Option Prices as Predictors of Equilibrium Stock Prices
Author(s): Steven Manaster and Richard J. Rendleman, Jr.
Source: *The Journal of Finance*, Vol. 37, No. 4 (Sep., 1982), pp. 1043-1057
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2327766
Accessed: 27/11/2009 08:20

THE JOURNAL OF FINANCE • VOL. XXXVII, NO. 4 • SEPTEMBER 1982

Option Prices as Predictors of Equilibrium Stock Prices

STEVEN MANASTER and RICHARD J. RENDLEMAN, JR.*

ABSTRACT

The Black-Scholes option pricing model, modified for dividend payments, is used to calculate jointly implied stock prices and implied standard deviations. A comparison of the implied stock prices with observed stock prices reveals that the implied prices contain information regarding equilibrium stock prices that is not fully reflected in observed stock prices. The implications of this finding are discussed.

THIS STUDY INVESTIGATES THE role of call option prices as predictors of the equilibrium prices of their underlying stocks using the Black-Scholes [3] (BS) model. Previous tests of the BS model have shown that the formula is highly successful in explaining the observed market prices of options (see Black and Scholes [2], Galai [8], Chiras and Manaster [6], and Macbeth and Merville [12]. According to the model, the option price is a function of the current value of the underlying stock, the instantaneous variance of the stock's rate of return, the time to maturity of the option, the risk-free rate of interest, and the exercise price of the option.[1] Given an observed option price and known values of all input parameters to the BS model except the stock price, one can determine the price of the underlying stock that equates the observed option price to its calculated value. It follows from the underlying logic of the model that the implied price is the value of the underlying stock for which a continuously revised option-bond portfolio would be a perfect substitute for the stock. Hence, if options are actually priced according to the model, implied stock prices will be the option market's assessment of equilibrium stock values.

Previous empirical studies have assumed that observed stock prices are the relevant stock prices for option valuation. However, just as stock prices may differ, in the short run, from one exchange to another (i.e., NYSE, Midwest,

* Assistant Professor at the University of Chicago Graduate School of Business; and Associate Professor of Finance at the Fuqua School of Business of Duke University respectively. The authors wish to thank participants in the finance workshops at the following schools for providing helpful comments: The University of Chicago, DePaul University, The University of Florida, Harvard University, Louisiana State University, The University of North Carolina, The University of Texas, and Wake Forest University. In addition, we owe a special thanks to Jonathan Ingersoll, the Editor, Michael Brennan, and James D. MacBeth.

[1] The Black-Scholes model assumes that the underlying stock pays no dividends. No closed form solution has been obtained, however, for pricing American call options on dividend paying stocks. The problem has been solved numerically by Brennan and Schwartz [5], Rubinstein and Cox [18], and Rendleman and Bartter [16]. Roll [17] has derived an analytical solution to the problem of pricing options on dividend paying stocks. However, his model requires knowledge of a critical stock price which must be determined numerically.

Pacific, Philadelphia, etc.), the stock prices implicit in option premia may also differ from the prices observed in the various markets for stock. In the long run, the trading vehicle that provides the greatest liquidity, the lowest trading costs, and the least restrictions is likely to play the predominant role in the market's determination of the equilibrium values of underlying stocks. In principle, there is nothing to prohibit the options market from playing an important role, if not the predominant role.

If some investors regard options as an investment vehicle superior to the underlying stock, option prices which are influenced by such investors should reveal information regarding equilibrium stock values. For the following reasons some investors may regard options as a superior vehicle:

(1) Trading Costs: some options may be over or underpriced,[2] thereby reducing the costs of taking an initial option position. Similarly, brokerage commissions may be lower,[3] and liquidity greater for some types of options when compared to an equivalent investment in the underlying stock;

(2) Short Sales: since there is no up-tick rule governing short sales of options, an investor who is prohibited from shorting the stock on a down tick could instead short its equivalent in options. Also, some types of option short sales may enable the investor to reinvest the proceeds of the short sale. This opportunity is not available to investors who short-sell stock. Moreover, Gastineau [9, pp. 100–102] has argued that when both puts and calls are traded on a stock, it is always cheaper (in terms of interest foregone) to buy a put and sell a call with the same terms than to short the stock directly; and

(3) Margin Requirements: margin requirements may often prohibit a stock investor from obtaining a desired amount of leverage. However, this leverage can often be obtained by investing in options instead. "Since an investor can usually get more action from a given investment in options than he can by investing directly in the underlying stock, he may choose to deal in options when he feels he has an especially important piece of information" (Black [1, p. 61]). Thus, the option trader is likely to be more informed than the average stock investor, and option prices may reflect additional information not captured by observed stock prices.

In theory, when implied stock prices differ significantly from observed stock prices, arbitrage opportunities will exist. Traders attempting to profit from such price discrepancies should cause implied and observed stock prices to move together.[4]

On the basis of our investigation, we reject the hypothesis that implied stock prices provide no information regarding the future movements of observed stock prices. This conclusion is based on two different tests: one an *ex post* test and the other an *ex ante* test. In both tests, we form stock portfolios based on the differences between implied and observed prices and compare the returns earned on the various portfolios. In the *ex post* test, we employ information contained in

[2] Overpriced and underpriced options have been identified by Black and Scholes [2], Latané and Rendleman [11], Galai [8], Trippi [20], and Chiras and Manaster [6].

[3] See Black [1], p. 61.

[4] See Black [1], p. 61 for a similar analysis.

closing stock and option prices to form the portfolios and unrealistically assume that a trader could simultaneously process the information and trade the stocks at closing prices. However, if an option transaction occurs after the stock's closing transaction, our simulated portfolio strategy will employ "future" information (closing option prices). Not surprisingly, we find in our *ex post* test that closing option prices do contain additional information that is not fully reflected in closing stock prices. Whether the additional information is due to "better" information or merely more recent information cannot be determined from the *ex post* tests alone.

The *ex ante* tests are similar to the *ex post* tests except that the simulated stock purchases are made at the following day's closing prices. Although the results of the *ex ante* tests still allow us to reject the hypothesis that implied stock prices contain no information about future stock returns, they are not as significant. We are unable to determine whether this information can be used profitably by traders to earn excess returns.

The remainder of the paper is organized as follows: in Section I a method for calculating the implied stock price is presented and discussed; in Section II a comparison is made between the implied and observed stock prices; in Section III the informational content of the implied prices is evaluated; and in Section IV a summary and concluding comment are provided.

I. Calculation of Implied Stock Prices

Price data were taken from the CRSP options tape which contains daily closing prices, and maturity dates for all options which traded on listed options exchanges from 26 April 1973 to 30 June 1976. There were 805 trading days over this period and 172 stocks with listed options. The number of days for which options traded varied from stock to stock. Only six stocks had options which traded on the first observation date. However, additional stocks entered the sample pool as option trading expanded.

In addition to the options data, the CRSP tape also contains information on the prices and returns of the underlying stocks. The stock information is taken from CRSP's daily stock master tape and includes stock price and return data as well as a complete dividend history of each stock. The risk free interest rate is collected weekly and is measured by the yield on 91 day U.S. Treasury Bills.[5]

A major limitation of the BS model is the assumption that no dividends are paid on the underlying stock over the life of the option. The data available for this study, however, consist almost exclusively of options on dividend paying stocks.

The BS model does not adjust for the fact that options on stocks which pay large dividends might be optimally exercised prior to maturity. Therefore, options that have the potential for optimal premature exercise are deleted from the sample. Specifically, an option is excluded on any day from which the present value of the dividends to be paid over the remaining life of the option exceeds the

[5] These data were provided by Jonathan Ingersoll.

present value of the interest foregone by early exercise.[6] The condition is stated in Expression (1) below:

$$\sum_{i=1}^{K} D_i e^{-r(t_i - t_0)} > (1 - e^{-r(T-t_0)})E \tag{1}$$

for $t_0 \leq t_i \leq T$, where t_0 is the current date, t_i is the date of the ith dividend, T is the maturity date of the option, E is the exercise price of the option, D_i is the dollar amount of the dividend paid on date t_i, r is the riskless interest rate per unit of time, and K is the number of dividends paid between t_0 and T. By excluding options which satisfy Expression (1), we are assured that the options remaining in the sample will be exercised optimally only at maturity. However, the influence of dividends must still be accounted for in the case that Expression (1) does not hold.

The BS formula is

$$W_0 = S_0 N(Z_1) - Ee^{-r(T-t_0)} \cdot N(Z_2)$$

where

$$Z_1 = \frac{\ln(S_0/E) + r(T - t_0)}{V\sqrt{T - t_0}} + \frac{V\sqrt{T - t_0},}{2}$$

$$Z_2 = Z_1 - V\sqrt{T - t_0} \tag{2}$$

In Equation (2), W_0 is the current call option price, so is the current price of the underlying stock, V^2 is the variance of the stock's rate of return per unit of time, and $N(\cdot)$ is the cumulative normal density function. As discussed above, the above formula applies only to options on nondividend paying stocks. Our data exclusion rules ensure that none of the options in our sample will be rationally exercised before maturity. However, an adjustment for the influence of dividends must still be made to the pricing formula. The adjustment employed was first suggested by Black [1] and requires that the present value of the dividends to be paid over the remaining life of the option be subtracted from the current stock price employed in Expression (2).

In addition to excluding options which could be optimally exercised prior to maturity, options with less than thirty days to maturity are also excluded from the sample. It has been observed that the BS model is quite sensitive to violations of its underlying assumptions for options which are close to expiration. Also, the influence of measurement errors on the calculated values of option prices from the BS formula is increased dramatically for short term to maturity options. The formula, is quite robust for options with longer times to maturity.

Finally, options are excluded from the sample on any day in which the closing prices imply the existence of arbitrage opportunities. Specifically, options are excluded on any day in which Condition (3) below is satisfied. (See Merton [13]).

$$W_0 < S_0 - Ee^{-r(T - t_0)} \tag{3}$$

These observations are eliminated because of the likelihood that they represent nonsynchronous trades in the option and stock markets. It is possible, however, that closing option and stock trades occur simultaneously and that options are

[6] See Roll [17].

irrationally priced because the option price contains information about the equilibrium price of the stock that is not contained in the stock's closing price. In such cases, the exclusion of these data would result in the exclusion of data most favorable to the hypothesis that option prices contain information about stock prices. Therefore, when we test using the exclusion rules outlined above, we are applying a more stringent test than if the data had been included.

Numerical techniques can be employed to invert Equation (2) (modified for dividends) to solve for the implied stock price, S^*. However, as a practical matter, the implied stock price cannot be determined from the price of a single option due to the fact that the standard deviation of the stock's return (V) cannot be observed. Because the option valuation equation is highly sensitive to the value of V employed in the equation, estimates of V based on historical stock return data may not be satisfactory.[7]

In order to estimate the option market's assessment of the equilibrium stock price, while at the same time avoiding the difficulties associated with errors of measurement in standard deviations, implied stock prices and implied standard deviations[8] are calculated simultaneously using data from several options on the same stock.

For stock j at time t, the implied stock price, S^*_{jt}, and implied standard deviation, V^*_{jt}, are calculated as the solution to the problem

$$\underset{S_{jt},\ V_{jt}}{\text{Min}}\ Q = \sum_{i=1}^{N_{jt}} (W^i - W^i(S_{jt},\ V_{jt}))^2 \tag{4}$$

where W^i is an observed option price, $W^i(S_{jt}, V_{jt})$ is the calculated BS price, and N_{jt} is the number of options on security j at time t. The solution to Expression (4) minimizes the sum of the squared deviations between observed and calculated option prices.[9]

II. Comparison of Implied and Observed Stock Prices

Implied stock prices and proportional errors, Δ_{jt}, as defined below, are calculated for each of 172 stocks on each available observation date.

$$\Delta_{jt} = (S^*_{jt} - S_{jt})/S_{jt} \tag{5}$$

Table I provides a frequency distribution of the Δ_{jt}'s. More than 60% of the implied prices are within 1% of the observed prices, while more than 75% of the implied prices are within 2% of the observed prices.

The average values of Δ_{jt}, $\bar{\Delta}_j$, for each of the 172 companies were also computed. In general, these average values are close to zero; more than 60% of the 172 estimates of $\bar{\Delta}_j$ have absolute values less than 1%, more than 85% have absolute values less than 2%.

Despite the fact that the values of Δ_{jt} and $\bar{\Delta}_j$ are close to zero, there is a

[7] For a discussion of the problems involved in using estimates of V based on stock return data, see Black and Scholes [2], pp. 416–17.

[8] Implied standard deviations have been investigated by Latané and Rendleman [11], Trippi [20], Chiras and Manaster [6], Schmallense and Trippi [19], and MacBeth and Merville [12].

[9] Expression (4) is solved numerically using a Newtonian search in which the partial derivatives of Q with respect to S and V are simultaneously set close to zero. A description of the numerical algorithm will be provided by the authors upon request.

Table I

Frequency Distribution of Δ_{jt}

Value of ($\Delta_{jt} \times 100$)	Number of Observations	Percent of Observations
less than −.9	833	2.22
−9 to −8.01	186	.50
−8 to −7.01	242	.65
−7 to −6.01	303	.81
−6 to −5.01	431	1.15
−5 to −4.01	579	1.54
−4 to −3.01	965	2.57
−3 to −2.01	1532	4.09
−2 to −1.01	2834	7.56
−1 to −0.01	6260	16.70
0 to 0.99	9958	26.56
1 to 1.99	6343	16.92
2 to 2.99	3478	9.28
3 to 3.99	1694	4.52
4 to 4.99	887	2.37
5 to 5.99	414	1.10
6 to 6.99	231	.61
7 to 7.99	114	.30
8 to 8.99	58	.15
9 to 9.99	34	.09
More than 10	114	.30
	37490	100.00[a]

[a] Total less than 100% due to rounding.

tendency for Δ's to be positive more frequently than negative. Only 37% of Δ_{jt} and 39% of $\bar{\Delta}_j$ are negative. A factor which contributes to the "excessive" number of positive Δ's is the exclusion of low option prices which could potentially provide arbitrage opportunities in accordance with Condition (3). However, there are two additional reasons why implied prices may differ from observed prices without signalling informational differences: nonsynchronous data and a bias attributable to misspecification of the option pricing model.

For the data employed in the study, there is reason to believe that closing stock transactions generally occur after closing option transactions. The data include prices on all options for the stocks in the sample. For many of these options, trading is quite sparse, particularly for those options which are very far in or out of the money. On the other hand, trades in the stock occur at a more or less continuous rate. Therefore, it is reasonable to conclude that the implied prices calculated from Expression (2) represent the option market's assessment of the equilibrium stock price at a time within the trading day, while the observed stock closing price represents the stock market's assessment of the equilibrium price at the close of the market day. This distinction between end-of-day prices and within-day implied prices, however, cannot explain the positive bias observed in the data. One would expect the within-day assessment of the equilibrium price to differ from the day-end equilibrium price in a purely random and unbiased fashion. The tendency for implied prices to be greater than observed prices more frequently than the reverse may instead be attributed to a misspecification of the option pricing formula.[10]

The finding of a positive bias in the Δ's indicates that the market data may not fully conform to the assumptions of the BS model. Therefore, the model may be slightly misspecified.[11] However, the possibility of model misspecification should not deter us from attempting to extract information regarding equilibrium stock prices from option prices by using the BS model.

III. Informational Value of the Differences Between Implied and Observed Stock Prices

The principal hypothesis for testing is H_0 given below:

H_0: *There is information contained in implied stock prices regarding equilibrium stock prices that is not contained in observed stock prices.*

The hypothesis can be interpreted as a test of the efficient markets hypothesis. In an efficient market, the observed stock price will fully reflect all available information regarding the equilibrium stock price. The discovery that option prices contain information not already reflected in observed stock prices would contradict this concept of market efficiency.

The implied stock price and the observed stock price can both be viewed as estimates of the unobservable equilibrium stock price. If there is informational value in implied stock prices, one would expect observed stock prices to move in the direction of the implied prices.

If the option market's assessment of equilibrium contains useful information, and the market is able to recognize the usefulness of this information over a relatively short period of time, then high (low) values of Δ_{jt} should be associated with abnormally high (low) short-run stock returns. On the other hand, if all relevant information is contained in observed stock prices, then Δ_{jt} will not be related to future stock returns.

[10] It should be noted that our exclusion rules will exclude negative Δ observations when Expression (2) is satisfied. This may partially explain the abundance of positive Δ's. As noted earlier, however, this exclusion rule eliminates data which are most favorable to the hypothesis that Δ contains information about future stock price movements.

[11] Previous authors have speculated as to the source of misspecification. Attention has centered on the assumptions, critical to the BS model, that stock returns follow a Weiner process with nonstochastic variance. Merton [14, 15] has speculated that stock returns follow a Wiener process with occasional discontinuities or jumps. Cox and Ross [7] have modeled call option prices for stocks with a stochastic variance that is related to the stock's price. Geske [10] has argued that option prices should be modeled as compound options if the underlying asset is the stock of a levered firm. In the empirical literature, there is not widespread agreement as to whether these potential departures from the BS model provide a better explanation of observed data than the original BS model. For example, Chiras and Manaster [6] claim to have found evidence of a jump process, since in their data the market values of short term out-of-the-money options were generally higher than their estimated BS price. On the other hand, MacBeth and Merville [12] claim to have found market data deviating from BS prices in the opposite direction. They attribute this finding to the influence of a stochastic variance not captured by the BS model. Finally, empirical work regarding the Geske model is still in its preliminary stages (See Blomeyer and Resnick [4]).

The tests to be reported below indicate that Δ_{jt} is positively related to future returns on stock j. We interpret this to mean that S^*_{jt} contains some information regarding equilibrium stock prices that is not contained in S_{jt} alone. This positive relationship may indicate that option prices contain information that is not simultaneously reflected in stock prices. However, it may simply reflect the fact that closing option and stock trades do not occur simultaneously.

In the data we employ, it is possible that the influence of this timing problem is mixed. Some values of S^*_{jt} represent more current prices than their associated values of S_{jt}; at other times, the reverse is true. Below we present a diagnostic check to identify whether S^*_{jt} or S_{jt} provides the most recent information. This diagnostic check is able to detect a very strong influence of S^*_{jt} being an earlier price than S_{jt}. It is difficult, however, to determine whether the information in S^*_{jt} is due to "better information" in option markets than stock markets or whether it merely represents more recent information.

If a closing stock transaction occurs after a closing option transaction, one would expect to observe a negative relationship between Δ_{jt} and the return on the stock, R_{jt}, during the trading day on which the implied prices are measured. For example, if the price of the stock rose from \$100 to \$102 during the trading day, and the implied stock price reflects a within-day estimate of the stock price, then the implied price is likely to fall somewhere between \$100 and \$102. If the implied price was \$101, one would observe a value of Δ_{jt} equal to $(101-102)/102 = -0.0098$, while the actual return on the stock would have been 0.02.

The influence of nonsynchronous observations in explaining differences between implied and observed stock prices can be measured from the estimation of Equation (6) below:

$$\tilde{R}_{jt} = a_j + b_j\tilde{R}_{mt} + c_j\Delta_{jt} + \tilde{u}_{jt} \tag{6}$$

In Equation (6), the returns of stock j, $\tilde{R}_{jt}$, and the returns on the market index, $\tilde{R}_{mt}$, are measured for the same day on which the implied prices are calculated. a_j, b_j, and c_j in (6) are constants to be estimated. $\tilde{u}_{jt}$ is a random error term. If implied prices contain within-day information, and if the stock trades after the last trade of the relevant options, one would expect the coefficient c_j in (6) to be negative. Table II summarizes the results of the estimation of Equation (6) for the 172 stocks in a sample.

The estimation of Equation (6) for each of the 172 companies provides strong support for the hypothesis that implied prices contain information regarding within-day equilibrium prices. Of course, such information is old relative to observed closing prices. Table II shows that 131 of the 172 estimates of c_j are negative and 60 are significantly different from zero at the 5% level. Only one of the positive estimates is significantly different from zero. The presence of 60 negative and significant estimates of c_j cannot be attributed to chance. The evidence does suggest that differences between implied and observed prices can be explained, to a large extent, by nonsynchronous observations, and that S_{jt} is frequently a more current estimate of equilibrium stock value than S^*_{jt}.

Despite the evidence in estimating Equation (6), it is still possible that a significant fraction of implied prices represent more recent information than

Table II

Stock Returns and Pricing Errors

Same Day Regression: $\tilde{R}_{jt} = a_j + b_j \tilde{R}_{mt} + c_j \Delta_{jt} + \tilde{u}_{jt}$
Previous Day Regression: $\tilde{R}_{jt} = \alpha_j + \beta_j \tilde{R}_{mt} + \gamma\Delta_{jt-1} + \tilde{\epsilon}_{jt}$

	Number of Companies	Number of Estimates Significant at 5% Level
Same Day:		
Regressions with Positive c_j Estimates	41	1
Regression with Negative c_j Estimates	131	60
Total	172	61
Previous Day:		
Regressions with Positive γ_j Estimates	96	13
Regressions with Negative γ_j Estimates	76	7
Total	172	20

observed stock prices. To investigate this possibility consider Equation (7):

$$\tilde{R}_{jt} = \alpha_j + \beta_j \tilde{R}_m + \gamma_j \Delta_{jt-1} + \tilde{\epsilon}_{jt} \tag{7}$$

Equation (7) is similar to (6) except that the returns on stock j and the market index, m, are now the returns earned on the day following the calculation of the Δ_{jt}. The α_j, β_j and γ_j are constants and $\tilde{\epsilon}_{jt}$ is an error term. In this equation, positive values of the γ_j reflect a combination of two possible influences; either S^*_{jt} provides more recent information regarding stock value, or option market prices reveal information above and beyond that reflected in the stock prices alone (or both).

Table II summarizes the results from estimating Equation (7). The results indicate a tendency for the estimates of γ_j to be positive. In 96 to 172 cases the estimate of γ_j is positive. Of these 96, 13 are significantly different from zero at the 5% level. Of the 76 negative estimates, seven are statistically significant at 5%. In summary, the evidence in Table II suggests that closing stock prices usually, but not always, contain or reflect more recent information than closing option prices. The remaining tests are designed specifically to test for the informational value of implied stock prices.

For every stock that had call option prices reported, the values of Δ_{jt} are calculated on each day of the sample period. The values of Δ_{jt} are then ranked from lowest to highest. Five stock portfolios are formed on the basis of the Δ_{jt} rankings. The first portfolio contains the 20% of the stocks with the lowest values of Δ_{jt} on that day. The fifth portfolio contains the 20% of the stocks in the sample with the highest value of Δ. The number of stocks in each portfolio is nearly equal on each day. However, the time series of the number of stocks in each portfolio varies from 1 to 34 as the number of stocks with listed options increases over time.[12]

If the Δ_{jt} contains information regarding equilibrium prices, then the low Δ portfolios will have lower returns than the high Δ portfolios. Let $\tilde{R}_{pt+1}$ be the pth portfolio on the day following the calculation of the individual Δ_{jt}'s. The return, $\tilde{R}_{pt+1}$, can be thought of as the return that would be earned by following the trading rule indicated below:

(1) compute Δ_{jt} for each stock based on closing option prices on day t;
(2) buy equal weights of all stocks in the pth quintile ranked by the Δ_{jt}. Purchase the stocks at their closing prices on day t; and
(3) Sell the portfolio at the close of day $t + 1$.

It should be clear that the trading rule described above could not be applied in a real world setting since it allows the investor to observe closing prices, make calculations, and trade at the same closing prices.

Recognizing the *ex post* nature of the portfolio formation, it is informative to see if the indicated trading rule provides different expected returns for each of the test portfolios. Table III shows estimated mean returns for each of the five portfolios over the 801 days for which data are available. The table also provides t-statistics for tests of whether the difference between the mean returns for each pair of portfolios is different from zero. In addition, an F statistic testing the hypothesis that average returns are equal for all five portfolios is provided. The information in the table strongly suggests that implied prices contain additional information not fully contained in observed prices. However, whether this information is due to different information being revealed in the options market rather than in the stock market, or merely due to the fact that options close after stocks close, cannot be determined from the information in Table III.

Before turning to additional tests, a discussion of how the numbers in Table III are computed is warranted. Note that from day to day the number of stocks in the five portfolios will vary. Early in the sample period few stocks are included in each portfolio. By the end of the sample period, the five portfolios each contain more than 30 stocks. This changing number of stocks will make the daily portfolio returns heteroscedastic. In general, the return on a portfolio of many stocks will be less volatile than that of a portfolio containing few stocks. To account for this heteroscedasticity, the means reported in Table III, are calculated as follows:

$$\bar{R}_p = \sum_{t=1}^{801} H_t \bar{R}_{pt} / \sum_{t=1}^{801} H_t \tag{8}$$

where H_t is $N_t/5$, and N_t is the number of stocks available for inclusion in the five portfolios on day t. Estimation of the portfolio means in this fashion is equivalent to generalized least squares regression estimates when the residual variance is assumed to vary directly with the reciprocal of the number of securities. The t-statistics and the F-statistic in the table have been computed to account for the

[12] Assignments of extra stocks were made as follows: one extra, portfolio 3; two extras, portfolios 2 and 4; three extras, portfolios 2, 3, and 4; four extras, portfolios 1, 2, 4, and 5.

Table III

Test of Ex-Post Trading Rule

A. Mean Returns and Standard Deviations of Portfolios Ranked on Δ

Portfolio	Mean	Standard Deviation
1	−.000442	.000474
2	−.000051	.000465
3	.000064	.000487
4	.000836	.000506
5	.001418	.000512

B. t-Statistics for Differences between Mean Portfolio Returns (4005 degrees of freedom)

	2	3	4	5
1	1.28	1.62	3.83	5.16
2		.41	2.98	4.29
3			2.45	4.05
4				1.67

$F(4,4005) = 8.735^{a}$ (equality of means test)

[a] Significant at the .0001 level.

heteroscedasticity and for the fact that returns on any given day will be correlated across portfolios.[13]

To test whether the results given in Table III are dependent on the treatment of the potential heteroscedasticity of returns, a related nonparametric test was performed. This test does not test for equality of portfolio mean returns. Instead, it is a test of whether the portfolio formation based on Δ rankings is different from random portfolio selection.

To perform this test, the returns on the five portfolios were ranked on each day. If the portfolio formation were completely random, the return rankings of the five portfolios should not be related to the Δ rankings. On the other hand, if Δ does provide information, the highest ranked portfolio should also have the highest returns. Table IV consists of a 5 by 5 matrix, each element of which represents the number of days out of a total of 801 that a particular portfolio had the indicated return rank.

A chi-square statistic is used to determine whether the pattern of numbers in the matrix is significantly different from random. The calculated value of χ^2 (16) is 94.97 and is highly significant. The probability that the matrix values observed in Table IV could be realized on the basis of chance alone is virtually zero. On the basis of the test for equality of means, and on the basis of the χ^2 test, we cannot reject the hypothesis that there is information in closing option prices not fully reflected in closing stock prices.

Although the tests reported above indicate an informational value in implied prices, we cannot determine if it is due to a true "information" effect or merely a matter of timing. In an attempt to discriminate between these two explanations, the tests discussed in the previous section are repeated. However, instead of

[13] The t and F statistics can be thought of as tests of across-equation linear restrictions in a "seemingly unrelated" regression model (see Zellner [21]) with each of the five equations having heteroscedastics disturbances.

Table IV

Ex-Post Test Frequency Distribution of the Return Ranks of the Five Portfolios

Portfolio	1	2	3	4	5
1	207	162	159	135	138
2	143	185	195	149	129
3	154	175	147	183	142
4	144	150	161	184	162
5	153	129	139	150	230

The no-information hypothesis maintains that the expected value of all entries above is equal to 160.2.

$\chi^2(16) = 94.97^a$

[a] Significant at the .0001 level.

Table V

Test of Ex-Ante Trading Rule

A. Mean Returns and Standard Deviations of Portfolios Ranked on Δ

Portfolio	Mean	Standard Deviation
1	.000161	.000494
2	.000173	.000475
3	.000356	.000467
4	.000361	.000508
5	.000811	.000550

B. t-Statistics on Difference between Portfolio Mean Returns (4000 degrees of freedom)

	2	3	4	5
1	.03	.62	.60	1.77
2		.61	.61	1.80
3			.02	1.33
4				1.32
5				

$F(4{,}4000) = 0.99^a$ (equality of means)

[a] Significant at the .4116 level.

purchasing each portfolio at the closing price of the day the portfolio was formed, the closing price the following day is employed, and the rate of return earned on the second day after the portfolio formation is used. With this procedure, we are assured that the option information we use is available by the time we purchase the stock.

The numbers in Table V are calculated in the same fashion as in Table III. As before, the estimated means, $\bar{R}_{pt+2}$, are in the same rank order as the Δ ranks of the five portfolios. Unlike the tests in Table III, the hypothesis that all five means are jointly equal is not rejected by the F statistic.

The nonparametric test of the random portfolio hypothesis is repeated. The observed rank and portfolio matrix is reported in Table VI. Although the results are much less pronounced than those of the *ex post* tests, the observations do appear to "bunch up" near the extremes of the diagonal. There is a tendency for the lowest ranked portfolio to have the lowest return and the highest ranked portfolio to have the highest return. It is these extremes that make the χ^2 tests significant. The χ^2 value is significant at the 1% level. On the basis of this χ^2 test,

Table VI

Ex-Ante Test Frequency Distribution of the Return Ranks of the Five Portfolios

	Rank				
Portfolio	1	2	3	4	5
1	180	136	174	149	161
2	148	175	171	147	159
3	143	174	169	175	139
4	162	173	159	158	148
5	167	142	127	171	193

The random selection hypothesis maintains that the expected value of all of the above entries will equal 160.

$\chi^2(16) = 38.62$[a]

[a] Significant at the .0001 level.

the hypothesis that yesterday's implied prices contain no information concerning tomorrow's return is rejected.

It appears paradoxical that the F-test fails to reject the equality of portfolio means while the χ^2 test does reject the hypothesis that portfolio formation based on quintiles is random. The reason for this is that the F-statistic is sensitive to the dispersion in the portfolio returns while the χ^2 statistic is not. For example, if on a particular day an extremely high return is earned on the low Δ portfolio, there will be a twofold impact on the calculated F-statistic. First, the observation will bring the estimated mean of the low Δ portfolio closer to the means of the other portfolios. Second, it will contribute to the estimated variance of the portfolio return. It is appropriate that both of these effects make the computed F-statistic less likely to reject the equality of means hypothesis. On the other hand, the χ^2 test is not concerned about the level of portfolio returns, but only its ranking, so that it is not as sensitive to the influence of extreme values.

A word of caution regarding the χ^2 statistic is warranted. Although the χ^2 value in Table VI is highly significant, it does not indicate a profit opportunity. To illustrate, if on each of the 800 days for which returns are calculated, a market participant bought the highest Δ portfolio and sold short the lowest Δ portfolio, he would have earned a positive profit on 414 of 800 days. This represents more profitable days than could be expected by chance. It is this type of information that is captured by the χ^2 statistic. However, for every dollar (long and short) invested, the average daily return would have been only $0.00065, and this amount is not statistically significant. It is this lack of significance that is reflected in the t and F statistics in Table V.

IV. Concluding Remarks

The results of this study show that the closing prices of listed call options contain information about equilibrium stock prices that is not contained in the closing prices of underlying stocks. There appear to be two potential explanations for this finding. The simplest explanation is that closing option and stock transactions do not always take place at the same time. Therefore, it is possible that the additional information contained in closing option prices merely reflects more recent rather than better information. The alternative explanation is that closing option prices reflect fundamental information about the equilibrium values of underlying stocks that is not contained in closing stock prices.

We attempted to isolate the information effect from the nonsynchronous data effect to determine whether a temporary disequilibrium can exist between the options and stock markets. In the test, we attempted to determine whether the information contained in closing option prices could enable an investor to earn excess returns by purchasing (selling) the underlying stock at the closing price the day after implied prices were calculated and maintaining the position for one day. Thus, it was assumed that a 24 hour period elapsed between the time option prices were evaluated and the underlying stocks were traded. Even with the 24 hour time lapse, mean portfolio returns ranked exactly as predicted if option prices had contained information that was not immediately reflected in stock prices. Moreover, there was a statistically significant association between predicted portfolio returns and actual returns. However, it did not appear that the mean returns of the various portfolios were significantly different on either a statistical or economic basis. Nevertheless, there did appear to be evidence that closing option prices contained information that was not reflected in stock prices for a period of up to 24 hours.

REFERENCES

1. Fischer Black. "Fact and Fantasy in the Use of Options." *Financial Analysts Journal* 31 (July/August 1975), 61–72.
2. ——— and Myron Scholes. "The Valuation of Option Contracts and a Test of Market Efficiency." *Journal of Finance* 27 (May 1972), 339–417.
3. ———. "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81 (May/June 1973), 637–59.
4. Edwin Blomeyer and Bruce Resnick. "An Empirical Investigation of the Compound Option Pricing Model." Working Paper, Louisiana State University, Baton Rouge, 1980.
5. Michael Brennan and Eduardo Schwartz. "The Valuation of American Put Options." *Journal of Finance* 31 (May 1977), 449–62.
6. Donald Chiras and Steven Manaster. "The Information Content of Option Prices and a Test of Market Efficiency." *Journal of Financial Economics* 6 (June/September 1978), 213–34.
7. John Cox and Steven Ross. "The Valuation of Options for Alternative Stochastic Processes." *Journal of Financial Economics* 3 (March 1976), 145–66.
8. Dan Galai. "Tests of Market Efficiency of the Chicago Broad Options Exchange." *Journal of Business* 50 (April 1977), 167–97.
9. Gary Gastineau. *Stock Options Manual.* New York: McGraw-Hill, 1975.
10. Robert Geske. "The Valuation of Compound Options." *Journal of Financial Economics* 7 (March 1979), 63–81.
11. Henry Latané and Richard Rendleman, Jr. "Standard Deviations of Stock Price Ratios Implied in Option Prices." *Journal of Finance* 31 (May 1976), 369–81.
12. James MacBeth and Larry Merville. "An Empirical Examination of the Black-Scholes Call Option Pricing Model." *Journal of Finance* 35 (December 1979), 1173–86.
13. Robert Merton. "Theory of Rational Option Pricing." *The Bell Journal of Economics and Management Science* 4 (Spring, 1973), 141–83.
14. ———. "The Impact of Option Pricing of the Specification Error in the Underlying Stock Price Returns." *Journal of Finance* 31 (May 1976), 333–50.

15. ———. "Option Pricing When the Underlying Stock Returns are Discontinuous." *Journal of Financial Economics* 3 (January/March 1976) 125–44.
16. Richard Rendleman and Brit Bartter. "Two State Option Pricing." *Journal of Finance* 34 (December 1979), 1093–1110.
17. Richard Roll. "An Analytic Valuation Formula for Unprotected American Call Options with Known Dividends." *Journal of Financial Economics* 5 (November 1977), 251–58.
18. Mark Rubinstein and John Cox. *Option Markets.* Forthcoming, Prentice-Hall.
19. Richard Schmalensee and Robert Trippi. "Common Stock Volatility Expectations Implied by Option Premia." *Journal of Finance* 33 (March 1978), 129–47.
20. Robert Trippi. "A Test of Option Market Efficiency Using A Random Walk Valuation Model." *Journal of Economics and Business* 29 (Winter 1977), 93–98.
21. Arnold Zellner. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *Journal of the American Statistical Association* 52 (June 1962), 340–68.