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Suggested citation format:

Irwin, S. H., C. Zulauf, and R. Pelly. 1991. “A Market Timing Test of Pricing Models for Agricultural Options.” Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. [http://www.farmdoc.uiuc.edu/nccc134].

A Market Timing Test of Pricing Models for Agricultural Options

Scott H. Irwin, Carl R. Zulauf, and Robert A. Pelly*

Recently, a number of studies have investigated the valuation of agricultural futures options (e.g. Eales and Hauser, Hauser and Neff, Irwin *et al.*, Jordan *et al.*, Wilson *et al.*). These studies have focused on the accuracy and bias of premiums predicted by theoretical pricing models. A different type of evaluation is arguably more fundamental. This is an evaluation of whether a pricing model may be used as the basis for profitable trading strategies. While trading strategies have been widely investigated in the literature on security options, only one study (Hauser and Liu) has examined this issue with respect to agricultural futures options.

In this study, the economic value of option pricing models in the markets for agricultural futures options will be investigated. Previous research is extended by: 1) investigating options on soybean and live cattle futures, 2) examining both puts and calls, 3) using transactions-matched rather than closing price-matched futures and options data, 4) evaluating both European and American pricing models, and 5) using a market timing test rather than simulated arbitrage positions.

A market timing test proposed by Merton will be used to investigate the economic value of the two option pricing models. Merton's basic assumption is that forecasts only have positive value if they cause rational investors to alter their expectations about the future. Based on this assumption, Merton proves that the sum of the conditional probabilities of a correct forecast is a sufficient statistic for forecasting value. In essence, the Merton test determines whether market premia trend in the direction predicted by the option pricing model.

The Merton market timing test has four important advantages over arbitrage efficiency tests used in previous studies: a) positions do not need to be altered over time in an effort to maintain a truly riskless hedge position, b) it does not require specification of an equilibrium model of asset pricing, c) it allows for the possibility that a model may forecast upward market moves better than downward moves, or vice versa, and d) the market timing test statistic is simple to estimate in a regression framework.

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II. THEORETICAL VALUATION OF EUROPEAN AND AMERICAN OPTIONS

The Black Model

Black and Scholes provided the seminal breakthrough in modern option pricing theory by deriving a closed-form equilibrium pricing model for securities options. Black later modified the Black and Scholes model to price options on futures contracts. The Black model (BOPM) for pricing calls on futures options is:

$$c = e^{-rT} [fN(d_1) - XN(d_2)] \qquad (1)$$

where

- c = equilibrium market value of a European call option on a futures contract,
- f = underlying futures price,
- T = time to expiration of the option contract,
- X = strike price,
- r = risk-free rate of interest,
- σ^2 = variance of the price changes of the underlying futures price,
- $N(.)$ = normal cumulative density function,
- $d_1 = [\ln(f/X) + (\sigma^2/2)T]/\sigma\sqrt{T}$,
- $d_2 = d_1 - \sigma\sqrt{T} = [\ln(f/X) - (\sigma^2/2)T]/\sigma\sqrt{T}$.

Substituting (1) into the put-call parity relationship for European futures options (Stoll) and noting that $N(-d) = 1 - N(d)$ yields Black's option pricing formula for a European put option on a futures contract (p):

$$p = e^{-rT} [\, XN(-d_2) - fN(-d_1) \,] \qquad (2)$$

The BOPM was derived assuming the option can be exercised only at expiration (European-type). However, options traded on regulated U.S. exchanges are American options because they can be exercised on or before their expiration. The potential value of the early exercise privilege can be seen by examining equation (1). As f becomes extremely large relative to X, $N(d_1)$ and $N(d_2)$ approach one and the value of a European call option approaches $(f-X)e^{-rT}$. However, an American option may be exercised immediately for (f-X) which is greater than $(f-X)e^{-rT}$ at any time before expiration. Hence, for futures prices that are substantially larger than the strike price, the call option is worth more when exercised early. The early exercise premium equals the discounted value of the interest income resulting from early exercise. Analogous arguments can be made for put options on futures contracts.

To date, a closed-form model for valuing American futures options has not been derived. While a number of models have been proposed based on approximation techniques, the only computationally efficient model was recently developed by Barone-Adesi and Whaley. Their model assumes that a value of f, F*, exists such that investors are indifferent to the feature of early exercise. Given X, the call (put) is exercised if f is greater than (less than) F*. Intuitively, their model calculates call (put) values as the value of Black's model plus an early exercise premium if $f < F^*$ $(f > F^*)$ or the option's immediate exercise value (intrinsic value) if $f \geq F^*$ $(f \leq F^*)$.

The Barone-Adesi and Whaley model (BAWOPM) for pricing an American call option is formally defined as follows:

$$C = c + A_2(f/F^*)^{q_2} \qquad \text{when } f < F^* \qquad (3)$$
$$C = f - X \qquad \text{when } f \geq F^* \qquad (4)$$

where

C = value of an American call option on a commodity futures contract,
c = BOPM value as defined in equation (1),
$A_2 = (F^*/q_2)\{1 - e^{-rT}N[d_1(F^*)]\}$,
$d_1(F^*) = [\ln(F^*/X) + .5\sigma^2 T]/\sigma\sqrt{T}$,
$q_2 = [1 + \sqrt{(1 + 4k)}]/2$,
$k = 2r/[\sigma^2(1 - e^{-rT})]$.

F^* is identified by using an iterative process developed by Barone-Adesi and Whaley to the following formula:

$$F^* - X = c^* + \{1 + e^{-rT}N[d_1(F^*)]\}F^*/q_2 \qquad (5)$$

where c^* is the BOPM evaluated at F^*.

The BAWOPM for pricing an American put is,

$$P = p + A_1(f/F^{**})^{q_1} \qquad \text{when } f > F^{**} \qquad (6)$$
$$P = X - f \qquad \text{when } f \leq F^{**} \qquad (7)$$

where

P = value of an American put option on a futures contract,
p = BOPM value of a European put as defined in equation (2),
$A_1 = -(F^{**}/q_1)\{1 - e^{-rT}N[-d_1(F^{**})]\}$,
$q_1 = [1 - \sqrt{(1 + 4k)}]/2$,

The iterative formula for determining F^{**} is,

$$X - F^{**} = p^{**} - \{1 - e^{-rT}N[-d_1(F^{**})]\}F^{**}/q_1 \qquad (8)$$

where p^{**} is the BOPM evaluated at F^{**}.

III. FUTURES OPTIONS PRICING: EMPIRICAL PREDICTION

Futures and Options Data

Futures and options data used in this study were obtained from the Chicago Board of Trade (CBOT) and Chicago Mercantile Exchange (CME). The original data set consisted of all transactions reported for soybean and live cattle futures and options contracts from the first day of trading in soybean and live cattle options, October 31, 1984, through September 30, 1988. This data set contained approximately four million observations. To reduce it to a manageable size, one observation per day for all put and call contracts and all strike prices was collected. The period from 10:00 a.m. and 12:00 a.m. was chosen to collect the options and futures prices. This period avoids the higher intraday variance of prices that occurs during the open and close (Jordan *et al.*).

Contemporaneous futures prices were collected to match the put and call observations using the following procedure. First, for each strike price and contract, data was collected for the option traded nearest to 11:00 a.m., midpoint of the trading period analyzed. The contemporaneous futures price was for the transaction traded closest to the time of the option contract was traded. A maximum window of 90 and 60 seconds was allowed between futures and options transactions for soybeans and live cattle, respectively. The criteria for the contemporaneous window was arrived at after testing progressively smaller windows between 300 and 20 seconds. Mean and standard deviation of the absolute difference between the time of the futures and options transactions declined without a large loss of observations until the time window approached the final criteria. Further reductions in the time window produced a substantial decrease in observations with little reduction in the mean or standard deviation of the absolute time difference.

Shastri and Tandon (1986) noted that deep out-of-the-money options should be deleted since the hedging strategies that underlie the pricing models require an unrealistic investment in such options. Hence, options with a premium of less than or equal to $0.01 per bushel for soybeans and $.05 per hundredweight for cattle were deleted.

Descriptive statistics for the data set are presented in Table 1. The final data base included 8,218 observations for soybean call and 3,988 observations for soybean puts. For live cattle, the final data base included 10,275 observations for calls and puts. The mean absolute times between futures and options observations ranged between about 16 and 21 seconds, indicating closely matched (i.e., contemporaneous) futures and options transactions.

Model Variable Estimation

Five variables are needed by both the Black and Barone-Adesi and Whaley models to calculate an option price: futures price, strike price, time-to-expiration, risk-free interest rate, and a measure of annualized volatility. The first two variables, plus the actual option premium and option expiration date, were taken directly from the data tapes for each daily observation. Time-to-expiration was calculated as the proportion of a year (365 days) remaining to the expiration date. The risk-free interest rate was estimated as the 90-day Treasury bill rate and was provided by the Federal Reserve Bank of Cleveland.

Previous research (e.g., Irwin *et al.*) has found that pricing errors of option models were substantially reduced if implied volatility estimates were used instead of volatility estimates based on historical futures prices. Implied volatility is calculated by solving for the volatility implied by the option pricing model. This is determined by substituting the observed option value plus the other four non-volatility variables into the option pricing model, and then solving iteratively for volatility, which is the remaining unknown variable.

Three implied volatility estimates were used in this study. Each was derived using a Newton-Raphson iterative search algorithm. The first is an arithmetic average of the previous trade day's implied volatilities derived for all traded strike prices of an option with a given maturity. The second estimate is the implied volatility for the option's strike price nearest to the quoted future price. This estimate, referred to as the at-the-money volatility estimate, reflects the option strike price most sensitive to changes in volatility. The third estimate is the implied volatility of the previous day's option with a strike price closest to the current day's option strike price being analyzed. This matched estimate is based on the finding from previous studies that pricing errors are related to the moneyness of the option (e.g. Jordan, Seale, McCabe, and Kenyon). Separate estimates were made for calls and puts.

Descriptive Statistics on Model Accuracy

Tables 2 and 3 display descriptive statistics on the accuracy of the models in pricing soybean and live cattle options. Accuracy is measured as market price minus model price. In general, model put and call values were underpriced relative to the market premiums. Consistent with previous research (Whaley), there was little difference in the pricing accuracy of American and European models, whether measured by mean pricing differences, standard deviations of price differences, or percentage of over- and under-pricing. Differences across the three implied volatility estimators also were small except that the at-the-money implied volatility estimator was substantially less accurate for soybean calls and live cattle puts.

Standard deviations of the pricing errors were substantially larger than the means for all volatility estimates. This implies relatively wide fluctuations within the sample data set regarding pricing performance.

IV. MARKET TIMING TESTS OF THE OPTION PRICING MODELS

Merton's Model of Market Timing Value

Merton's derivation of forecast value begins with a basic assumption that forecasts only have positive value if they cause rational investors to alter their expectations about the future. If expectations are not altered, the information contained within the forecast has already been assimilated into the investor's expectations. Merton's methodology for obtaining the value of this forecast is independent of the investor's preferences, endowments, or prior assessments of an asset's return stream.

Merton defines a forecast variable Z_{t+1} such that $Z_{t+1} = 1$ if the forecast, made at t, for time period t+1 is that price will rise. Analogously, $Z_{t+1} = 0$ if price is forecast to stay constant or fall. Probabilities for Z_{t+1} conditional upon the realized change in price, M_{t+1}, are defined by:

$$p1 = \text{Prob} \{ Z_{t+1} = 0 \mid M_{t+1} \leq 0 \} \quad (9a)$$
$$1 - p1 = \text{Prob} \{ Z_{t+1} = 1 \mid M_{t+1} \leq 0 \} \quad (9b)$$
$$p2 = \text{Prob} \{ Z_{t+1} = 1 \mid M_{t+1} > 0 \} \quad (9c)$$
$$1 - p2 = \text{Prob} \{ Z_{t+1} = 0 \mid M_{t+1} > 0 \} \quad (9d)$$

The conditional probability of a correct forecast given that $M_{t+1} \leq 0$, is p1, while p2 is the conditional probability of a correct forecast given that $M_{t+1} > 0$. Merton assumes that p1 and p2 do not depend upon the magnitude of the realized change in price, M_{t+1}. Hence, the conditional probability of a correct forecast depends only on the realized direction of price change.

Under the previous assumptions, Merton proves (1) that the sum of the conditional probabilities of a correct forecast, p1 + p2, is a sufficient statistic for evaluation of forecasting value and (2) that the sum of conditional probabilities p1 and p2 must exceed one for a model to exhibit forecasting value. Because the test statistic is p1 + p2, it is not necessary that the conditional probabilities remain constant across time, only that their sum be stationary. It is also not necessary that p1 = p2, allowing for the possibility that a model is better equipped to forecast upward market moves than downward market moves, or vice versa (Henriksson and Merton).

To illustrate Merton's market timing condition, take the case of a model clearly without market timing ability: one that always forecasts price will rise. The conditional probability of correctly forecasting price will rise, p2, will equal one. However, the conditional probability of forecasting price will be constant or fall, p1, is equal to zero. Since p1 + p2 equals one, the model does not satisfy the necessary and sufficient condition for market timing ability.

Market Timing Tests

Breen *et al.* show that Merton's test of market timing ability can be implemented in a regression framework. First, define a market direction variable M_{t+i} such that:

$$M_{t+i} = 1 \text{ if } PA_{t+i} > PA_t \qquad (10a)$$
$$M_{t+i} = 0 \text{ if } PA_{t+i} \leq PA_t \qquad (10b)$$

where PA_{t+i} is the market price for an option (put or call at a particular strike price) on day t+i and PA_t is the market price for day t. Next, define a forecast direction variable $Z_{t+i,j}$ such that:

$$Z_{t+i,j} = 1 \text{ if } PF_{t+i,j} > PA_t \qquad (11a)$$
$$Z_{t+i,j} = 0 \text{ if } PF_{t+i,j} \leq PA_t \qquad (11b)$$

where $PF_{t+i,j}$ is the option price forecast for day t+i by option model j.

Then, the following regression equation can be specified:

$$Z_{t+i,j} = \alpha_j + \beta_j M_{t+i} + \epsilon_{t+i,j} \qquad (12)$$

where $\epsilon_{t+i,j}$ is a standard normal error term. Breen *et al.* show that β_j = p1 + p2 - 1. As a result, if β_j is significantly greater than zero, then the option price forecasts have met the necessary and sufficient condition for market timing value (Breen, *et al.*).

Two trading strategies were considered in the market timing tests. In the first strategy, trades were assumed to be initiated on the same day as the generation of model predictions. Positions were assumed to be offset on the following day at the 11:00 a.m. trade. In the second strategy, trades were assumed to be initiated at the 11:00 a.m. on the day following the generation of the model predictions. Positions were assumed to be offset one day after the initiation of the trade. This strategy was designed to test the sensitivity of the results to order delays, which may be frequent in relatively illiquid options markets.

The estimates of β and associated t-statistics for soybeans over the full sample period are presented in Table 4. In the case of same day trades, none of the β coefficients were significant for soybean put prices. In contrast, for soybean calls β coefficients for the European and American models at-the-money or strike price matched implied volatility estimates were significant. However, the level of market timing value was not large. Recall that β minus one equals the sum of the conditional probabilities of a correct forecast of market direction. Hence, the largest sum of conditional probabilities for correctly predicting the direction of soybean call prices was 1.0256. This is only a 2.56 percent improvement over a naive prediction model.

When trades were delayed one day, none of the β coefficients for the European or American models were significant. This suggests that any market timing opportunities provided by the models for soybean options dissipates quickly and/or is highly sensitive to order delays and transaction costs.

Market timing test results for soybeans over the first and second half of the sample are presented in Tables 5 and 6, respectively. The results indicate that estimates for the strategy of same day trades were somewhat sensitive to the sample period considered. Over the first half of the sample (Table 5), no model had significant market timing value in predicting soybean call prices, but, two models had significant market timing value in predicting put prices. Over the second half of the sample (Table 6), results were similar to that over the entire sample.

Estimates of β and associated t-statistics for live cattle over the full sample period are presented in Table 7. In contrast to the results for soybeans, β coefficients for same day trades were significant in all cases for both puts and calls. Further evidence of the models' greater success predicting live cattle option prices was the relative size of the coefficients. For example, the largest coefficient for live cattle (0.0611) was more than twice the largest soybean coefficient (0.0256). Similar to soybeans, if trades were delayed one day, none of the β coefficients for live cattle options were significant. This provides further evidence that any market timing opportunities provided by the models may dissipate quickly and/or is highly sensitive to order delays and transaction costs.

Market timing test results for live cattle over the first and second half of the sample are presented in Tables 8 and 9, respectively. The results again were sensitive to the sample period considered. Results over the first half of the sample (Table 8), were similar to those for the entire sample. Over the second half of the sample (Table 9), only two models had significant market timing value in predicting put prices.

V. SUMMARY AND CONCLUSIONS

This study investigated the economic value of option pricing models in the markets for agricultural futures options. Only one previous study (Hauser and Liu) has examined this issue with respect to agricultural futures options. We extended previous research by: 1) investigating options on soybean and live cattle futures, 2) examining both puts and calls, 3) using transactions-matched rather than closing price-matched futures and options data, 4) evaluating both European and American pricing models, and 5) using Merton's market timing test rather than simulated arbitrage positions.

The data sample for the study began on October 31, 1984 and extended through September 30, 1988. It included 13,255 (6,716) daily observations for soybean calls (puts) and 10,275 (9,509) daily observations for live cattle calls (puts). The futures and options observations were closely matched (i.e., contemporaneous), in that mean absolute times between futures and options observations were between 16 and 21 seconds.

The results indicated that the models exhibited significant market timing value in predicting soybean and live cattle call prices, as well as live cattle put prices. These results were contingent on the assumption that trades were initiated the same day as the generation of model predictions and exited one day later.

If initiation of trades was delayed one day, no case option pricing model exhibits significant market timing value. This suggests that any market timing opportunities provided by the models dissipates quickly and/or is highly sensitive to order delays and transaction costs.

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TABLE 1. SOYBEAN AND LIVE CATTLE OPTIONS AND FUTURES DATA BASE DESCRIPTIONS, OCTOBER 31, 1984 TO SEPTEMBER 30, 1988.

		TIME BETWEEN TRADED OPTIONS AND FUTURES CONTRACTS		TIME BETWEEN TRADED OPTION AND 11:00 a.m.	
OPTION	OBSERVATIONS	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION
	--NUMBER--	-------SECONDS-------		--MINUTES.SECONDS--	
Soybeans:[a]					
Calls	8,218	21.20	21.30	14.81	15.27
Puts	3,988	17.40	18.80	16.75	15.61
Live Cattle:[b]					
Calls	10,275	16.21	14.36	18.22	16.20
Puts	9,509	16.29	14.50	19.44	16.37

[a] Chicago Board of Trade.

[b] Chicago Mercantile Exchange.

TABLE 2. ACCURACY RESULTS COMPARING MARKET AND MODEL PRICES FOR SOYBEAN OPTIONS, CHICAGO BOARD OF TRADE, OCTOBER 31, 1984 TO SEPTEMBER 30, 1988.

MODEL/ VOLATILITY ESTIMATOR[b]	PRICING DEVIATIONS[a]		FREQUENCY OF MODEL MIS-PRICING		
	Mean	SD	% < 0	% = 0	% > 0
	-----$/BU.------		--------PERCENT--------		
CALLS:[c]					
EUROPEAN					
IV1	-0.43	2.83	51.3	0.0	48.7
IV2	0.97	2.51	28.2	0.0	71.8
IV3	0.12	1.68	42.2	0.0	57.8
AMERICAN					
IV1	-0.36	2.80	50.6	0.2	49.2
IV2	0.96	2.55	28.3	0.3	71.4
IV3	0.11	1.69	42.3	0.3	57.4
PUTS:[d]					
EUROPEAN					
IV1	0.13	1.66	49.2	0.0	50.8
IV2	0.16	1.71	42.7	0.0	57.3
IV3	0.26	1.42	41.2	0.0	58.8
AMERICAN					
IV1	0.14	1.63	48.9	0.2	50.9
IV2	0.16	1.68	42.8	0.3	56.9
IV3	0.26	1.42	41.5	0.3	58.2

[a]The pricing deviations were calculated as market price - model price.

[b]IV1 = Averaged put or call implied volatility estimate.
IV2 = At-the-money put or call implied volatility estimate.
IV3 = Strike price matched put or call implied volatility estimate.

TABLE 3. ACCURACY RESULTS COMPARING MARKET AND MODEL PRICES FOR LIVE CATTLE OPTIONS, CHICAGO MERCANTILE EXCHANGE, OCTOBER 31, 1984 TO SEPTEMBER 30, 1988.

MODEL/ VOLATILITY ESTIMATOR[b]	PRICING DEVIATIONS[a]		FREQUENCY OF MODEL MIS-PRICING		
	Mean	SD	% < 0	% = 0	% > 0
	-----$/CWT.------		--------PERCENT--------		
CALLS:[c]					
EUROPEAN					
IV1	0.0081	0.1127	43.7	5.4	50.9
IV2	0.0174	0.1162	39.3	4.7	56.0
IV3	0.0147	0.1155	40.7	5.6	53.7
AMERICAN					
IV1	0.0091	0.1120	42.9	5.5	51.6
IV2	0.0172	0.1159	39.4	4.8	55.8
IV3	0.0143	0.1153	40.9	5.6	53.6
PUTS:[d]					
EUROPEAN					
IV1	0.0008	0.1197	44.2	4.5	51.3
IV2	0.0301	0.1232	33.3	4.4	62.2
IV3	0.0129	0.1417	40.0	5.7	54.3
AMERICAN					
IV1	0.0008	0.1236	44.1	4.5	51.4
IV2	0.0302	0.1238	33.2	4.4	62.4
IV3	0.0124	0.1418	40.2	5.7	54.1

[a]The pricing deviations were calculated as market price - model price.

[b]IV1 = Averaged put or call implied volatility estimate.
IV2 = At-the-money put or call implied volatility estimate.
IV3 = Strike price matched put or call implied volatility estimate.

TABLE 4. MARKET TIMING TEST FOR SOYBEAN OPTIONS, CHICAGO BOARD OF TRADE, OCTOBER 31, 1984 TO SEPTEMBER 30, 1988.

		SAME DAY TRADES		TRADES DELAYED ONE DAY	
OPTION PRICING MODEL	VOLATILITY ESTIMATE[a]	β COEFFICIENT	T-STATISTIC	β COEFFICIENT	T-STATISTIC
CALLS:					
EUROPEAN					
	IV1	-0.0129	-1.19	-0.0210	-1.93
	IV2	0.0256**	2.52	-0.0061	-0.60
	IV3	0.0250*	2.30	-0.0193	-1.78
AMERICAN					
	IV1	-0.0018	-1.09	-0.0218	-2.00
	IV2	0.0239**	2.34	-0.0061	-0.59
	IV3	0.0221*	2.03	-0.0207	-1.91
PUTS:					
EUROPEAN					
	IV1	0.0219	1.16	-0.0190	-0.98
	IV2	0.0194	1.01	0.0110	0.56
	IV3	0.0201	1.05	0.0217	1.10
AMERICAN					
	IV1	0.0139	0.73	-0.0209	-1.07
	IV2	0.0135	0.71	0.0118	0.60
	IV3	0.0112	0.59	0.0257	1.31

Note: One star indicates statistical significance at the .05 level. Two stars indicate statistical significance at the .01 level.

[a]IV1 = averaged put or call implied volatility estimate.
IV2 = at-the-money put or call implied volatility estimate.
IV3 = strike price matched put or call implied volatility estimate.

TABLE 5. MARKET TIMING TEST FOR SOYBEAN OPTIONS, CHICAGO BOARD OF TRADE, OCTOBER 31, 1984 TO SEPTEMBER 12, 1986.

		SAME DAY TRADES		TRADES DELAYED ONE DAY	
OPTION PRICING MODEL	VOLATILITY ESTIMATE[a]	β COEFFICIENT	T-STATISTIC	β COEFFICIENT	T-STATISTIC
CALLS:					
EUROPEAN					
	IV1	-0.0199	-0.95	-0.0423	-2.63
	IV2	0.0140	0.71	-0.0248	-1.73
	IV3	0.0309	1.48	-0.0420	-2.64
AMERICAN					
	IV1	-0.0202	-0.96	-0.0418	-2.60
	IV2	0.0164	0.84	-0.0260	-1.81
	IV3	0.0318	1.52	-0.0442	-2.78
PUTS:					
EUROPEAN					
	IV1	0.0266	0.93	-0.0465	-1.54
	IV2	0.0768**	2.70	0.0059	0.19
	IV3	0.0462	1.61	0.0003	0.01
AMERICAN					
	IV1	0.0178	0.62	-0.0463	-1.53
	IV2	0.0694**	2.43	0.0094	0.31
	IV3	0.0299	1.04	0.0093	0.31

Note: One star indicates statistical significance at the .05 level. Two stars indicate statistical significance at the .01 level.

[a]IV1 = averaged put or call implied volatility estimate.
IV2 = at-the-money put or call implied volatility estimate.
IV3 = strike price matched put or call implied volatility estimate.

TABLE 6. MARKET TIMING TEST FOR SOYBEAN OPTIONS, CHICAGO BOARD OF TRADE, SEPTEMBER 15, 1986 TO SEPTEMBER 30, 1988.

		SAME DAY TRADES		TRADES DELAYED ONE DAY	
OPTION PRICING MODEL	VOLATILITY ESTIMATE[a]	β COEFFICIENT	T-STATISTIC	β COEFFICIENT	T-STATISTIC
CALLS:					
EUROPEAN	IV1	0.0281	1.57	-0.0053	-0.36
	IV2	0.0640**	3.86	-0.0012	-0.08
	IV3	0.0673**	3.76	-0.0079	-0.53
AMERICAN	IV1	0.0273	1.52	-0.0062	-0.42
	IV2	0.0586**	3.39	-0.0012	-0.08
	IV3	0.0605**	3.37	-0.0090	-0.60
PUTS:					
EUROPEAN	IV1	0.0311	1.22	0.0046	0.18
	IV2	0.0167	0.65	0.0259	1.01
	IV3	0.0294	1.13	0.0413	1.59
AMERICAN	IV1	0.0294	1.16	0.0015	0.06
	IV2	0.0111	0.43	0.0242	0.94
	IV3	0.0252	0.97	0.0411	1.58

Note: One star indicates statistical significance at the .05 level. Two stars indicate statistical significance at the .01 level.

[a]IV1 = averaged put or call implied volatility estimate.
IV2 = at-the-money put or call implied volatility estimate.
IV3 = strike price matched put or call implied volatility estimate.

TABLE 7. MARKET TIMING TEST FOR LIVE CATTLE OPTIONS, CHICAGO MERCANTILE EXCHANGE, OCTOBER 31, 1984 TO SEPTEMBER 30, 1988.

		SAME DAY TRADES		TRADES DELAYED ONE DAY	
OPTION PRICING MODEL	VOLATILITY ESTIMATE[a]	β COEFFICIENT	T-STATISTIC	β COEFFICIENT	T-STATISTIC
CALLS:					
EUROPEAN					
	IV1	0.0418**	4.19	-0.0112	-1.12
	IV2	0.0491**	4.94	0.0084	0.85
	IV3	0.0586**	5.88	-0.0032	-0.33
AMERICAN					
	IV1	0.0405**	4.06	-0.0148	-1.48
	IV2	0.0486**	4.89	0.0081	0.81
	IV3	0.0611**	6.13	-0.0021	-0.22
PUTS:					
EUROPEAN					
	IV1	0.0327*	3.14	0.0126	1.21
	IV2	0.0304*	3.01	0.0013	0.13
	IV3	0.0493**	4.75	0.0093	0.90
AMERICAN					
	IV1	0.0332*	3.19	0.0118	1.12
	IV2	0.0316*	3.12	-0.0028	-0.28
	IV3	0.0501**	4.83	0.0069	0.66

Note: One star indicates statistical significance at the .05 level. Two stars indicate statistical significance at the .01 level.

[a]IV1 = averaged put or call implied volatility estimate.
IV2 = at-the-money put or call implied volatility estimate.
IV3 = strike price matched put or call implied volatility estimate.

TABLE 8. MARKET TIMING TEST FOR LIVE CATTLE OPTIONS, CHICAGO MERCANTILE EXCHANGE, OCTOBER 31, 1984 TO SEPTEMBER 12, 1986.

OPTION PRICING MODEL	VOLATILITY ESTIMATE[a]	SAME DAY TRADES β COEFFICIENT	SAME DAY TRADES T-STATISTIC	TRADES DELAYED ONE DAY β COEFFICIENT	TRADES DELAYED ONE DAY T-STATISTIC
CALLS:					
EUROPEAN	IV1	0.0088	0.54	-0.0234	-1.43
	IV2	0.0366*	2.27	-0.0119	-0.73
	IV3	0.0432**	2.65	-0.0235	-1.44
AMERICAN	IV1	0.0176	1.08	-0.0310	-1.91
	IV2	0.0382**	2.36	-0.0092	-0.57
	IV3	0.0469**	2.88	-0.0209	-1.28
PUTS:					
EUROPEAN	IV1	0.0637**	3.73	0.0269	1.57
	IV2	0.0642**	3.79	0.0095	0.56
	IV3	0.0702**	4.12	0.0078	0.46
AMERICAN	IV1	0.0713**	4.18	0.0253	1.47
	IV2	0.0678**	4.01	0.0083	0.49
	IV3	0.0743**	4.36	0.0059	0.35

Note: One star indicates statistical significance at the .05 level. Two stars indicate statistical significance at the .01 level.

[a]IV1 = averaged put or call implied volatility estimate.
IV2 = at-the-money put or call implied volatility estimate.
IV3 = strike price matched put or call implied volatility estimate.

TABLE 9. MARKET TIMING TEST FOR LIVE CATTLE OPTIONS, CHICAGO MERCANTILE EXCHANGE, SEPTEMBER 15, 1986 TO SEPTEMBER 30, 1988.

		SAME DAY TRADES		TRADES DELAYED ONE DAY	
OPTION PRICING MODEL	VOLATILITY ESTIMATE[a]	β COEFFICIENT	T-STATISTIC	β COEFFICIENT	T-STATISTIC
CALLS:					
EUROPEAN					
	IV1	0.0630**	4.98	-0.0027	-0.21
	IV2	0.0563**	4.47	0.0204	1.61
	IV3	0.0701**	5.55	0.0108	0.85
AMERICAN					
	IV1	0.0557**	4.41	-0.0039	-0.30
	IV2	0.0544**	4.32	0.0182	1.44
	IV3	0.0716**	5.67	0.0107	0.85
PUTS:					
EUROPEAN					
	IV1	0.0146	1.11	0.0041	0.31
	IV2	0.0029	0.23	-0.0112	-0.89
	IV3	0.0358**	2.73	0.0091	0.68
AMERICAN					
	IV1	0.0109	0.83	0.0040	0.30
	IV2	0.0025	0.20	-0.0172	-1.37
	IV3	0.0348**	2.65	0.0062	0.47

Note: One star indicates statistical significance at the .05 level. Two stars indicate statistical significance at the .01 level.

[a]IV1 = averaged put or call implied volatility estimate.
IV2 = at-the-money put or call implied volatility estimate.
IV3 = strike price matched put or call implied volatility estimate.