Alternative Estimates of Weighted Implied Volatilities from Soybean and Live Cattle Options

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The volatility implied by options on future contracts is defined as that standard deviation which equates the theoretical Black (1978) option pricing formula to the observed option price. The measure is valuable as an *ex ante* predictor of futures price variance, and a substantial body of literature has found that this implied volatility (IV) is a more efficient predictor of option prices than historical volatility measures (Park and Sears (1985); Jordan (1987); Latane and Rendleman (1976); Chiras and Manaster (1978); Beckers (1981); and Hauser and Neff (1985)). Implied volatilities are of particular value to hedgers and commodity analysts in providing anticipatory futures price changes, but are also of value to researchers studying market efficiency (e.g., Trippi (1977); Schmalansee and Trippi (1978); Beckers (1981); Park and Sears (1985); Hauser and Neff (1985); Chiras and Manaster (1978); Latane and Rendleman (1976); Whaley (1982); and Day and Lewis (1988)).

The use of implied volatilities is, however, hampered by the fact that there are many options written on a single futures contract (referred to as a class) and sometimes substantial differences in their implied volatilities. For an analyst or hedger a single measure of the implied volatility for purposes of prediction and evaluation is ideal. Four approaches to finding this measure are evaluated in this article. The first uses a simple average of the implied volatilities (Trippi (1977) and Schmalansee and Trippi (1978)), the second uses the IV of the option nearest to, or at the money (Beckers (1981)), the third weights the implied volatilities by the partial derivative of the option price with respect to the standard deviation (Latane and Rendleman (1976)) and the fourth weights the implied volatilities by the elasticity of the option price with respect to its standard deviation (Chiras and Manaster (1978))[1].

The purpose of this article is to determine which of the above methods, when used in the Black (1978) formula, most closely approximates observed put option premia on soybeans and live cattle futures. The article differentiates itself from previous research in that no study has compared the predicted and actual option premiums using all four methods on the same data set.

This research was partially funded by a grant from Agriculture Canada and the Ontario Ministry of Agriculture and Food. The author would like to thank two anonymous reviewers for their very helpful and constructive comments.

[1]These methods can be considered 'explicit' approaches to volatility measurement. Whaley (1982) introduces an 'implicit' econometric method to obtain the implied volatilities. (see also Parks and Sears (1985), and Day and Lewis (1988)).

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The Journal of Futures Markets, Vol. 10, No. 4, 353–366 (1990)

CCC 0270-7314/90/040353-14$04.00

METHOD

The study first calculates the volatilities implied by put options prices on soybeans and live cattle futures. Soybean and live cattle options are used for two reasons. First, the underlying futures contracts are actively traded in high volume and second, soybeans and live cattle are representative of storable and nonstorable commodities. For each option class a single valued implied volatility is determined according to the four methods outlined in the introduction. These single valued volatilities are referred to, generically, as weighted implied volatilities (WIV). The WIV's are then substituted into the Black (1978) option pricing formula to estimate the option price (P). The methods employed are discussed in this section.

Put option prices, (P), on futures contracts are, according to Black's (1978) model (for a European put), a function of the current futures price (F), the strike price (S), the riskless interest rate (r), time to expiration (T), and the instantaneous standard deviation of the percentage changes in futures prices (v) and is notated as

$$P = (F, S, r, T, v)\,. \tag{1}$$

Specifics of the European option formula are discussed by Black (1978), Merton (1973), Asay (1982), Wolf (1984) and others. (Barone-Adesi and Whaley (1987) provide a solution procedure for American options but find little difference in their premiums to European option formulas.) For any given option, F, S, r, and T are directly observable. However, v is not observed and has to be empirically estimated. Estimates can be obtained by taking the variance of the log change in futures prices but past research finds that these estimates do not perform well with the Black (1978) or Black and Scholes (1973) model. Accordingly researchers and commodity analysts calculate v directly from the option formula using an iterative numerical procedure. In this study implied volatilities are calculated using the Newton-Raphson method (Manaster and Koehler (1982)) and a polynomial approximation to the cumulative normal density function. IV's are generated for each option written on each futures contracts from January 1987 through December 1988.

To develop single-valued WIV's for options in each class four methods are employed. The first applies equal weight to all of K options in each class. This is termed the average implied volatility (AVEIV) (Trippi (1977) and Schmalansee and Trippi (1978)),

$$\text{AVEIV} = \sum_{i=1}^{K} V_i / K \tag{2}$$

The second method uses the IV of the option nearest to, or at, the money (ATIV) (Beckers (1981)). This method assumes that most trading takes place with at-the-money options and therefore places zero weight on options which are in or out of money.

The third method, (DERIV), uses a weighting scheme based on the derivative of the option pricing formula (eq. 1) with respect to its standard deviation, P_v, (Latane and Rendleman (1976)),

$$\text{DERIV} = \left(\sum_{i=1}^{K} V_i^2 P_{vi}^2\right)^{1/2} \Bigg/ \left(\sum_{i=1}^{K} P_{vi}^2\right)^{1/2}. \tag{3}$$

Latane and Rendleman (1976) argue that this method puts less weight on options within each class which are less sensitive to a precise specification of the market's underlying expectation of the standard deviation. Thus, use of this weighting scheme tends to place proportionally more weight on options at-the-money than options in or out of the money.

The fourth method, (ELIV), uses a weighting scheme based on the elasticity of the option pricing formula with respect to its standard deviation, (W) (Chiras and Manaster (1978)),

$$\mathrm{ELIV} = \sum_{i=1}^{K} W_i V_i / \sum_{i=1}^{K} W_i , \tag{4}$$

where W_i equals $P_{vi}(V_i/P_i)$. Chiras and Manaster (1978) argue that rational investors are more concerned with the relative percentage change in the option price relative to its standard deviation, rather than the absolute change implied by Latane and Rendleman's (1976) method.

These four methods are not without criticism. Whaley (1982) levels the general criticism that the implied volatilities are accurate only in-so-far as the option model is correctly specified and these explicit measures fail to reflect the early exercise feature of American options and, for stock options, the dividend yields. The AVEIV is criticized because it puts equal weight on all options in a class without considering the relative importance of options which are in and out of the money. The use of ATIV can be criticized because the information content of options in or out of the money are lost. Day and Lewis (1988) criticize the DERIV and ELIV approaches because the former places more weight on IV's at-the-money while the latter places more weight on options out of the money.

Despite these criticisms examining the *ex ante* performance of the WIV's is important. Clearly each method biases in one way or another the option price. This study determines which method provides the minimum *ex ante* prediction error.

Soybean and live cattle data are compiled from the options and futures tapes of the Chicago Mercantile Exchange from January 9, 1987 through December 30, 1988. Interest rates are calculated as the annualized returns reflected in the nearby U.S. 90 day T-Bill futures. The IV's for each option are estimated to within a \$.0001 tolerance level of the actual put option price. WIV's are calculated for each class of options according to the four methods described above. These volatility measures are used to estimate same day premiums, and predict 1, 7, 21, and 60 day ahead premiums. The estimated forecast premiums are *ex ante* with respect to the volatilities only. The interest rates, futures prices and strike prices are all *ex post* measures.

To determine which of the four WIV's is the best *ex ante* predictor several measures are reported in this study including the mean prediction error (actual-predicted), the percentage error, and the standard deviation of the prediction error. These measures are reported for the total time period used, as well as control checks using the periods before and after the 1988 drought (May 2, 1988).

It is anticipated that the prediction error is strongly related to the difference in the WIV relative to the actual IV, and from the literature cited, whether or not the option is in or out of the money. Thus the errors associated with AVEIV and ELIV are expected to be more closely related to each other than ATIV and DERIV.

To examine the *ex ante* predictive power of the various WIV's the following regression, with the intercept suppressed is run;

$$(P_i - \hat{P}_i) = B_1(\mathrm{IV}_i - \mathrm{WIV}) + B_2\mathrm{DIN} + B_3\mathrm{DOUT} + e_i , \tag{5}$$

where P_i is the actual premium, $\hat{P}_i$ is the premium estimated using the WIV's, DIN is a dummy variable with a value 1 if the option is in the money and 0 otherwise, DOUT is a dummy variable with value 1 if the option is out of the money and zero otherwise, and e is the residual error term. The purpose of (5) is two fold. First B_1 measures how much of the error in the estimate is due to the weighting method used and second, B_2 and B_3 measure the degree by which the option is in, or out of, the money contribute to the prediction errors.

RESULTS

Summary Statistics

Table I summarizes the means and standard deviations (for the same day forecast) of the WIV's over the entire period of analysis and the pre and post drought periods.[2] General results over the total period for live cattle indicate the WIV averages are very similar. The smallest WIV is attributed to ATIV with a value of .1441 on average. However, the least variable WIV is AVEIV with a mean of .1540 and a standard deviation of .0235. The lowest WIV for soybeans is ATIV with an average WIV of .1634. ATIV also exhibits the lowest standard deviation which is .0312.

There are substantial differences between soybeans and live cattle WIV's. Soybean volatility is consistently higher than live cattle volatility and the standard deviations are also higher. This relationship also holds for the pre and post drought control periods, with the sole exception being that the standard deviation of DERIV for the drought period is lower than the corresponding live cattle standard deviation.

The results in Table I provide information as to the relative WIV measures. Consistently ELIV gives the highest value, followed by AVEIV, DERIV, and ATIV. It should be noted that the mean WIV for AVEIV is also the average (unweighted) mean volatility

[2]Pre and Post drought periods are selected as a convenient way to check for the robustness of the results over two easily identifiable subperiods. the results are not intended to reflect an analysis of options or volatilities under drought conditions, although such an investigation would be fruitful.

Table I
WEIGHTED IMPLIED VOLATILITIES FOR SOYBEANS AND LIVE CATTLE[a]

	Observations	AVEIV	ATIV	DERIV	ELIV
		Total Period			
Soybeans	17488	.1800	.1634	.1670	.1857
		(.0398)	(.0312)	(.0343)	(.0428)
Live Cattle	20199	.1540	.1448	.1480	.1578
		(.0235)	(.0244)	(.0272)	(.0254)
		Predrought[b]			
Soybeans	10337	.1845	.1732	.1761	.1888
		(.0397)	(.0304)	(.0365)	(.0417)
Live Cattle	13828	.1546	.1482	.1501	.1571
		(.0240)	(.0242)	(.0243)	(.0255)
		Post Drought[b]			
Soybeans	7151	.1735	.1492	.1539	.1814
		(.0391)	(.0267)	(.0255)	(.0440)
Live Cattle	6371	.1528	.1375	.1434	.1596
		(.0223)	(.0233)	(.0323)	(.0248)

[a]Standard deviations in parenthesis.

[b]The pre drought period covers the period from January 9, 1987 to May 2, 1988, whereas the post drought period covers the period from May 3, 1988 to December 30, 1988.

measure (IV) of the total sample. Thus, ELIV as a weighted volatility measure is consistently greater than the average IV, whereas ATIV and DERIV are less.[3]

The weighted implied volatilities, averaged by contract month, over the sample period are presented in Table II. The results indicate that the same relationship between the WIV's hold. Namely, that for both soybeans and live cattle, AVEIV and ELIV consistently provide higher volatility estimates than ATIV and DERIV. For example, the

[3]A useful extension of this analysis would be to characterize the distribution of implied volatilities based upon the degree of moneyness. That is, are implied volatilities significantly different between options which are in, or out of the money? This could explain part of the differences in the WIV's presented in Table I.

Table II
MEAN WEIGHTED IMPLIED VOLATILITIES FOR SOYBEANS AND LIVE CATTLE, BY CONTRACT MONTH[a]

Month	Number of Observations	AVEIV	ATIV	DERIV	ELIV
		Soybeans			
Jan	2,408	.1780	.1646	.1675	.1843
		(.0357)	(.0349)	(.0344)	(.0386)
Mar	2,580	.1829	.1737	.1769	.1865
		(.0309)	(.0289)	(.0290)	(.0320)
Apr	2,142	.1972	.1788	.1822	.2030
		(.0452)	(.0304)	(.0287)	(.0544)
May	1,837	.1770	.1674	.1706	.1822
		(.0256)	(.0252)	(.0290)	(.0262)
Aug	2,546	.1815	.1617	.1650	.1881
		(.0469)	(.0237)	(.0259)	(.0523)
Sep	2,024	.1757	.1582	.1614	.1814
		(.0320)	(.0227)	(.0223)	(.0366)
Oct	2,040	.1778	.1529	.1587	.1841
		(.0569)	(.0328)	(.0533)	(.0536)
Nov	1,911	.1676	.1458	.1503	.1740
		(.0269)	(.0350)	(.0338)	(.0289)
		Live Cattle[b]			
Feb	3,663	.1539	.1454	.1482	.1565
		(.0258)	(.0276)	(.0277)	(.0244)
Apr	3,737	.1572	.1497	.1521	.1604
		(.0250)	(.0265)	(.0260)	(.0257)
June	3,558	.1567	.1480	.1507	.1613
		(.0235)	(.0232)	(.0229)	(.0259)
Aug	3,633	.1544	.1426	.1455	.1588
		(.0165)	(.0211)	(.0194)	(.0231)
Oct	2,766	.1504	.1416	.1478	.1543
		(.0242)	(.0214)	(.0417)	(.0255)
Dec	2,825	.1499	.1397	.1425	.1543
		(.0242)	(.0236)	(.0234)	(.0262)

[a]Standard deviations in parenthesis.
[b]17 observations on September live cattle are not reported.

WIV's for January soybeans futures are .178, .165, .168, and .184 for AVEIV, ATIV, DERIV, and ELIV, respectively. Likewise the values for February live cattle are .154, .145, .148, and .157. These results are consistent with model expectations since average volatilities and elasticity weighted volatilities apply more weight to options in and out of the money than near-the-money or derivative weighted volatility measures. This fact has important implications for the *ex ante* prediction power of the volatilities. Is the market information implied by option premiums reflected mostly by options nearest, or at the money, or is additional information provided by options in and out-of-the-money? In the following sections the WIV's are used as *ex ante* variance measures in predicting option premiums. The WIV which minimizes the mean prediction error could, therefore, be considered as that which best reflects the markets' perception of future price movements.

Tables III through VI summarize the differences between actual put premiums and the *ex ante* estimates using the WIV's. Negative elements in these tables indicate that the actual put premium is overestimated. For both soybeans and live cattle the mean prediction errors are small for all of the forecasts considered (Table III). However, they are not statistically different from zero. As the forecast period increases, so does the variance. This result is expected. For example, the mean error for the soybean same-day prediction using AVEIV is −4.86 cents with a standaard deviation of .1475 cents. The % error is only 3.17. For the 60 day forecast the mean prediction error is −3.15 cents (3.39%) but the standard deviation is more than doubled to .3076 cents.

The results in Tables II through VI indicate a general (but not wholly consistent) result that AVEIV and ELIV measures have a tendency to overestimate the actual premiums (the prediction errors are negative) whereas ATIV and DERIV tend to underestimate the premiums. This generality holds for both the pre drought and drought periods (Tables IV and V) and across contract months (Table VI).

There are also differences in the mean prediction errors of the pre drought and drought periods. The tendency in Tables IV and V is for the mean prediction error, % error, and standard deviation to be larger in the drought period. For example, the % errors in the predrought period for the 60 day forecasts are 3.90%, 4.76%, 3.98%, and 4.34% for AVIV, ATIV, DERIV, and ELIV, respectively. The corresponding values for the post-drought period are, in contrast, 10.1%, 6.84%, 8.49%, and 11.44%. This result is expected, but a direct relationship between these differences and the WIV's cannot be deemed conclusive.

The prediction errors associated with the 7 day forecast are presented in Table VI. with the sole exceptions of the May soybean and October live cattle contracts the prediction errors associated with the DERIV are smallest. Indeed, other than these exceptions the % errors are less than 1%. This contrasts with ranges of 1.26–5.34%, .24–3.01%, and 2.36–8.56% for soybean AVIV, ATIV, and ELIV % errors, respectively. Similarly, the ranges for live cattle are respectively 2.01–3.33%, .68–2.04%, and 3.44–5.91%.

The results in Tables III through VI provide an indication as to which volatility measure is best. In terms of the % prediction error, the derivative weighted implied volatility appears to be best since in most cases the mean prediction error is less than 1%. Strengthening this conclusion is the fact that the % prediction error is mostly below 1% for both the pre drought and post drought period and across most contract months. In contrast, the remaining WIV measures show relatively higher % errors.

The results imply that the DERIV measure best captures the underlying behaviorial characteristics of the put options. These results are in contrast to Becker's (1981) conclusions that ATIV out performs DERIV (for stock options). However, it is also evident that using the ATIV is quite accurate. The explicit characteristic considered is that the option premia is positively related with its volatility. Thus, an anticipated increase in the

Table III

MEAN PREDICTION ERROR BY WEIGHTED IMPLIED VOLATILITY FOR SOYBEAN AND LIVE CATTLE OPTIONS[a]

Time Period	Number of Observations	AVEIV Mean	AVEIV %	ATWIV Mean	ATWIV %	DERIV Mean	DERIV %	ELIV Mean	ELIV %
				Soybeans (cents/bu.)					
0	17488	−.0486	3.17	0.284	1.85	.0059	.39	−.0824	5.37
		(.1475)		(.0827)		(.1123)		(.1845)	
1	17164	−.0483	3.16	.0270	1.77	.0047	.31	−.0814	5.33
		(.1722)		(.1252)		(.1521)		(.2003)	
7	16010	−.0428	2.91	.0212	1.44	.0005	.03	−.0731	4.84
		(.2363)		(.2148)		(.2301)		(.2527)	
21	13430	−.0321	2.37	.0119	.88	−.0062	.46	−.0511	3.78
		(.2982)		(.2891)		(.2993)		(.3043)	
60	7301	−.0315	3.39	−.0132	1.42	−.0246	2.65	−.0377	4.07
		(.3076)		(.3039)		(.3130)		(.3084)	
				Live Cattle (cents/lb.)					
0	20199	−.0410	2.30	.0324	1.81	.0049	.274	−.0765	4.28
		(.1107)		(.0562)		(.1272)		(.1574)	
1	20030	−.0418	2.34	.0310	1.74	.0039	.22	−.0771	4.32
		(.1331)		(.0893)		(.1461)		(.1717)	
7	19004	−.0446	2.60	.0240	1.39	−.0015	.09	−.0791	4.61
		(.2035)		(.1745)		(.2080)		(.2287)	
21	16654	−.0389	2.47	.0198	1.26	−.0024	.15	−.0691	4.39
		(.2724)		(.2515)		(.2698)		(.2888)	
60	10645	.0171	1.52	.0460	4.10	.0335	2.99	.0034	.30
		(.3417)		(.3322)		(.3357)		(.3467)	

[a]Standard deviation of prediction error in parenthesis.

Table IV
MEAN PREDICTION ERROR, PRE AND POST DROUGHT, SOYBEANS (CENTS/BU).[a]

Days Forecast	Number of Observations	AVDIF Mean	AVDIF %	ATDIF Mean	ATDIF %	DERDIF Mean	DERDIF %	ELDIF Mean	ELDIF %
				Pre Drought					
0	10337	−.0325 (.1223)	1.99	.0162 (.0809)	.99	.0014 (.1302)	.86	−.0552 (.1456)	3.38
1	10111	−.0326 (.1558)	2.01	.0147 (.1282)	.90	.0000 (.1729)	.00	−.0546 (.1686)	3.36
7	9302	−.0280 (.2282)	1.79	.0112 (.2201)	.71	−.0222 (.2456)	1.42	−.0458 (.2324)	2.92
21	7505	−.0169 (.2802)	1.17	.0073 (.2774)	.503	−.0037 (.2962)	.37	−.0267 (.2820)	1.84
60	3415	.0389 (.2788)	3.90	.0441 (.2803)	4.76	.0369 (.3002)	3.98	.0402 (.2739)	4.34
				Drought					
0	7151	−.0719 (.1751)	5.16	.0462 (.0821)	3.32	.0123 (.0791)	.88	−.1218 (.1218)	8.75
1	7053	−.0707 (.1909)	5.10	.0448 (.1185)	3.23	.0115 (.1156)	.83	−.1199 (.2332)	8.64
7	6708	−.0633 (.2456)	4.72	.0351 (.2063)	2.62	.0042 (.2065)	.31	−.1066 (.2746)	8.12
21	5925	−.0514 (.3185)	4.19	.0177 (.3031)	1.44	−.0095 (.3032)	.75	.0820 (.3279)	6.44
60	3886	−.0935 (.3182)	10.1	−.0635 (.3149)	6.84	−.0787 (.3141)	8.49	−.1061 (.3206)	11.44

[a]Standard deviation of prediction error in parenthesis.

Table V
MEAN PREDICTION ERROR, PRE AND POST DROUGHT, LIVE CATTLE (CENTS/LBS)[a]

Days Forecast	Number of Observations	AVDIF Mean	AVDIF %	ATDIF Mean	ATDIF %	DERDIF Mean	DERDIF %	ELDIF Mean	ELDIF %
				Pre Drought					
0	13828	−.0268 (.0797)	1.44	−.0219 (.0485)	1.17	−.0053 (.0469)	.28	−.0479 (.1192)	2.57
1	13697	−.0274 (.1137)	1.48	.0209 (.0908)	1.13	.0044 (.0926)	.237	−.0482 (.1409)	2.58
7	12911	−.0278 (.1910)	1.56	.0167 (.1745)	.93	.0012 (.1787)	.07	−.0474 (.2058)	2.65
21	11117	−.0153 (.2497)	.94	.0196 (.2374)	1.21	.0066 (.2424)	.40	−.0303 (.2561)	1.85
60	6816	.0611 (.3361)	5.23	.0746 (.3361)	6.38	.0681 (.3385)	5.83	.0565 (.3326)	4.83
				Drought					
0	6371	−.0718 (.1538)	4.45	.0551 (.0646)	3.42	.004 (.2157)	.25	−.1385 (.2051)	8.59
1	6331	−.0729 (.1632)	4.54	.0529 (.0818)	3.29	.0026 (.2212)	.16	−.1397 (.2112)	8.69
7	6093	−.0801 (.3077)	5.10	.0396 (.2778)	2.52	−.0072 (.3169)	.46	−.1463 (.3319)	9.32
21	5537	−.0861 (.3077)	5.83	.0202 (.2778)	1.37	−.0203 (.3169)	1.37	−.1470 (.3320)	9.95
60	3829	−.0611 (.3377)	4.45	−.0049 (.3189)	.47	−.0280 (.3215)	2.70	−.0910 (.3512)	8.77

[a]Standard deviation of prediction error in parenthesis.

Table VI
SEVEN DAY MEAN AND PERCENT PREDICTION ERRORS; SOYBEANS AND LIVE CATTLE BY CONTRACT MONTH[a]

Month	Number of Observations	AVDIF		ATDIF		DERDIF		ELDIF	
		Mean	%	Mean	%	Mean	%	Mean	%
				Soybeans (cents/bu.)					
Jan	2253	−.0389	2.41	.0331	2.41	.0126	.92	−.0757	5.50
		(.2663)		(.2459)		(.2428)		(.2919)	
Mar	2362	−.0245	1.26	.0300	1.59	.0052	.27	−.0476	2.44
		(.2687)		(.2692)		(.2613)		(.2765)	
Apr	1930	−.0221	1.32	.0268	1.59	.0105	.63	−.0397	2.36
		(.2563)		(.2463)		(.2397)		(.2699)	
May	1647	−.0601	5.04	.0029	.24	−.0332	2.78	−.0827	6.93
		(.1968)		(.1261)		(.3157)		(.1775)	
Aug	2353	−.0479	3.10	.0078	.50	.0064	.41	−.0777	5.03
		(.1768)		(.1547)		(.1504)		(.2013)	
Sep	1836	−.0488	3.49	.0152	1.09	−.0019	.14	−.0784	5.60
		(.2135)		(.1952)		(.1909)		(.2299)	

Oct	1851	−.0491	3.64	.0174	1.29	.0017	.13	−.0810	6.01
		(.2183)		(.1911)		(.1835)		(.2503)	
Nov	1778	−.0592	5.34	.0334	3.01	−.0092	.83	−.0950	8.56
		(.2653)		(.2277)		(.2292)		(.2855)	
				Live Cattle (cents/lbs)[b]					
Feb	3453	−.0387	2.01	.0272	1.41	.0045	.23	−.0662	3.44
		(.2012)		(.1757)		(.1804)		(.2228)	
Apr	3487	−.0352	2.21	.0288	1.43	.0071	.45	−.0655	4.05
		(.2042)		(.1854)		(.1880)		(.2217)	
June	3341	−.0423	2.23	.0301	1.59	.0029	.15	−.0786	4.15
		(.2082)		(.1747)		(.1812)		(.2441)	
Aug	3423	−.0584	2.96	.0135	.68	−.0056	.28	−.1024	5.19
		(.1907)		(.1646)		(.1673)		(.2265)	
Oct	2605	−.0469	3.18	.0154	1.05	.0275	1.87	.0814	5.52
		(.1895)		(.1443)		(.3239)		(.1977)	
Dec	2685	−.0467	3.33	.0286	2.04	.0051	.36	−.0829	5.91
		(.2268)		(.1947)		(.1981)		(.2528)	

[a]Standard deviation of prediction error in parenthesis.
[b]10 observations on September live cattle are not reported.

volatility implies a marginal increase in the option price. Weighting the implied volatilities by this derivative appears to capture this effect. The practical implication of this result is that hedgers, researchers, and market analysts may fare well by using the derivative weighted implied volatility to estimate put premiums.[4]

Regression Results

The results reported above indicate significant differences in the four WIV measures. These differences may accentuate prediction errors. However, an alternative (and joint) hypothesis is that the prediction errors are related to whether or not the actual option observation is in or out of the money. Given that most criticisms of the various measures are related to this point, it is important that the resulting degree of prediction error be measured. Equation (5), in its estimated form, is intended to examine the degree by which the WIV's, and whether or not the actual option was in or out of the money, affects the prediction error.

The results of regression (5) are presented in this section for soybeans and live cattle. The regressions for live cattle are presented as eq. 6 with t statistics in parenthesis and soybean results are presented as eq. 7. The regressions are estimated using all observations of the same day forecasts.

$$\underset{(150.918)}{\text{AVDIF} = 5.1901\,(\text{IV-AVIV})} - \underset{(-51.95)}{.0526\ \text{DIN}} - \underset{(-57.95)}{.0358\ \text{DOUT}}, \qquad F = 10142 \tag{6(a)}$$

$$\underset{(73.33)}{\text{ATDIF} = 1.393\,(\text{IV-ATIV})} + \underset{(19.70)}{.0133\ \text{DIN}} + \underset{(48.49)}{.0221\ \text{DOUT}}, \qquad F = 4818 \tag{6(b)}$$

$$\underset{(136.30)}{\text{DERDIF} = 4.1800\,(\text{IV-DERIV}} - \underset{(17.35)}{.0213\ \text{DIN}} - \underset{(-24.38)}{.0193\ \text{DOUT}}, \qquad F = 6320 \tag{6(c)}$$

$$\underset{(197.34)}{\text{ELDIF} = 7.486\,(\text{IV-ELIV})} - \underset{(-53.99)}{.0673\ \text{DIN}} - \underset{(-51.98)}{.0394\ \text{DOUT}}, \qquad F = 18276 \tag{6(d)}$$

The dependent variables in (6) are the difference between the actual and estimated put option premiums for live cattle. The prefixes correspond to the type of WIV used. A positive coefficient implies that $d(P - \hat{P})$ is positive which implies that the predicted premium is decreasing relative to the actual premium. Similarly, a negative coefficient estimate implies that the predicted premium is increasing relative to the actual premium. The variable (IV-WIV) is the difference between the actual implied volatility and the weighted implied volatility. The estimated coefficient is positive for each of the WIV measures. This implies that an increase in the difference between IV and WIV decreases $\hat{P}$, the predicted value. The net effect is that an increase in (IV–WIV) increases the prediction error. This, in itself, is somewhat of a tautology; however, the important result is the relative values across the different methods. The AVIV and ELIV measures tend to have the greatest effect on the dependent variable with coefficients of 5.19 and 7.49 respectively. That is, for example, a 1 percent difference in the AVIV volatility measures increases the prediction error by 5.19 percent. The ATDIF and DERDIF prediction errors are less affected by the IV differential (1.39 and 4.18, respectively) thus implying that obtaining WIV's from these methods provides the least prediction error.

[4]Although solving a slightly different problem, Whaley (1982) states that his implicit method yields "more accurate estimates of subsequent realized volatility than the weighted average methods (p. 57)," (AVIV, DERIV, and ELIV). The results, however, are not reported.

The effect due to whether or not the option is in or out of the money are represented by the coefficients on DIN and DOUT. A negative sign on the dummy variables implies that the prediction error decreases. This implies that the predicted value is an overestimate of the actual value. Similarly a positive sign implies an underestimate. The results indicate that for AVIV, DERIV, and ELIV the premium is overestimated and for ATIV it is underestimated when the option is both in and out of the money. The relative magnitudes of the coefficients indicate that the prediction error due to moneyness is greatest for AVDIF and ELDIF and the least for ATDIF and DERDIF.

The regression results for soybeans are presented as eq. (7).

$$\underset{}{\text{AVDIF}} = \underset{(93.79)}{2.3457}\ (\text{IV-AVIV}) - \underset{(-39.73)}{.0792}\ \text{DIN} - \underset{(-40.56)}{.406}\ \text{DOUT}, \qquad F = 4288 \tag{7(b)}$$

$$\text{ATDIF} = \underset{(23.32)}{.2917}\ (\text{IV-ATIV}) + \underset{(1.99)}{.0027}\ \text{DIN} + \underset{(29.84)}{.0289}\ \text{DOUT}, \qquad F = 1050 \tag{7(b)}$$

$$\text{DERDIF} = \underset{(31.68)}{.5675}\ (\text{IV-DERIV}) - \underset{(-13.41)}{.0234}\ \text{DIN} + \underset{(4.55)}{.0044}\ \text{DOUT}, \qquad F = 474 \tag{7(c)}$$

$$\text{ELDIF} = \underset{(115.59)}{3.1626}\ (\text{IV-ELIV}) - \underset{(-45.17)}{.1049}\ \text{DIN} - \underset{(-46.55)}{.0538}\ \text{DOUT}, \qquad F = 7046 \tag{7(d)}$$

The results for soybeans are similar to live cattle results. Differences between IV and, AVIV and ELIV contribute most to the error in premium estimates while ATIV and DERIV contribute the least. AVIV and ELIV overestimate the premiums for options both in and out of the money. ATIV tends to underestimate the premiums when options are in and out of the money; whereas, DERIV tends to underestimate options out of the money and over estimates options in the money. The results imply that, the derivative, and nearest-the-money weighted volatilities are least sentive to the options which are in or out of the money.[5] The evidence supports the use of DERIV as the primary method for evaluating put options on soybean futures (although using ATIV also provides a fairly good estimate).

CONCLUSIONS

The volatility of futures price movements is an important measure for hedgers, market analysts, and researchers. It provides an *ex ante* estimate of the market's perception of the futures price variance. Past research shows that the implied volatility is a better *ex ante* predictor of variance than historical data when options are valued with the Black (1978), or Black-Scholes (1973), option pricing models. However, past studies also note that options written on a single futures contract often have different valued implied volatilities. In response to this problem, various methods to weight the implied volatilities into a single valued, weighted implied volatility are proposed in the literature. Four of these methods are evaluated in this article with the purpose of determining which method provides the best *ex ante* estimates of premiums on soybean and live cattle put options. The methods evaluated are: an average of the IV's; giving full weight to options nearest, or at, the money; weighting the IV's by the derivative of the put option price

[5]The robustness of the regression results are examined relative to the pre and post drought periods, as well as by contract month over the entire period. Because there are not substantive differences in the conclusions the results are not reported here. However, the integrity of the regression results presented, are proved to be very robust.

with respect to it's standard deviation; and weighting the IV's by the elasticity of the option price with respect to its standard deviation.

The results show that weighting the implied volatities by the derivative of the option provided *ex ante* predictions which are on average, better than the other measures. This conclusion is reached by examining sample means but is supported by regression results which show that prediction errors for options in and out-of-the-money are also relatively low. This conclusion provides a strong recommendation for volatility measurement by hedgers, analysts, and researchers who routinely predict option prices using Black's option pricing model on commodity futures.

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