NCCC-134

APPLIED COMMODITY PRICE ANALYSIS, FORECASTING AND MARKET RISK MANAGEMENT

Option Price Behavior in Grain Futures Markets

by

William W. Wilson

Option Price Behavior in Grain Futures Markets

William W. Wilson[*]

I. Introduction

Since the inception of the recent trading of options on selected agricultural futures contracts, many new opportunities have become available for participants of those markets. Traders are capable of locking-in price floors or ceilings in futures through the use of options as opposed to locking-in futures price levels as in traditional hedges. Hedgers, of course, are still exposed to basis risk due to their underlying cash position. Speculators and hedgers have numerous opportunities ranging from holding long- or short-option positions to a multitude of spreading strategies. Central to decision making for option market participants is the value of underlying premiums. The dominant model used for option valuation has been that developed by Black. Through use of this model, traders can identify fair market values for option premiums. The primary purpose of this paper is to analyze the behavior of option premiums on selected grain and oilseed futures relative to those derived from the Black model. Discrepencies between actual premiums and Black premiums are expected to exist because American options are compared against those of European options on the basis of the Black model. Of primary importance is that premiums for American options should reflect the priviledge for early exercise versus the European options. Actual premiums are compared to Black premiums in this study for wheat at the Mid-America Commodity Exchange, Kansas City Board of Trade, and Minneapolis Grain Exchange and for soybeans and corn at the Chicago Board of Trade. Comparisons are first made to analyze the extent actual premiums deviate from Black premiums in two respects: time to maturity and the extent the option is in- or out-of-the-money. A regression model is then specified to test hypotheses about factors influencing differences between actual and Black premiums. In addition, the statistical relationship between actual premiums and Black premiums is examined.

The development of the Black model is briefly reviewed in the first section below along with other studies that have analyzed the behavior of actual option premiums. The logic underlying the potential for significant deviations is explained and a tentative model is specified for subsequent hypothesis testing. In the second section, data sources and variable formulations are described. The third section describes the behavior of selected variables and presents the empirical results, and the final section presents conclusions and implications.

II. Model Specification

In his seminal paper, Black (1976) derived a closed form valuation model for commodity options. That model was developed assuming the option is European (i.e., it can be exercised only at maturity), there are no taxes or

*Associate professor, Department of Agricultural Economics, North Dakota State University, Fargo.

transaction costs, the underlying asset is a forward contract, interest rates are constant, and rate of change in the futures price follows the Wiener diffusion process. Although other theoretical extensions of Black's model incorporating early exercise privilege and stochastic interest rates are available [Brenner, Courtadon, and Subrahmanyam (1985), and Ramaswamy and Sundaresan (1985)], they do not provide a closed-form solution for option pricing. Thus, their applicability is limited. Merton (1973) has demonstrated that the European option model is equally applicable to price American options so long as the European option is protected against any cash outflows from the underlying security. Given a valuation model such as the Black model, it is important to analyze the behavior of actual premiums vis-a-vis the theoretical or predicted premiums.

Important questions about the model assumptions, such as early exercise priviledge, may be raised if systematic discrepencies are detected between actual and Black premiums. The existence of significant discrepencies implies neither market inefficiency nor the model's inaccuracy. It simply verifies that Merton's theorem is correct in that "the right to exercise an option prior to the expiration date always has non-negative value" (Merton 1973 p. 144). However, this value for the right to exercise at any time during the option's life should be a function of such variables as time to maturity, market volatility, market liquidity, in-the-moneyness, etc. [Asay (1982), Shastri and Tandon (1986), Hausser and Neff (1985), and Whaley (1986)].

In this study, option pricing error (OPE) is defined as the market determined option premium (AP) less the premium predicted from Black's model (BP), i.e., OPE = AP - BP. First, the behavior of OPE is investigated for various commodities and contracts. Second, a regression model is developed to test the significance of factors influencing OPE. The motivation for investigating option pricing error in agricultural futures is based on inherent differences between American and European options, and on results from previous studies. Several previous studies in stock and commodity options [Gultekin, Rogalski, and Tinic (1982), Black and Scholes (1972), MacBeth and Merville (1979)] have demonstrated that option pricing error is systematically related to several important variables. Most notable is that option pricing error may vary depending on whether the option is in-the-money or out-of-the-money, with respect to volatility, and with respect to time to maturity.

Two additional variables which are somewhat unique to options on grain futures were included in this analysis. First, potential exists for OPE to vary across delivery months. Since this study includes analysis of OPE from the commencement of trading, possibility exists that the efficiency of the market would improve with maturity. In other words, in early trading the potential for significant OPE may be greater. Second, because some agricultural futures suffer from liquidity problems, it follows that the potential exists for illiquidity to be problematic also in the options market. Gray (1983) indicated that certain futures markets have entry and exit costs due to illiquidity. This results in hedging costs and price distortions in the futures market. Because the Black premium price is based on the implicit assumption of a highly liquid market, pricing error is expected to be small given a liquid market.

The potential variables influencing option pricing error and variable definition used in this study are as follows:

$$OPE_{ijt} = f(TTM_{ijt}, ITM_{ijt}, OTM_{ijt}, SD_{ijt}, ML_{ijt}, FM_i) + e_{it} \qquad (1)$$

where:

subscripts ijt represent contract month, strike price, and time, respectively.

Variable Definitions:

OPE = option price error defined as actual premium (AP) less predicted premium (BP)
TTM = time to maturity (number of days)
ITM = amount the option is in-the-money ($\mathcal{c}$)
OTM = amount the option is out-of-the-money ($\mathcal{c}$)
SD = standard deviation of the futures price ($\mathcal{c}$)
ML = market liquidity (ratio discussed below)
FM = futures market delivery month for option contract (one for the delivery month, zero for other months)
e_{ijt} = error term

Separate analyses were conducted for each of the futures markets and commodities.

III. Data Sources and Dimensions of Analysis

Pricing error was examined on options traded at five different futures exchanges. Contracts and futures exchanges included in the analysis were wheat at the Minneapolis Grain Exchange (MGE), Kansas City Board of Trade (KCBT), and the MidAmerica Commodity Exchange (MACE), soybeans at the Chicago Board of Trade (CBT), and corn at the Chicago Board of Trade (CBT). In order to capture both new and old crop behavior, the contract months examined were March, July, and December for wheat and corn options, and March, July, and November for soybean options. The time period of the analysis was from the inception of option trading, which was October 31, 1984, for wheat and soybean options, and February 27, 1985, for corn options, up to December 31, 1985. Only call options were examined since low trading volumes were inherent in the put options. For each daily futures price, three call option contracts were examined: one closest to at-the-money (ATM) and one directly above (OTM) and below (ITM). Deep in- or out-of-the-money options were traded only very sporadically and were not incorporated in the analysis. Also, options which had zero trading volume were deleted from the analysis.

Too few participants may distort the market determined price of options. To capture this potential effect, a variable was specified to represent market liquidity. Following Ward and Dasse (1977), market liquidity was defined as

$$ML = \frac{V}{|\Delta OI|} \quad \text{if } |\Delta OI| \geq 1$$

$$ML = V \qquad \text{if } |\Delta OI| = 0$$

where V and OI are volume and open interest, respectively. Volume should exceed changes in open interest sufficiently to prevent price distortions. The above formulation is appealing because it indicates how much volume of trading occurs relative to changes in contract commitments. For example, if ML equals three, there are three trades for every change in commitments. The range of ML is 1 < ML < V. As ML approaches one, there may be possible problems associated with illiquidity, and as ML increases, problems of illiquidity subside. In order to capture the potential inverse nonlinear impact of ML on OPE, its reciprocal (1/ML) was used in the empirical analysis.

IV. Empirical Results

The purpose of comparing Black premiums to actual premiums is to assess the value of early exercise potential, among other factors, embedded in American option premiums (actual premiums). If the early exercise potential inherent in the actual premium has any non-negative value, OPE should be related to time to maturity, and other variables. Simple descriptive results of OPE and selected variables are presented first, followed by the results of the regression analysis.

The behavior of actual and predicted option premiums for selected contracts, exercise prices, and time periods is shown in Figures 1 through 3. In general, the actual and Black premiums are highly correlated, but in some cases persistent deviations do exist. Descriptive statistics of OPE for each contract are shown in Table 1. The results indicate that OPE on average for CBT soybeans is not significantly different from zero. Those for the other exchanges all are significantly different from zero. CBT corn and MACE wheat each have OPE greater than zero indicating that actual premiums exceed Black premiums. Option premiums for KCBT and MGE wheat are smaller relative to Black premiums by .68¢/bushel and 1.96¢/bushel, respectively. Thus, the results regarding the non-negative value implied by the American option's early exercise potential in the case of agricultural options are inconclusive.

An empirical model was specified similar to Equation 1 to test hypotheses about effects of time to maturity, variance, and the extent the option is in- or out-of-the-money on option pricing error. In addition, a measure of market liquidity was added, and a separate dummy variable for each contract month was included. Casual observation of the agriculture option markets during the time period of this study suggests that inadequate liquidity may be a problem and may result in sizeable option pricing error. The average measure of market liquidity (ML) for each option market contract is shown below along with the equivalent measure for the underlying future contract:
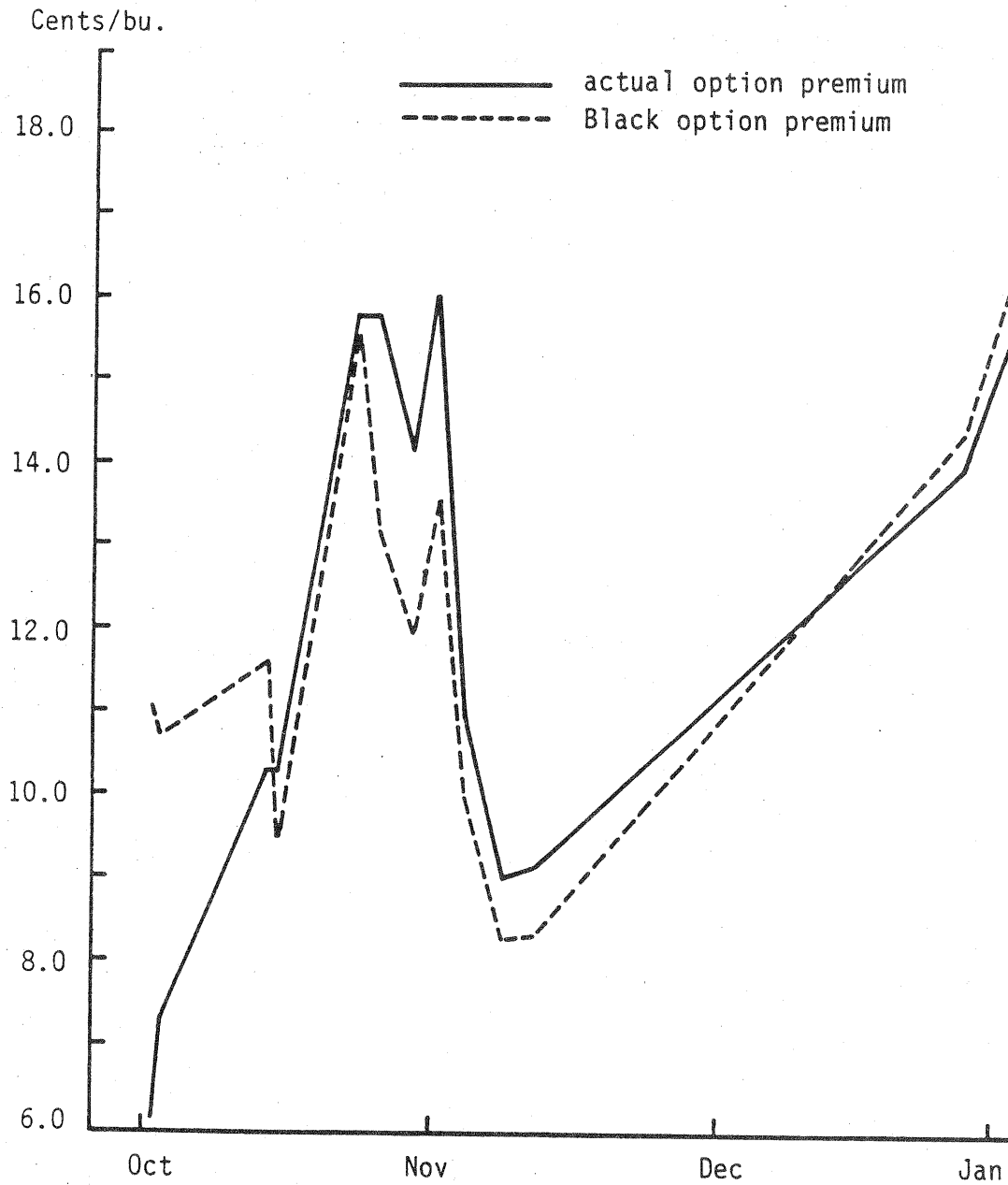
Figure 1. Actual and Predicted Option Premiums for MidAmerica
Commodity Exchange Wheat, March 1986 Futures Contract With A
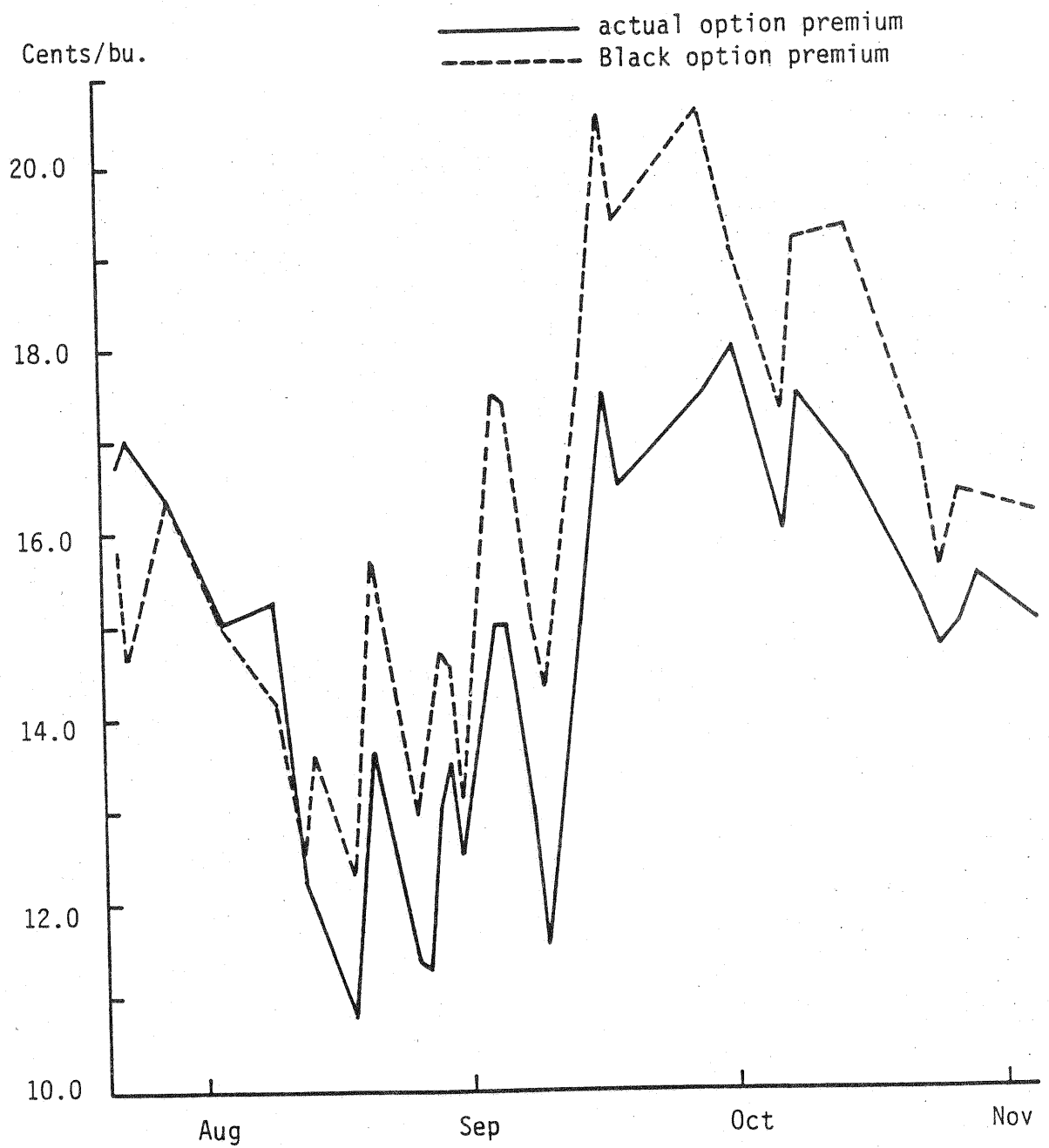Strike Price of $3.30, October 1984 to January 1985

Figure 2. Actual and Predicted Option Premiums for Chicago Board of Trade Corn, March 1986 Futures Contract With A Strike Price of $2.20, August to November 1985
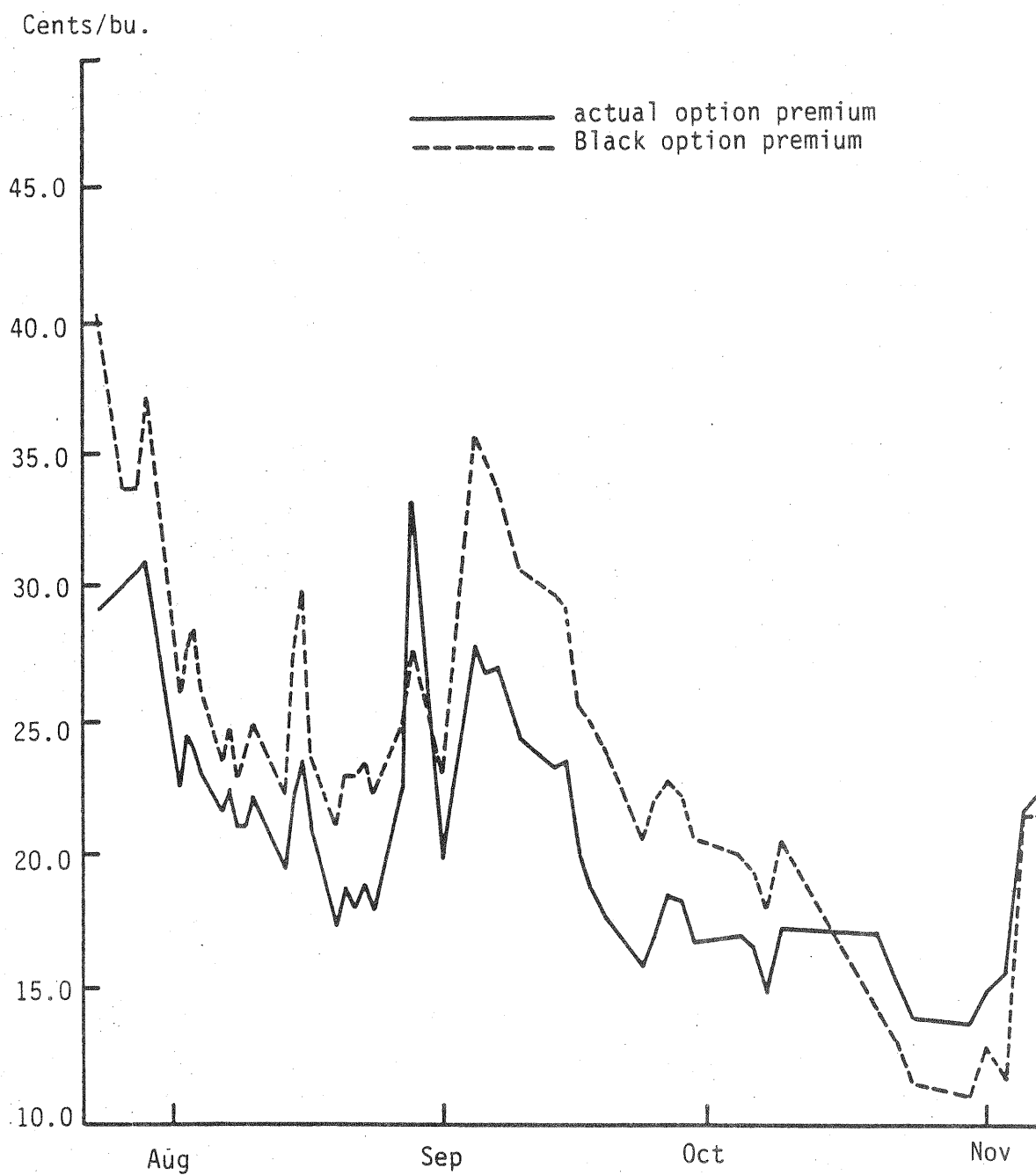
Cents/bu.

Figure 3. Actual and Predicted Option Premiums for Chicago Board of Trade Soybeans, March 1986 Futures Contract With A Strike Price of $5.25, August to November 1985

TABLE 1. SUMMARY STATISTICS FOR OPTION PRICING ERROR (OPE)[1]

Contract	n	Mean	Standard Deviation	t=0
		----------------¢/bushel----------------		
CBT Soybeans	1,346	-0.25	5.97	-1.50
CBT Corn	1,265	0.24	2.10	4.08*
KCBT Wheat	525	-0.68	3.29	-4.73*
MGE Wheat	378	-1.96	3.46	-10.98*
MACE Wheat	473	.26	2.65	2.14*

[1]n denotes number of observation; t, t-statistics.
*Significantly different from zero at the 5 percent level.

| | Market Liquidity | |
	Option	Futures
CBT Soybeans	5.3	76.1
CBT Corn	4.4	98.0
KCBT Wheat	2.4	38.8
MGE Wheat	2.1	21.3
MACE Wheat	2.3	10.2

Over the study period there were 5.3 soybean options contracts traded for every change in open interest. Each of the wheat option contracts had much less liquidity vis-a-vis soybeans and corn. However, there was substantially more liquidity in the underlying futures contract for each corresponding option market. In order to capture the effects of variability in market liquidity on OPE, the reciprocal of ML was included as a variable in the regression. Using the reciprocal allows for a nonlinear asymptotic relationship to exist between the two variables as ML approaches 1.0.

The results presented in this paper contain two modifications from Equation 1. First, the amount the option is in-the-money or out-of-the-money was included as two separate variables, and for ease of interpretation, each was measured as an absolute value. Second, after analyzing descriptive statistics of the data, a very important interaction effect, the product of price variability (SD) and time to maturity (TTM) was found to be statistically significant in the explanation of OPE behavior. To capture this an interaction term, SD*TTM, was included in the results presented here. In addition, for comparison, two models are presented, one with and one without inclusion of market liquidity (1/ML).

The regression models using the actual value of OPE (OPE = AP -BP) as the dependent variable are shown in Table 2. The coefficient values in this case should be interpreted as the movement of AP relative to BP in response to changes in the independent variable. Thus, the results are useful in direct interpretation of the impact of various factors on the discrepency between actual premiums (representing American options) and Black premiums (representing European options). A positive relation exists between |OTM| and OPE, while a negative relation exists between |ITM| and OPE. Signs are consistent across exchanges, but the coefficients were not significantly different from zero at two of the exchanges. These results indicate that as the amount that an option moves into-the-money increases, actual premiums decrease relative to Black premiums. Similarly, as the amount that an option moves out-of-the-money increases, actual premiums increase relative to Black premiums. This finding is consistent with previous studies using actual data [Gultekin et al. (1982), Black-Scholes (1972), and Black (1975)] but inconsistent with the studies using simulation procedures [Hausser and Neff (1985)] and [Shastri and Tandon (1986)]. The actual premium is expected, a priori, to be greater than Black premium due to early exercise potential for in-the-money option vis-a-vis out-of-the-money option [Merton (1973), Wolf (1982), Hausser and Neff (1986), and Shastri and Tandon (1986)]. However, findings in the study are contrary to expectation but are consistent with other empirical results discussed above.

OPE is positively related to TTM, but the responsiveness decreases for increases in SD. Thus, AP tends to increase relative to BP as time to

TABLE 2. REGRESSION MODELS ON ACTUAL OPTION PRICING ERROR, OPE = AP - BP

Contract	Int	|ITM|	|OTM|	TTM	SD	SD*TTM	1/ML	July 1985	Dec/Nov 1985¹	Mar 1986	July 1986	Adj. R²
CBT Soybeans	7.98*	-.026*	.030*	.08*	-45.35*	-.425*	--	-1.03*	-1.33*	-4.77*	-6.78*	.79
	(10.39)	(2.89)	(4.12)	(18.23)	(11.79)	(16.24)	--	(3.97)	(5.20)	(14.57)	(16.64)	
CBT Corn	1.55*	-.025*	.0003	.03*	-18.4*	-.14*	--	--	.89*	.04	-.62*	.77
	(8.19)	(3.31)	(.03)	(17.12)	(10.58)	(13.0)	(.72)	--	(5.67)	(.26)	(3.45)	
KCBT Wheat	-1.80*	-0.028	.062*	.029*	-20.83*	-.25*	--	.42	.33	.89*	2.91*	.82
	(4.20)	(1.47)	(3.78)	(9.31)	(6.03)	(11.1)	(.23)	(1.49)	(1.06)	(2.42)	(5.11)	
MGE Wheat	-.04	-.014	.036*	.039*	-3.54	-.48*	.54*	-.004	-.225	2.87*	--	.90
	(.07)	(.66)	(2.22)	(11.10)	(.68)	(14.03)	(7.92)	(.02)	(.64)	(7.40)	--	
MACE Wheat	2.25*	-.03*	.004	.049*	-20.36*	-.40*	--	-.23	1.93*	2.45*	--	.87
	(6.42)	(1.98)	(.01)	(17.18)	(8.50)	(18.05)	(.22)	(1.64)	(10.73)	(12.39)	--	

t-ratios in ( ).

*Indicates significance at 5 percent level, and ** indicates significance at 10 percent level.

¹November 1985 for CBT soybeans and December 1985 for all other contracts.

expiration increases, but the response decreases with increases in SD. The total effect of TTM on OPE depends on the volatility of the underlying futures (SD). At times in which futures prices are stable (volatile), AP tends to increase (decrease) relative to BP as time to expiration increases.[1] Thus, as expected, the value of an American option (AP) increases relative to European option (BP) as time to maturity increases. As time to maturity diminishes, the implicit value of early exercise diminishes. This result is consistent with previous studies [Hauser and Neff (1985), Shastri and Tandon (1986), Gultekin, et al. (1983)]. The effect of SD on OPE can be similarly derived and in all cases is negative. Increases in SD cause AP to decrease relative to BP. These results are similar to the studies of Black and Scholes (1972), Capozza and Asay (1978), and Gultekin et al (1982) who indicated that "actual prices on options written on relatively high return variances tended to be smaller than the values that are estimated by their formula" [Gultekin et al., (1982), p. 65], but inconsistent with simulated results of Hauser and Neff (1985).

Option market liquidity was included in each of the equations but was significant only in the case of MGE wheat. This result indicates an inverse relationship exists (due to the reciprocal) between market liquidity and OPE. During periods of high liquidity AP tends to decrease relative to the BP. On the other hand, during periods of less liquidity AP tends to rise relative to BP. Variability in option market liquidity at the other exchanges did not have a significant impact on OPE.

No a priori expectations were made regarding sign of variables associated with contract month. However, there were fairly drastic differences in coefficient values for different contract months. As an example, after controlling for other factors OPE was not significantly different from zero for MGE wheat, July and December 1985 contracts but AP increased by nearly 3¢/bu. relative to the BP for March 1986. The most extreme case is CBT soybeans for which the coefficient for July 1985 was -1.03¢ but decreased to -6.8¢ by July 1986.

V. Summary and Implications

Trading of options on agricultural futures began in October 1984. An integral tool of market participants for valuing option premiums is the Black model. Comparisons of market determined premiums to those estimated from the Black model is important in developing trading strategies. Differences may exist between actual and Black premiums for a number of reasons. Of particular importance is the inherent discrepencies due to the fact that actual premiums are American options and are expected to have an implied non-negative value associated with the early exercise priviledge, versus the

---

[1]Critical values can be found by solving the first derivative with respect to SD. These critical values for each of the contracts are as follows: CBT soybeans .19(.18), CBT corn .21(.14), KCBT wheat .12(.13), MGE wheat .08(.12), and MACE wheat .12(.14), where the figures in parenthesis are mean values for the sample used in this study, and are included for comparison.

Black premiums which are on European options. This study made various comparisons between actual and predicted premiums for selected grain and oilseed options contracts. In addition, the functional relationships between option pricing errors and various explanatory variables were estimated.

Several important conclusions are summarized as follows:

(1) Of the five grain option markets, only two show significant positive option pricing error (i.e., actual premiums greater than Black premiums). Thus, results regarding the non-negative value of the early exercise potential in the actual premium is inconclusive for options on grain futures contracts;

(2) As options move into-the-money, actual premiums decrease relative to Black premiums, and as options move out-of-the-money, actual premiums increase relative to Black premiums;

(3) The actual premium increases relative to the Black premium as time-to-maturity of the option lengthens. This result suggests implied value of the early exercise potential becomes larger for options with greater duration;

(4) As volatility of the futures market increases, actual premiums decrease relative to Black premiums;

(5) The impact of market liquidity on option pricing is analyzed, and only in the case of wheat at the Minneapolis Grain Exchange did it have a significant effect. The results indicated in this case that increases in market liquidity resulted in actual premiums decreasing relative to Black premiums. In all other cases, market liquidity did not have a significant impact on actual premiums versus Black premiums.

This paper contributes to the literature by empirically testing the relationship between actual market determined premiums and Black premiums in the case of agricultural options. In general the results of this study are consistent with the empirical findings of the existing stock options literature which compare actual to theoretical European premiums. Slight differences do exist, however, from the results which use simulation procedures to test for differences between actual and European option premiums.

References

Asay, M. 1982. "A Note on the Design of Commodity Option Contracts." Journal of Futures Markets, 2(1):1-7.

Belongia, M. T. and T. H. Gregory. 1986. "Are Options on Treasury Bond Futures Priced Efficiently?" Federal Reserve Bank of St. Louis, January, pp. 5-13.

Black, F. 1975. "Fact and Fantasy in the Use of Options." Financial Analyst Journal, July-August, pp. 36-72.

Black, F. 1976. "The Pricing of Commodity Contracts." Journal of Financial Economics, 3:167-179.

Black, F. and M. Scholes. 1972. "The Valuation of Option Contracts as Test of Market Efficiency." Journal of Finance, 27:399-417.

Brenner, M., G. Courtadon, and M. Subrahmanyam. 1985. "Options on the Spot and Options on Futures." Journal of Finance, 5:1303-1317.

Capozza, D. R. and M. Asay. 1978. "Option Prices and Diffusion Processes: Some Empirical Tests." Financial Review, Spring, 1-21.

Figleswki, S. and M. D. Fitzgerald. 1982. "The Price Behavior of London Commodity Options." Review of Research in Futures Markets, Chicago Board of Trade, Chicago, 1(1):90-105.

Galai, D. 1977. "Tests of Market Efficiency of the Chicago Board Options Exchange." Journal of Business, 167-193.

Gray, R. W. 1983. "The Characteristic Bias in Some Thin Futures Markets," Selected Writings on Futures Markets: Basic Research in Commodity Markets. Chicago Board of Trade, Chicago, 2:113-130.

Gultekin, N. B., R. J. Rogalski, and S. M. Tinic. 1982. "Option Pricing Model Estimates: Some Empirical Results." Financial Management, 1:58-69.

Hauser, R. J. and D. Neff. 1985. "Pricing Options on Agricultural Futures: Departures from Traditional Theory." Journal of Futures Markets, 5(4):539-577.

Hoag, J. N. 1978. "An Introduction to Valuation of Commodity Options," Center for the Study of Futures Markets. Columbia Business School.

MacBeth, J. P. and L. J. Merville. 1979. "An Empirical Examination of the Black-Scholes Call Option Pricing Model." Journal of Finance, 34:1173-1186.

Mayer, T. 1986. Commodity Options: A User's Guide to Speculating and Hedging, New York Institute of Finance, New York.

Merton, R. 1973. "The Theory of Rational Option Pricing." Bell Journal of Economics and Management, 141-186.

Phillips, S. M. and C. W. Smith. 1980. "Trading Costs for Listed Options." Journal of Financial Economics, 179-201.

Ramaswamy, K. and S. M. Sundaresan. "The Valuation of Option on Futures Contracts." Journal of Finance, 40(5) 1985. pp. 1319-1340.

Shastri, K. and Tandon, K. 1986. "Options on Futures Contracts: A Comparison of European and American Pricing Models." Journal of Futures Markets, 6(4):593-618.

Trippi, R. R. 1977. "A Test of Option Market Efficiency Using a Random-Walk Valuation Model," Journal of Economics and Business, Winter, pp. 93-98.

Ward, W. and F. Dasse. 1977. "Principal Contribution to Basis Theory: The Case of Citrus and Fruits." American Journal of Agricultural Economics, 59:71-80.

Whaley, R. 1986. "Valuation of American Futures Options: Theory and Empirical Tests." Journal of Finance, March, pp. 127-150.

Wolf, A. 1982. "Fundamentals of Commodity Options on Futures." Journal of Futures Market, 2(4):391-408.