Implied Volatilities of Options on Soybean Futures

by

Robert J. Hauser and David Neff

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Traditional option pricing models are a function of five factors: the current price of the underlying commodity, strike price, time to maturity, interest rate, and the variance of the underlying commodity's log-price return during the option's life. In theory, these factors provide the information needed to mathematically describe the portfolio adjustment process that can be used to form a risk-free investment, enabling valuation of the option under the assumption that each of the five factors is known. In practice, an obvious departure from the theoretical model is that the future price-return variance is not known and therefore speculative opportunities are created by variance uncertainty.

The focus of this paper is on the option market's forecast of the soybean futures price-return variance. Trading of options on soybean futures began at the Chicago Board of Trade on October 31, 1984 under a three-year pilot program. Given this market's option premia, estimates of the market's variance forecast can be derived from an option pricing model (OPM) since the four non-variance factors of the OPM are known.[1]

The volatility implied by a premium provides considerable information to both speculator and hedger as the implied volatilities (IV's) represent the best standardized measurement of an option value. For example, consider two options which differ in time to maturity but are equal in all other respects. The premium of the longer-maturity option is greater than the

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premium of the shorter-maturity option. Comparison of the IV's, however, provides perspective on the values of the two options under equal conditions since the effect of time to maturity on the premium level is taken out when estimating the IV. Likewise, options which vary by strike price, futures price, the time at which they were traded, etc. can be compared easily by using this standardized measurement under a particular OPM. These comparisons help identify "mispriced" options, the relative price of options across different periods, bias characteristics of the OPM, and other types of information that can be used in and out of an option-pricing context.

Evaluating Option Pricing Models

Most contemporary OPM's have evolved from the work by Black and Scholes (1973) and by Merton (1973). These models are based on the trader's ability to balance the option and underlying commodity positions in a manner which yields the risk-free rate of return. Black (1976) developed an equilibrium pricing model under the same balancing process for European options on futures. The basic difference between Black's OPM (BOPM) and the Black-Scholes model (BSOPM) emanates from the different cost rates involved in holding futures versus holding physicals (such as stocks).

An OPM's performance can be evaluated in either "accuracy" or "efficiency" terms. Pricing accuracy is defined here as the ability of the OPM to produce premia at those levels traded in the market, assuming input data are correct. The pricing efficiency of an OPM is judged by simulating the portfolio adjustment process according to the balancing ratio (delta) derived from the OPM. An "efficient" OPM (or, more appropriately, an OPM which is not inefficient) will enable the trader to buy (sell) undervalued (overvalued) options, readjust hedges against the option through time with the underlying commodity according to the OPM's delta, and earn at least the appropriate rate of return. (See Whaley (p. 35) for an excellent summary of the general procedure which has been used to determine this appropriate return and to test efficiency.) Efficiency studies associated with options have usually focused on whether the option market is efficient under the implicit or explicit assumption that the best pricing model is that being used. However, if rates of return are found to be below normal when using a particular OPM, then in our opinion it is unclear whether the market is inefficient or whether the OPM is inefficient in the sense that other OPM's might yield appropriate rates of return. Thus, the efficiency of the OPM is also being analyzed when conducting "market efficiency" tests.

Numerous studies on the accuracy and/or efficiency of the BSOPM for stock options have been conducted. With respect to pricing accuracy, the results have been somewhat conflicting; however, the "large" differences between the Black-Scholes estimates and market prices have usually involved options which are deep in or out of the money, or when variances are very high or low, or when times to expiration are extreme (e.g. Black (1975), MacBeth and Merville (1979) and Rubinstein).

The important sources of these biases are not revealed clearly by a review of the literature because, to a large extent, the bias explanations tend to focus on the subject of study, excluding many other potential sources. For example, Gilster and Lee suggest that the biases are created by transaction costs and the borrowing/lending spread; Geske attributes them to a non-stationary variance caused by stocks which represent an option on firm assets; Merton (1976) blames biases on a jump process; Black and Scholes (1972) suggest the variance is not estimated well; Bookstaber and McDonald contend that correct identification of ending distributions would correct biases; and on and on. These examples were chosen somewhat randomly from a much larger set of examples to illustrate that caution should be exercised when attributing premium biases to one factor.

There is no doubt that biases exist. However, it should be emphasized strongly that the Black-Scholes formula has performed extremely well overall. According to Jarrow and Rudd (1983, p. 142), "There are few models in finance or economics that have such high predictive power...[and that], on average, the pricing model is sufficiently accurate to be a useful valuation tool."

Option market efficiency has been examined by Black and Scholes (1972), Bhattacharya, Chiras and Manaster, Finnerty, Galai, Phillips and Smith, Trippi, Whaley, and many others. The efficiency results are analogous to the findings of price-accuracy studies in that (a) no one set of conditions consistently explains when the market is inefficient under the Black-Scholes model, (b) the inefficiencies found are usually eliminated after the "proper" pricing formula is used, (c) the proper formula suggested is usually a modification of the Black-Scholes formula, based on the subject or approach being considered, and (d) in general, the use of the Black-Scholes model (or a version of it adjusting for dividend payments) yields results which are consistent with market efficiency.

In summary, the Black-Scholes model has withstood fairly extensive tests regarding its pricing accuracy and efficiency implications. However, from a practitioner's viewpoint, the BSOPM and BOPM (or versions of them) require a volatility estimate that is not certain and thus can lead to mispricing. In virtually all of the pricing studies cited above, the volatilities used in the OPM are based on functions of past IV's. In their seminal piece on IV's, Latane and Rendlemen suggested that weighted IV's (weighted by the change in premium with respect the change in the respective IV) provide better forecasts than historical variances. Subsequent work (e.g., Chiras and Manaster, Schmalensee and Trippi, and Whaley) sought better weighting schemes but the results and conclusions have varied considerably in terms of the importance of IV's in forecasting variance and of the best weights.

The empirical focus on IV's in the next section is different than that taken in the studies cited above in that the primary emphasis of this study is on explaining the market's forecasts as opposed to developing models to forecast variances for use in OPM's; i.e., we work in an explanatory framework whereas most IV studies are in a forecasting context. This explanatory approach is used for two primary reasons. First, it is important at this time to determine whether the IV's of the new soybean option market have different general relationships with historical variances and with other factors than those found for stock options, and thus whether subsequent work in developing forecast models should vary from traditional approaches. The second reason is that, because volume data are available by strike price and because options are offered on a number of futures contracts for the same commodity, there is much more potential to conduct cross-sectional, explanatory work than with non-commodity options. This point is very important in those cases where IV is reflecting more than just a variance forecast. The additional information reflected, by definition, represents an error in the

OPM since the premium and four non-variance factors are known. For instance, the BOPM does not yield a theoretical equilibrium solution for American options on futures which are marked to market daily. This downward bias is revealed clearly by BOPM premia which are less than intrinsic value--an outcome which is most likely when time to maturity is long and variance is large. Other potential "errors" in the BOPM might be caused by log-price returns which follow a non-lognormal diffusion process, serial dependence in the returns, discrete rather than continuous hedging, non-zero transaction costs, and other factors not considered in the theoretical construct used to develop OPM's.

The objectives of the following analysis are (a) to identify and measure factors affecting soybean option IV's by contract and (b) based on this IV explanatory model, identify adjustments needed in the BOPM to reflect pricing factors not included in traditional theory.

Analysis

The options on soybean futures traded at the Chicago Board of Trade from October 31, 1984 through March 29, 1985 are analyzed. Option data were gathered from daily reports published by the Market Information Department of the Board.[2] These reports provide volume, open interest, number of options exercised, and premiums by option maturity and strike price.

To gain perspective on the level and type of trading which occurred during the first five months, Table 1 presents daily averages of contract volumes by option type and by strike-futures relationship.[3] Note three general characteristics. First, as the option's time to maturity decreases, its volume increases. Second, volume increases as the option's strike

Table 1. Average Contract Volume per Day of Soybean Options by Month, Futures Contract, Option Type, and Strike-Futures Relationship.

		Soybean Futures									
		January		March		May		July		November	
Month	F-S[a]	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls	Puts	Calls
Nov	1	0.0	35.4	0.0	40.0	0.0	1.2	0.0	5.8	0.0	1.8
	2	13.4	337.9	2.9	68.1	0.2	8.5	0.0	5.1	4.0	29.1
	3	322.1	412.1	34.7	85.2	2.3	12.1	1.4	9.1	4.0	10.1
	4	196.5	12.6	13.0	2.1	0.5	0.3	1.0	0.1	0.9	0.0
	5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec.	1	0.0	0.1	0.1	73.1	0.0	28.3	0.0	16.7	11.7	29.8
	2	16.6	187.7	19.1	283.8	0.9	39.0	0.9	23.8	2.8	15.6
	3	320.6	489.2	235.6	335.0	16.3	17.5	9.2	22.2	3.3	3.8
	4	34.4	0.0	28.5	5.3	0.7	0.1	3.1	0.5	0.0	0.0
	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan.	1	--[b]	--	0.7	46.6	0.3	43.2	0.0	20.3	3.7	58.8
	2	--	--	19.9	564.2	3.9	117.6	1.7	56.6	0.1	24.9
	3	--	--	471.6	1001.0	54.5	124.1	20.0	48.4	14.2	31.9
	4	--	--	103.5	4.7	56.2	1.4	48.1	7.0	0.0	0.0
	5	--	--	0.0	0.0	0.1	0.0	1.4	0.0	1.2	0.0
Feb.	1	--	--	0.0	0.0	0.0	101.7	0.0	46.0	0.8	50.5
	2	--	--	31.3	202.5	13.5	474.4	1.6	103.1	4.9	35.2
	3	--	--	426.0	1148.8	273.8	473.8	58.7	129.7	21.5	21.9
	4	--	--	29.5	1.3	84.3	12.7	59.7	1.7	20.0	0.0
	5	--	--	0.0	0.0	0.3	0.0	0.3	0.0	0.5	0.0
Mar.	1	--	--	--	--	0.0	4.7	0.0	224.7	0.5	89.6
	2	--	--	--	--	3.3	239.1	5.1	151.0	1.0	41.8
	3	--	--	--	--	280.7	915.5	105.1	227.6	27.4	65.7
	4	--	--	--	--	141.9	38.9	52.3	23.5	33.1	0.3
	5	--	--	--	--	0.0	0.0	0.1	0.0	0.4	0.0

[a]Futures minus strike. Values 1-5 designate, respectively: $-75>F-S$; $-25>F-S>-75$; $25>F-S>-25$; $75>F-S>25$; and $F-S>75$, where F and S are in cents per bushel.

[b]Expired.

approaches the futures price. This characteristic reflects traders' confidence in explaining how the premium should react to various factors in that it is felt that OPM's, in general, do a "better" job of pricing options which are near or slightly out of the money. Another reason why out-of-the-money options are traded more than in-the-money options is that in-the-money options require a greater delta (i.e., more futures positions have to be acquired to reduce risk), causing an increase in transaction costs even though this cost is assumed zero under the BOPM. Furthermore, as the option goes deep in the money, its value becomes more dependent on the futures price and thus speculation on deep-in-the-money options is virtually the same as speculation in the futures market, discouraging trades in options. The third characteristic, which is probably more pronounced in non-commodity options, is that calls are traded more than puts. When asked why, traders usually indicate that calls are the instrument with which they are most comfortable due to either pricing characteristics of the OPM or to the snowballing effect that takes place when one option type becomes more popular than another.

Shown in Figure 1 are the weekly averages of the IV's of the May option as well as the 30-, 60-, and 90-day historical variances. These IV's and historical variances also reflect the general characteristics of the other markets analyzed. When trading began, IV's were around 23.[4] The average IV fell from this level to about 18 during the first eight weeks of trading and then fluctuated between 16 and 20 for the remainder of the study period. The average IV of the March contract was usually higher in level and sharper in turns than May's. The July contract exhibited smoother IV movements than either May's or March's. (While only the July, May, and March contracts are

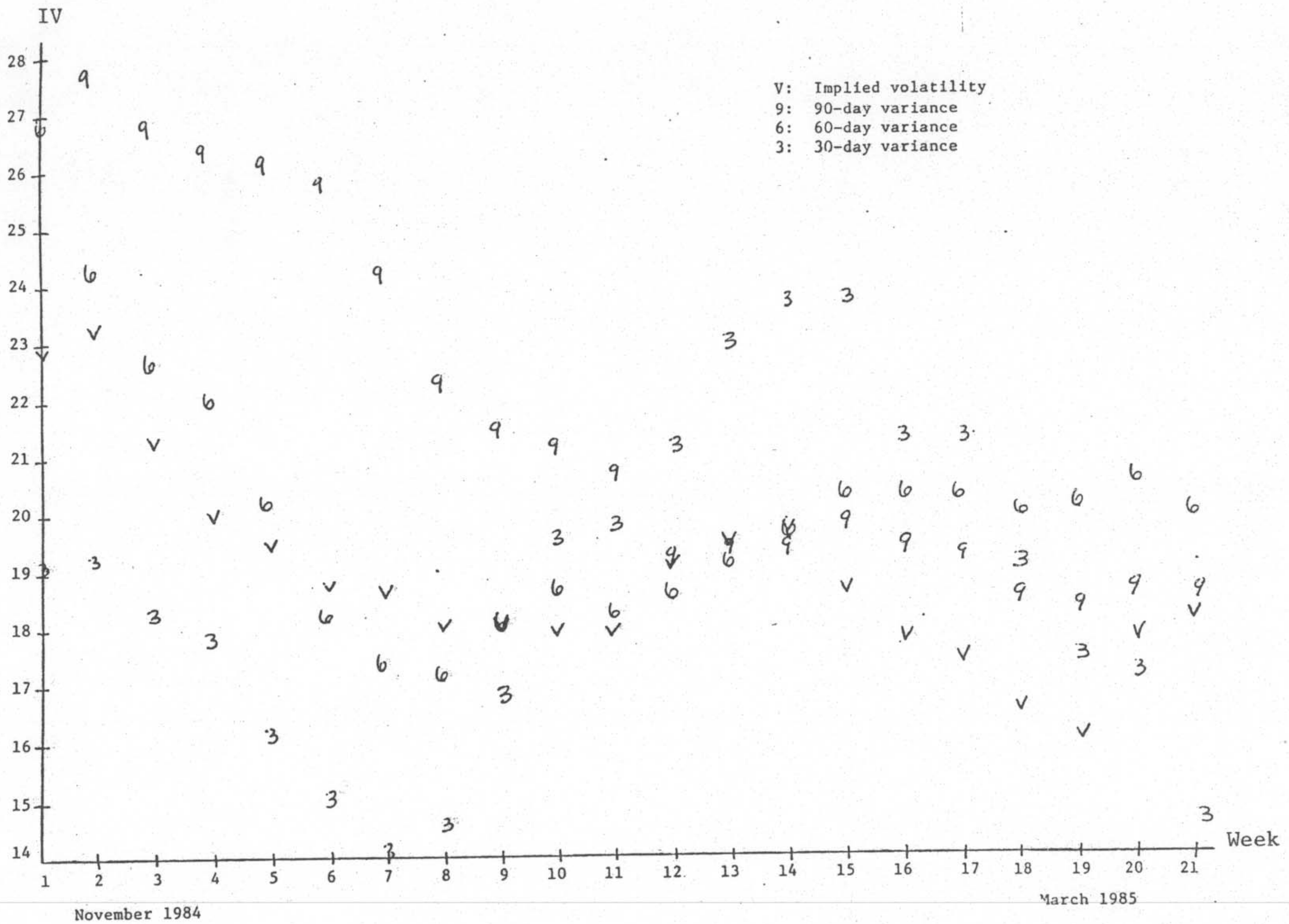

Figure 1. Implied Volatilities and Historical Variances for May Soybean Options.

analyzed statistically below, it is interesting to note that November's average IV's were virtually flat at about 19.)

The central empirical issue of this paper is whether these past variances, as well as other factors, affect soybean futures premia and the resultant IV's. To address this issue, the following function with linear coefficients is considered:

$$\text{(1)} \quad \ln(IV_{tfos}) = g(INT, \ln(HVAR_{tfd}), \ln(FUT_{tf}), \ln(VOL_{tfos}), \left|\ln(RET_{tf})\right|, I2, I1, O1, O2),$$

where $\ln(IV_{tfos})$ is the natural logarithm of implied volatility on day t (t=1, 2,...,104) of a put option (o=1) or a call option (o=2) with a strike price s on futures contract f (f=March, May or July); INT is the intercept; $HVAR_{tfd}$ is the historical variance of $\ln(\frac{FUT_{tf}}{FUT_{t-1,f}})$ calculated with the most recent t-d trading days of FUT_{tf}, where FUT_{tf} is the closing futures price for soybeans; VOL_{tfos} is contract volume; RET is $\frac{FUT_{tf}}{FUT_{t-1,f}}$; and I1, I2, O1, and O2 are dummy variables reflecting the level at which the option is in or out of the money. If the option is in the money by at least 12.5 cents but by no more than 25 cents then the I1 is one. I2 is one if the option is in the money by at least 25 cents. Likewise, if the option is out of the money by the range of 12.5 to 25, then O1 is one whereas O2 is one if the option is out of the money by at least 25 cents. Otherwise, the dummy variables are zero. This dummy structure means that the effects reflected through their coefficients are relative to near-the-money options (i.e., relative to those options which have strikes not more than 12.5 cents below or above the futures price).

If traders use past variances to help set volatilities for OPM's, the

HVAR would be expected to have a positive effect on IV. There is a trade-off, however, between improving the variance estimate by increasing d versus detecting quickly the changes in the actual variance. Thus, during preliminary investigations, twelve HVAR's (d=10, 20, 30, ...,120) were examined. To estimate the effect of futures price level on traders' expectation of variance, $\ln(FUT_{tf})$ was included in the model. A common finding in stock-option work is that the price level and return variance are inversely related (Jarrow and Rudd, 1983, p. 154). On the other hand, Choi and Longstaff provide evidence of a positive relationship for soybean futures. The volume variable (VOL) reflects a reality of the market which is assumed away in most OPM's. In theory, it is usually assumed that there are no transaction costs. However, one type of cost (among many others) is associated with the risk of not being able to acquire positions quickly in a low-volume market. Therefore, an increase in trading activity would be expected to have a negative effect on the premium and thus on the IV. The absolute value of $\ln(RET_{tf})$ is presumed to be another measure of the variance which is easily observable by traders. Beckers shows that the underlying distribution of this variable, given ln(FUT) is normally distributed, is approximately proportional to the theoretical variance needed for traditional OPM's. Thus, the expected sign for this variable is positive. The expected signs of the dummy variable coefficients were based on the fact that the BOPM, used to derive the IV's, underestimates American option premia in theory. Under most feasible conditions, this bias increases as the option changes from out-of-the-money to in-the-money levels. Since the coefficients are relative to near-the-money levels, the signs for O1 and O2 were expected to be negative and the O2 coefficient was expected to be more negative than O1's. The I2 coefficient was expected to be larger than I1's and both were expected to be positive.[5]

IV's were estimated with a search procedure which finds a variance that, when used in the BOPM, yields a premium that is not more than 0.1 cents from the observed premium. Settlement premia and closing futures prices were used with the respective time to maturity and strike. Option strikes which did not trade during the day were excluded from analysis. An eight percent annual interest rate was used.[6]

The primary reason for specifying a log-log model is because it will become important, as discussed later, to interpret the futures-IV relationship in terms of a constant elasticity.

Ordinary-least-squares regression results for equation (1) using either the 30-, 60-, or 90-day historical variance are presented in Table 2. Across specifications, the general results for the non-HVAR variables are similar. Volume has a negative effect on IV, suggesting that the lower costs associated with large trading volume causes premiums to decrease. The absolute value of the daily return has a direct influence on IV, indicating that short-term price movement is an important factor in determining the market's variance forecast. However, less weight is put on this short-run phenomenom when projecting variance over longer periods of time given that, for each HVAR and option-type pair, the RET coefficient decreases as the time to contract expiration increases; i.e., the coefficients are larger for March options than for May options, and larger for May than for July.

The dummy variable coefficients for call options are consistently and significantly opposite of our a priori expectations. Relative to the IV's of near-the-money call options, out-of-the money calls have large IV's whereas in-the-money calls have small IV's. The dummy effects for puts are e 2. Results of IV Models by Option Contract and Number of Days in Historical Variance.

Option Type	Contract	INT	HVAR	FUT	VOL	RET	O2	O1	I1	I2	$\bar{R}^2$	Observations
Put	March	-1.714	.789	1.316	-.013	.741	.041	.014	.065	.069	.54	233
		(-3.3)*[a]	(11.7)*	(4.5)*	(-2.5)*	(.61)	(2.0)*	(.63)	(2.5)*	(2.9)*		
	May	-1.628	.216	2.160	-.009	.544	.024	-.002	.001	.016	.49	284
		(-4.8)*	(7.5)*	(12.2)*	(-2.7)*	(.81)	(2.1)*	(-.12)	(.09)	(1.0)		
	July	-.692	.213	1.633	-.009	-.131	-.005	.003	.003	-.071	.40	246
		(-1.9)	(7.5)*	(9.0)*	(-3.1)*	(-.18)	(-.49)	(.20)	(.19)	(-4.9)*		
Call	March	-1.369	.604	1.464	-.026	3.492	.079	.054	-.060	-.076	.54	323
		(-3.5)*	(10.0)*	(6.3)*	(-5.8)*	(3.2)*	(5.0)*	(2.5)*	(-2.3)*	(-2.5)*		
	May	-.604	.179	1.679	-.017	1.105	.060	.028	-.024	-.043	.60	504
		(-2.9)*	(9.7)*	(15.8)*	(-8.6)*	(2.4)*	(7.9)*	(2.6)*	(-1.8)	(-3.0)*		
	July	.623	.121	1.088	-.015	.403	.028	.012	-.040	-.076	.47	515
		(3.2)*	(7.5)*	(11.4)*	(-8.3)*	(.96)	(4.2)*	(1.1)	(-3.8)*	(-6.9)*		
Put	March	-.757	.153	1.774	-.008	5.444	.058	.020	.064	.063	.27	233
		(-.84)	(.94)	(2.5)*	(-1.2)	(3.5)*	(2.3)*	(.70)	(2.0)	(2.1)*		
	May	-.955	.294	1.670	-.009	1.966	.036	.004	-.003	.019	.43	284
		(-2.9)*	(4.8)*	(8.1)*	(-2.7)*	(2.8)*	(3.0)*	(.23)	(-.18)	(1.5)		
	July	.316	.164	1.146	-.010	1.595	.002	-.002	.005	-.077	.28	246
		(.85)	(2.5)*	(6.0)*	(-3.0)*	(2.0)*	(.20)	(-.14)	(.24)	(-4.9)*		
Call	March	-.485	.207	1.569	-.018	6.690	.075	.041	-.033	-.052	.40	323
		(-.67)	(1.7)	(2.7)*	(-3.6)*	(5.4)*	(4.1)*	(1.6)	(-1.1)	(-1.4)		
	May	.061	.326	1.052	-.015	2.252	.066	.024	-.015	-.052	.60	504
		(.31)	(9.7)*	(8.7)*	(-7.8)*	(5.0)*	(8.7)*	(2.2)*	(-1.2)	(-3.7)*		
	July	1.343	.105	.713	-.017	1.157	.027	.015	-.041	-.078	.42	515
		(7.5)*	(3.7)*	(6.6)*	(-8.8)*	(2.7)*	(3.9)*	(1.4)	(-3.8)*	(-6.7)*		
Put	March	-3.398	-.866	5.048	-.015	4.036	.034	.021	.053	.066	.54	233
		(-6.2)*	(-11.5)*	(13.8)*	(-3.0)*	(3.5)*	(1.7)	(.95)	(2.1)*	(2.7)*		
	May	-.846	.019	2.030	-.004	1.468	.040	.0002	.011	.033	.39	284
		(-2.3)*	(.33)	(8.6)*	(-1.1)	(2.0)*	(3.2)*	(.01)	(.68)	(1.9)		
	July	1.316	.238	.462	-.005	1.063	.014	.003	-.010	-.069	.33	246
		(3.7)*	(4.9)*	(1.9)	(-1.7)	(1.4)	(1.2)	(.22)	(-.54)	(-4.5)*		
Call	March	-2.947	-.699	4.482	-.025	5.880	.084	.048	-.051	-.101	.55	323
		(-7.1)*	(-10.4)*	(15.6)*	(-5.6)*	(5.8)*	(5.4)*	(2.2)*	(-2.0)	(-3.3)*		
	May	.008	.007	1.602	-.012	2.009	.063	.027	-.017	-.037	.53	504
		(.04)	(.20)	(10.3)*	(-5.3)*	(4.1)*	(7.6)*	(2.3)*	(-1.2)	(-2.3)*		
	July	1.737	.147	.414	-.013	.890	.031	.010	-.030	-.068	.44	515
		(9.0)*	(5.4)*	(3.2)*	(-6.3)*	(2.1)*	(4.6)*	(.88)	(-2.7)*	(-5.9)*		

'arenthesized numbers are t values; *: signicant at 95 percent level.

less consistent than for calls in terms of sign and magnitude patterns across contracts and across futures-strike relationship. Before further discussion of these seemingly unexpected results, we wish to turn to the relationship found between FUT and IV, for this has important implications regarding the dummy variable results.

The parameter estimate for ln(FUT) is always positive and always significantly different than zero at the 95 percent level. At first glance, this may not seem surprising given the common observation that the variance of a variable tends to increase as the level of the variable increases. Measured in this case, however, is the variance of the percentage change in price (i.e., the variance of the log-price first differences) and therefore, a priori, the expected sign between this return variance and futures price does not seem obvious. Furthermore, as mentioned above, the consensus within the finance literature is that, if non-constant, the stock-return variance tends to be inversely related to stock price.[7]

To deal with this nonconstancy problem, Cox developed a constant elasticity of variance (CEV) model given that a one percent change in price causes a fixed and <u>negative</u> percentage change in variance, regardless of price level. If the market as a whole follows the CEV model behavior (regardless of whether the individual trader knows that this process is being followed), then the IV from the BSOPM will, for both calls and puts, tend to underestimate option premia for options having an underlying commodity price larger than the strike, and overestimate premia for options having a price less than the strike. Choi and Longstaff find the same bias in the BOPM after modifying the CEV model to enable the pricing of a futures option when the price-return variance exhibits a <u>positive</u> and constant elasticity.[8] This bias, by itself, implies that the BOPM will yield IV's which underestimate the true variance for in-the-money calls and out-of-the-money puts whereas the IV's overestimate the variance for out-of-the-money calls and in-the-money puts. Under this bias, the true variance is best reflected by at- or near-the-money options. Interestingly, these biases imply the dummy variable results found for each contract's call options.

For puts, the in-the-money dummies (I1 and I2) have relatively large and positive coefficients for the March contract. The I2 coefficient for May puts is larger than for I1 but both are statistically insignificant. A positive sign for I1 and I2 for puts is consistent with both the American option bias and the constant-elasticity bias. However, the size and significance of the negative I2 coefficient for July puts suggest that pricing effects not considered in this analysis are playing an important role in determining these deep-in-the-money, distant options.

For O1 and O2, the only significant coefficients for puts are the positive O2 coefficients for the March and May contracts. These O2 results for puts are inconsistent with both theoretical biases. While the reasons for this inconsistency are not revealed by this analysis, it is interesting to note that, in general, the IV's reflect an upward adjustment in premium for both in-the-money and out-of-the-money puts when compared to near-the-money puts. Should this relationship prove stable over time then this information in itself, regardless of cause, is useful to practitioners who want to adjust the BOPM according to market characteristics.

The dummy variable results for calls consistently imply that the cause for adjustment is due to a dependent relationship between price-return variance and futures price level. To focus on this relationship, puts and calls were pooled and only those options for which the futures price is not more than 12.5 cents on either side of the strike were considered. These near-the-money options yield IV's which best reflect the "true" variance under the BOPM if the CEV relationship holds. The same model as expressed in equation 1 (excluding O2, O1, I1, and I2) was used with an additional dummy variable (CP) which is one if the option is a put and zero otherwise. The 30-day variance was used for HVAR (discussed further below). Regression estimates are based on ordinary-least-squares under classical assumptions about the error structure. Results are presented in Table 3.

As indicated by the parameter estimates for HVAR and RET, pricing of the March and May options relied heavily on recent variance behavior, and the futures-price elasticity of IV for these nearby contracts are, respectively, 2.4 and 2.3. These elasticities are extremely close to those estimated by Choi and Longstaff when examining historical variances. Choi and Longstaff estimate an average constant elasticity of 2.3 across three soybean futures contracts (March, July and November) by regressing log prices on respective log price-return variances (correcting for serial dependence) during 1979-1983. Our results indicate that traders incorporated this relationship (probably implicitly) in their variance forecasts for nearby options. For the distant option (July's), the variance forecast relies less on recent variance behavior and less on the futures price level.

Another pricing characteristic revealed by Table 3 is that, on average, put options yielded lower IV's than calls. This characteristic would not be expected under traditional OPM's but, based on discussions with traders, may reflect traders' probability expectations about downward price changes at the relatively low price levels during the study period. While these expec-

Table 3. Results of Pooled IV Models for Options Near the Money.

Contract	INT	HVAR	FUT	VOL	RET	CP	$\bar{R}^2$	Observations
March	-2.655 (-5.0)*[a]	.414 (5.6)*	2.443 (7.7)*	-.012 (-2.1)*	3.940 (3.0)*	-.024 (-1.7)	.66	120
May	-1.891 (-6.5)*	.221 (8.6)*	2.321 (15.2)*	-.017 (-6.4)*	1.549 (2.4)*	-.019 (-2.4)*	.79	170
July	-.188 (-.5)	.143 (4.4)*	1.499 (7.6)*	-.014 (-3.3)*	-.221 (-.2)	-.044 (-4.1)*	.46	162

[a] Parenthesized numbers are t values; *: significant at 95 percent level.

tations should not affect the IV under traditional theroy, a theoretical interpretation might be based on a non-traditional diffusion process for the underlying commodity price.

The last pricing issue pertains to the use of historical variance when estimating premia. Preliminary investigations focused on identifying the best price series length (among 10,20, 30,..., 120 days) which, when used to calculate HVAR, explained IV. Plots of the various HVAR's on IV clearly indicated that the level of IV was best represented by the 50- or 60-day historical variances (exemplified in Figure 1). Indeed, based only on the first five months of trading, we recommend the use of 50 to 60 day soybean variances to researchers simulating option pricing during pre-trading periods. However, three caveats are in order. First, although the general level of the 50 to 60 day HVAR's corresponded well with the IV levels during the study period, this correspondence may have been spurious in the sense that most of the HVAR series had the same general pattern but at different levels--other factors could have caused the IV to be at the 60-day level and, in our opinion, a much longer time series is needed to adequately choose the single best HVAR for setting IV levels. Second, while the HVAR plots fit relatively well for the January, March, May and July IV's, none of the HVAR's reflected November's IV. When estimating variance forecasts for long-term (particularly new-crop) options, HVAR's may not provide good perspective on the level at which the market would forecast the variance over the entire option life. It will be interesting to observe when HVAR's begin to play a larger role in this forecast. The third and perhaps most important caveat is that, as shown in the above analysis, factors other than historical variance are very important in explaining IV. When these other factors are included in our explanatory model, the most consistent results across contracts in terms of the HVAR coefficient and adjusted R^2 are found with the 30-day HVAR. In general, the 30-day variance seemed to reflect the variance changes perceived by the market better than the longer-term variances. Of course, limiting the explanatory model to only one HVAR is probably a misspecification in itself and we do not claim to have found the "correct" HVAR specification. However, the use of one HVAR avoids collinearity problems and provides a model which can be easily interpretted.

Summary and Concluding Remarks

The general objective of this paper is to explain the price-return variances implied by market premia for options on soybean futures when Black's option pricing model (BOPM) is used to estimate the implied volatility (IV). Analyzed are the March, May, and July soybean options traded at the Chicago Board of Trade during the first five months of trading (November 1984 - March 1985). The model used specified IV as a function of historical variance, option contract volume (by strike), futures price, absolute daily price return, and dummy variables reflecting the futures-strike relationship. The quantity variables are in log-log form.

It is found that past variance behavior (in the form of recent historical variance and absolute daily price returns) are important factors in determining the market's forecast of variance but that their importance diminishes as the option's time to expiration increases. Trading volume has an inverse effect on IV, reflecting lower premiums associated with greater liquidity. Coefficients of the dummy variables indicate that the call's IV increases as the call changes from in-the-money levels to out-of-the-money levels. For puts, the IV's tend to increase as the option moves away from near-the-money levels to either out-of-the-money or in-the-money conditions.

Perhaps the most important result of the analysis with respect to option pricing is the strong evidence that IV is directly influenced by the futures price level. To focus on this relationship, the model was run with only those options which are very close (within 12.5 cents) to being at the money. The resultant futures price elasticities of IV are 2.4, 2.3, and 1.5 for the March, May, and July contracts, respectively.

The regression results reveal (a) factors influencing the market's variance forecast and (b) conditions under which the BOPM deviates from actual pricing. The next step of investigation for both practitioner and academician might address the issue of whether it is beneficial to use a pricing model (such as Cox's) which accounts for a relationship between futures price and variance. The most appropriate procedure to do this would probably involve the type of efficiency tests discussed in the "OPM Evaluation" section of this paper. However, when testing a constant-elasticity-variance (CEV) model relative to the BOPM (or numerical technique based on the BOPM), a critical and practical point concerns the stability of the elasticity. The primary advantage of using the CEV model is that the variance does not have to be adjusted in response to changes in the futures price. The disadvantage of using this model is that another parameter (reflecting elasticity) must be estimated and if this parameter changes over time then adjustments to the estimate may be frequent. Given the simplicity of finding Black's solution as opposed to the numerical technique required for a CEV solution, a practical question can be raised as to whether it is more desirable to use the CEV model to account for price-related variance changes or the BOPM which must be adjusted frequently (but easily) to reflect this characteristic. This issue becomes particularly important if the elasticity is not stable and if there are other reasons for adjusting both models' variance input. We suspect that the use of simple pricing models with correction adjustments will prevail in practice.

Footnotes

1 In theory, the applicable interest rate is that which exists over the option contract's life and thus is not known when pricing the option. However, feasible changes in the interest rate are usually not of practical importance when pricing options on futures.

2 The authors wish to thank Mr. Jeffrey Hersh for gathering these data at the Board on a daily basis.

3 During the latter half of this study's analysis period, the January 1986 and March 1986 contracts began trading. The volume for these contracts has, thus far, been extremely small.

4 IV's used here and throughout the paper are calculated in terms of the units commonly quoted in practice. The variance of the daily log-price returns is multiplied by 365, and the square root of this product is multiplied by 100; i.e., the IV is an annualized standard deviation percentage.

5 The only bias considered here is that due to the theoretical underestimation caused by using the BOPM for American options and by the fact that futures are marked to market daily. To get perspective on this bias,

compare the premia found with Cox, Ross, and Rubenstein's binomial pricing model (which partially corrects for this error) to BOPM premia under various option conditions.

6 Initial runs with options traded through February used IV's calculated with March 1985 treasury bill futures rates. When compared to regression results using the fixed eight percent rate, virtually no difference was found. Thus, the final runs (using options traded through March) use IV's derived with the constant rate.

7 For Black-Scholes type models, a theoretical equilibrium exists if the variance changes are a known function of time and/or underlying commodity price (Ingersoll, p. 112). Hauser, Andersen, and Offutt examine the implications of pricing soybean options under the assumption that variance is a function of time.

8 This bias is related only to the non-constant variance issue and does not reflect the bias discussed in footnote 5. It should be noted that the premium table presented in Choi and Longstaff's forthcoming article does not reveal the same bias as that stated in their text (also stated in this paper). Unfortunately, based on discussion with Jin Choi, the examples used in the table were too extreme in terms of futures-strike relationships. When more reasonable examples are used, the stated bias is revealed.

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