t/2] \,/\, \sigma t^{1/2}$$

where C is the call premium, F is the futures price, r is the annualized "risk-free" rate of return, t is time to maturity in years, N(•) is the cumulative normal density function, and σ^2 is our forecast of the instantaneous variance. A new delta was calculated daily based on updated values of futures price, time to maturity, and volatility forecast.

For illustration, assume that on February 5, the June near-the-money option is judged to be under-priced because its IV is 6% less than the forecasted volatility. The resulting hedge ratio from equation 1 is .5. Thus, a long position in one contract of the option and a short position in .5 futures contracts are established. On the next day, February 6, the option is still estimated to be undervalued, but the hedge ratio changes to .6, and thus an additional short position of .1 futures is obtained. On February 7, the IV and volatility forecast are such that the option is now judged to be over-priced, and the hedge ratio is .4; therefore, the option position is changed from one long to one short, and the futures position is changed from -.6 to .4. On February 8, the IV is within 5% of our forecast, and so all positions are liquidated. The search for mispriced options begins again on February 9.

The daily net returns of the portfolio are calculated as either

$$R_u = C_{t+1} - C_t - d_t\,(F_{t+1} - F_t) - BF - OC$$

or

$$R_o = d_t\,(F_{t+1} - F_t) - (C_{t+1} - C_t) - BF - OC$$

where R_u is the estimate of return when the option is judged to be undervalued; R_o is the return for overvalued options; C_t is the premium on day t; F_t is the futures price on day t; BF is the brokerage fee and OC is the opportunity cost. BF is equal to $12.5 times the absolute change in option position plus $25 times the absolute change in the futures position. OC is the opportunity cost of holding (selling) the call option and is positive (negative). The 90-day t-bill rate is used. The option and futures prices were obtained from the <u>Daily Information Bulletin</u> published by the Chicago Mercantile Exchange. Closing futures and option prices were used.

The volatility forecasts used to identify mispriced options are derived by one of four methods. The first method is to use a historical volatility based on the most recent 21 days of trading. Daily closing futures prices for cattle were used.

The next method was used in an attempt to capture potential seasonality in volatility, although past studies have not provided strong evidence of variance seasonality for livestock futures (Anderson, Kenyon et al.). Monthly volatilities were computed for the February, June, and October cattle contracts from 1966 through 1984. The volatilities, averaged by month and contract, are shown in Figures 1 and 2 for 1977-84 and 1966-84, respectively. For both time periods, the average volatility tends to decrease from March through May, increase sharply in June, fall through August, and then increase or decrease from month to month depending on the contract. The averages for the 1977-84 period are used here to calculate an average percentage change from month to month by contract. This index is then applied to the 21-day historical variance to forecast volatility. The 1977-84 period was chosen under the assumption that this period, as opposed to the 1966-84 period, would better represent the volatility behavior of the 1984-87 simulation period.

The third forecast model can be described as:

$$V_t = f(HV_t, AP_t),$$

where V_t is the forecast made on day t, HV_t is the historical volatility based on the last 21 trading days, and AP_t is the average futures price over the last 21 trading days. In other words, this model is based on the hypothesis that future variance is a function of recent variance and price level. The OLS results for each contract for the 1966-84 period are presented in Table 1. As expected, a positive serial dependence between volatilities is found. However, the positive effect of past price level on volatility is inconsistent with the negative price/volatility relationship found by Kenyon et. al. The R^2's, ranging from .54 to .64, do not suggest that these are reliable predictive models.

Table 1. OLS Results of Regressing Variance on Past Variance and Price Level*

	Live Cattle Futures Contract		
	Feb	June	Oct
Intercept	3.3	3.0	0.8
Historical Variance	0.69	0.68	0.72
Price Level	0.06	0.06	0.09
R^2	.59	.54	.64
M-test t ratio	-1.4	-1.1	0.21

* All coefficients are significant at the .01 level. One observation per 21 days is used during 1966-84.

Figure 1. Average Monthly Volatilities (1977-1984)

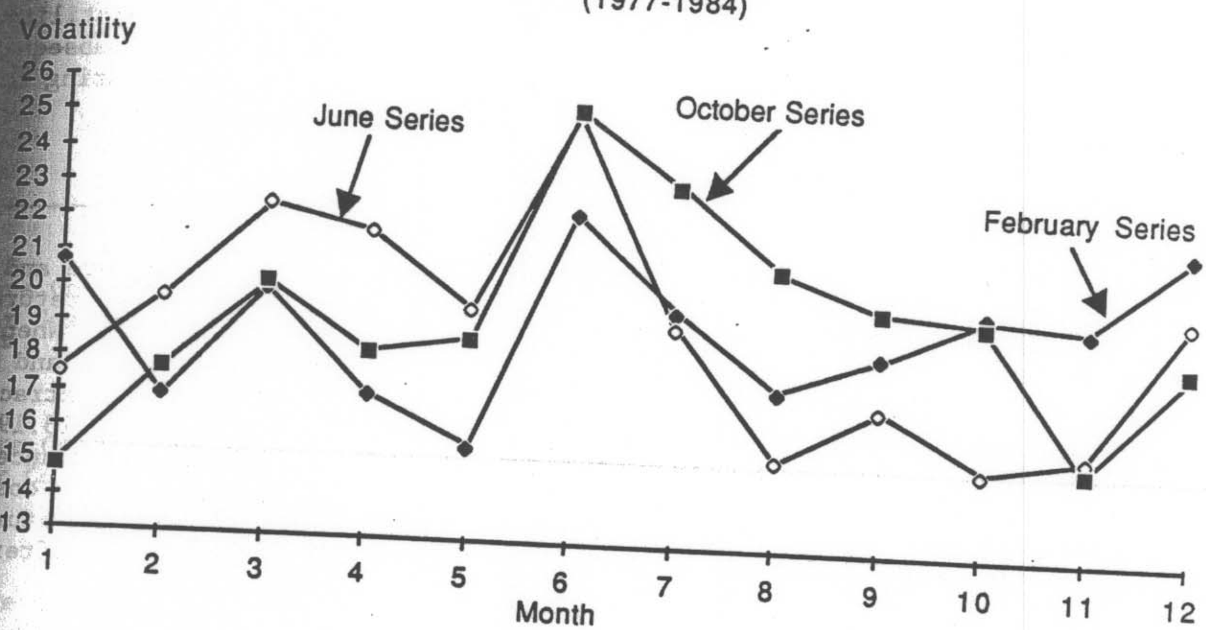
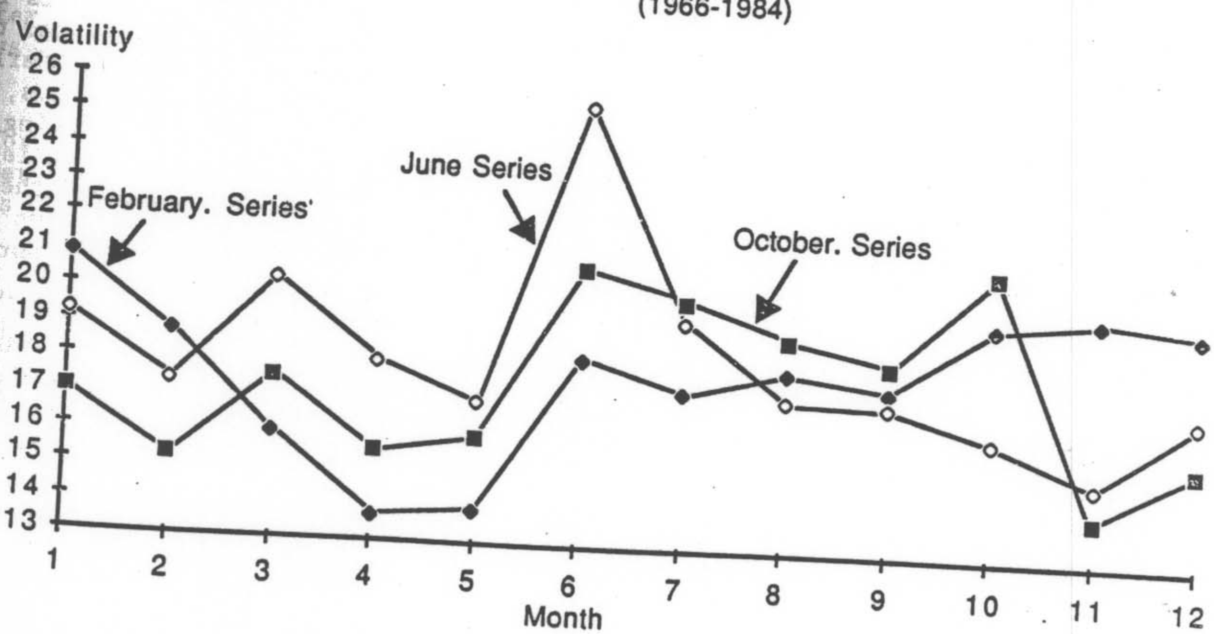


Figure 2. Average Monthly Volatilties (1966-1984)



The final two variance "forecasts" are estimates of subsequent realized or observed variances. The purpose of using the "true" variance as the forecast is to provide an evaluation standard in terms of the profits which could be obtained through riskless hedging if the predicted volatility equals the realized volatility. One forecast is based on the subsequent 21 trading days' prices, while the other is based on the prices during the option's life.

Results

Table 2 presents the average daily portfolio returns, before and after costs, by contract and volatility forecast. First consider the returns simulated under the two known or "realized" variance scenarios. When using the 21-day realized variance (21RV) as the forecast, the before- and after-cost returns are positive for every contract except the 10/87 contract. The before-cost average daily return across all seven contracts is $13.19; the average after-cost return is $9.62. When using the constant variance realized over the option's life (CRV), negative before- and after-cost returns are generated for four of the contracts, while positive returns are generated for three contracts. Over all contracts, the average after-cost return under the CRV forecast is $0.93.

The 21RV results suggest that riskless hedging profits are possible *if* "good" short-term forecasts of variance can be made. The simulated profit levels, however, vary considerably by contract. This variation can be caused by many factors. First, the degree of mispricing relative to Black's IV may vary in terms of the number of days during which the option is found to be mispriced, and the difference between the forecast variance and the IV. Second, the pricing model (Black's) may be wrong due to the underlying distribution assumption, price jumps, or for many other reasons; thus, even if correct volatilities are predicted, their use in a riskless hedging simulation may not generate profits. Third, assuming Black's model is correct, the *estimate* of the realized variance may be wrong due to the discrete and small number of observations, or due to the fact that we are forecasting the 21-day variance and not the variance path over the option's life.

As with any price-efficiency, the "best" forecast can never be defined, and efficiency conclusions are never absolute. However, comparisons of the returns under the 21RV forecast with the other returns provide some interesting efficiency and methodological implications. Examination of the CRV results relative to the 21RV results indicates that it is more important to be able to forecast variance rates than total variance when making delta trades. Four of the seven CRV net returns are negative. Five of the seven CRV returns are considerably less than the 21RV returns. If constancy in the variance rate is assumed, or if variance rate changes are linear over time, then an appropriate ex-post estimate of the volatility used in Black's model is represented by the variance of log-price returns over the option's life. In other words, a common "test" of whether the market is providing reliable volatility forecasts involves the comparisons of the premium's IV to the CRV. However, it is suggested here that correct forecasts of non-constant variance, even if only for the nearby variance behavior, will likely lead to profitable arbitrage.

Table 2. Average Daily Returns Before and After Costs in Dollars.

	Contract						
	6/85	2/86	6/86	10/86	2/87	6/87	10/87
21RV[a]							
Before Cost	20.49[c]	19.23	9.33	13.99	22.57	6.83	-0.08
After Cost	16.68	15.16	6.38	11.03	17.71	4.96	-4.06
Days[b]	98	38	92	83	84	124	121
CRV							
Before Cost	-1.00	-12.80	-0.68	4.28	29.85	12.88	-4.49
After Cost	-5.11	-14.25	-1.67	2.17	23.70	10.78	-9.11
Days	94	38	86	76	44	96	81
SV							
Before Cost	4.74	-5.64	3.08	-13.52	-0.50	12.82	0.68
After Cost	2.53	-9.64	-0.27	-15.88	-5.01	10.06	-1.72
Days	129	48	84	78	75	101	128
MV							
Before Cost	0.35	6.10	2.27	12.46	-1.46	6.62	4.52
After Cost	-3.16	2.16	-3.99	8.01	-7.78	4.62	0.07
Days	131	50	64	71	58	122	93
HV							
Before Cost	8.45	-6.83	5.66	5.70	6.89	12.88	-0.11
After Cost	4.11	-13.27	-0.22	2.74	2.80	10.78	-2.90
Days	106	56	62	77	70	119	122

[a] 21RV: 21-day ahead realized variance; CRV: constant realized variance over option's life; SV: variance based on seasonal index; MV: variance as a function of recent variance and cattle price level; HV: 21-day historical variance.

[b] Number of trading days a portfolio was held; i.e., number of days in which mispriced options were assumed.

[c] Under normality, all returns are significantly different than zero at the .05 level except those which are less than absolute one.

Predicting nearby changes in volatility may be important, but difficult to do. The two models used here to reflect the possibility of nearby changes are based on a seasonal index (SV) and on a regression which makes variance a function of recent cattle price level and variance (MV). The SV and MV results in Table 2 suggest that the underlying forecast models would not generate consistently positive returns. The SV returns are negative for six of the seven contracts, relatively small ($2.53) for one contract, and relatively large ($10.06) for the 6/87 contract. Note that with the exception of the 10/86 contract, the general pattern of returns in the SV case is the same as that for the historical variance (HV) case. Like the SV model, the HV model generates the largest return ($10.09) for the 6/87 contract. The similarity between the SV and HV results suggests that the SV model is providing little additional information over the historical variance that can be used profitably in a riskless hedging framework.

The results do not suggest that the live cattle options market is, in general, inefficient. While arbitrage profits could have been made consistently _if_ the 21-day ahead variance forecast were known, the after-cost returns available from ex-ante forecasts are often close to zero or very negative. One exception is the 6/87 contract, for which all after-cost returns are positive. The large and consistent profits for this contract indicates inefficiency. However, since none of the other six contracts exhibit this type of arbitrage opportunity, particularly when using ex-ante variance forecasts, the general results suggest an efficient market _given_ Black's model as the valuation construct.

Summary

An efficiency test of the live cattle options market was conducted by examining arbitrage opportunities for seven contracts. Simulations of riskless hedging (i.e., delta-neutral trading) were done under the assumption that Black's model represents the correct valuation technique. Five different types of variance forecasts were used to identify arbitrage opportunities and delta levels.

Two ex-post variance "forecasts" were used -- a 21-day ahead variance estimate, and an estimate of the variance over the option's life. Use of the 21-day ahead forecast produced consistently large after-cost returns, implying two things: (a) profits can be made by identifying mispriced options, and thus the profit levels helped set a standard by which ex-ante forecasts can be evaluated and (b) since the 21-day ahead estimate performed much better than the option life's variance, it is more important that short term variances or variance "rates" be predicted than overall variances; i.e., it is important that the variance-rate path be known.

In general, the profits from using the three ex-ante forecasts were small and often negative. Except for one contract, the results suggest that there are no consistent arbitrage opportunities available from using the forecast methods specified in this study. Furthermore, none of the forecast methods was clearly superior to the others when evaluated in terms of arbitrage profits.

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