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Stock Splits, Volatility Increases, and Implied Volatilities

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ABSTRACT

A test of the efficiency of the Chicago Board Options Exchange, relative to post-split increases in the volatility of common stocks, is presented. The Black-Scholes and Roll option pricing formulas are used to examine the behavior of implied standard deviations (ISDs) around split announcement and ex-dates. Comparisons with a control group of stocks find no relative increase in ISDs of stocks announcing splits. However, a relative increase is detected at the ex-date. Therefore, the joint hypothesis that 1) the Black-Scholes and Roll formulas are true and 2) the CBOE is efficient can be rejected.

RECENT STUDIES BY OHLSON and Penman (1985), Dravid (1984), and Dubofsky and French (1985) have documented significant increases in the observed variance of common stock returns subsequent to splits larger than 25%. This is surprising because, in theory, no real event is associated with the actual day of the split. Dravid (1988) and Lim and Vijh (1986) have tried to explain the post-split variance increase as the effect of stock price discreteness and the bid-ask spread.[1] The evidence in Lim and Vijh (1986) and Ohlson and Penman (1985) suggests, however, that this is at best a partial explanation.[2]

Although the causes of the volatility increase are not apparent, the post-split volatility increase should increase prices of calls (on the splitting stock) that expire after the ex-date relative to those that expire before the ex-date. Similarly, prices of post-split expiration calls on splitting stocks should increase relative to prices of calls on stocks that do not split. In an efficient options market, these relative price changes should occur at the announcement of the split. In fact, Reilly and Gustavson (1985) find that prices of calls on stocks announcing splits do increase relative to prices of calls on a control group of stocks.

A problem with tests based on call price increases is that they may be due to

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[1] Dravid (1984, 1988), e.g., has shown that estimated return variances are biased upward due to the bid-ask spread and rounding of stock prices to the nearest $0.125.

[2] For example, the median post-split serial covariance of returns was positive for the Ohlson and Penman sample, whereas significant discreteness and bid-ask effects would make this covariance negative.

increases in the share prices of firms announcing splits.[3] Moreover, call values are increasing in the time to maturity, and any study of option prices that covers a reasonable period of time (one month in the present study) around the relevant dates will capture a downward move in the values of calls as time progresses. Thus, no clear inference about anticipated stock volatility can be drawn from a simple examination of call price movements around split announcement and ex-dates.

In this paper, I examine the announcement and ex-date behavior of return volatilities implied by call prices, thereby controlling for stock price and maturity changes. The Black-Scholes (1973) and Roll (1977) call option pricing formulas are used to solve for implied standard deviations (ISDs) of stock returns.[4] An increase, on average, over the month surrounding the split announcement, in the implied volatilities of call options maturing after the ex-split date may indicate that the options market properly anticipates the post-split increase in stock return volatility.

Implied volatilities, however, have been found to be negatively related to option maturities (Rubinstein (1985)). Implied volatilities of different stocks also move together (Schmalensee and Trippi (1978)). Therefore, ISDs may increase around split announcements simply because of decreasing maturities of the underlying calls or market-wide changes in anticipated volatilities. The relevant question, addressed in this study, is whether ISDs of stocks that announce a split increase relative to ISDs of other stocks.[5] No such increase is detected at the announcement date. A relative increase is detected at the predictable ex-date, however, and translates into excess returns for market-makers in the options market.

The rest of the paper is organized as follows: the methodology is discussed in Section I. Section II contains the results of the tests, and Section III summarizes and concludes the paper.

I. Methodology

A. Data

The study includes all CBOE optionable stocks that split between December 1, 1976 and December 31, 1983, had split factors larger than 0.25, and did not undergo major structural changes, such as mergers, in the nine months following the split. This leads to a sample of 83 stock splits, of which 30 had split factors smaller than one. The smallest length of time between announcement and ex-dates was 34 days, the largest 165 days. The splits were identified from the CRSP Monthly Master file and checked against a list of stocks with CBOE options.

[3] These increases have been observed at both the announcement and ex-dates by Grinblatt, Masulis, and Titman (1984) and Dravid (1984).

[4] Past work, e.g., Beckers (1981), has found ISDs to be better predictors of the future volatility of stock returns than volatilities estimated from the past time series of returns and strongly suggests that ISDs do reflect the expected future volatility of a stock's returns.

[5] After this research was completed, a paper on the same issue by French and Dubofsky (1986) was brought to my attention. My research, however, differs significantly from theirs because I account for the effect of early exercise by using the Roll model, employ transactions data, carefully screen the data to exclude records that do not represent market prices, and use a control group to abstract from maturity-related and market-wide changes in anticipated volatilities.

The Ohlson and Penman test was repeated on this sample: the post-split standard deviation estimated from daily returns was found to be larger than the pre-split estimated standard deviation in 55 out of 83 cases, with an associated z-statistic of 2.85, which is significantly positive at the 1% level.[6] The median change in estimated standard deviations was 20.6%. Thus, consistent with the findings of Ohlson and Penman, the split sample exhibits a significant ex-date increase in return variances.

It is important to identify the earliest date at which the CBOE may have known about the split. The *Wall Street Journal Index* was scanned for six months prior to the split announcement date on the CRSP files for articles that discussed a possible split before the CRSP date. Eighteen splits were found to have been proposed before the date given by CRSP. For these, the trading day before the date of the *Wall Street Journal* article was taken as the announcement date.

Maturity-related biases in ISDs and market-wide changes in anticipated volatilities were controlled by matching each split with a stock that did not split or announce a split in the period 15 days before the announcement of the split to 15 days after the ex-date. The split and match had comparable betas and monthly return variances in the year preceding the split. Betas and variances were estimated by an OLS regression of (when available) 60 monthly stock returns on the returns to the CRSP value weighted index. When possible, the stocks were also matched on the first two digits of their SIC codes.[7] The return data and the SIC codes were obtained from the CRSP Monthly Returns and Master files.

Transactions data on call options were obtained for one month surrounding the split announcement and ex-dates.[8] The data were retrieved from the Consolidated Data Tapes of the Berkeley Options Data base. These tapes contain a summary of all available trades and quotes on the Chicago Board Options Exchange (CBOE) from August 23, 1976 to December 31, 1983. During each interval when the underlying stock is not traded, all records for a given option are consolidated into a single record containing the high and low option prices during the interval, the contract volumes at the high and the low, the total volume, the number of raw trade and bid-ask records consolidated, the number of bid-ask quotes in the first five minutes of the interval, the last trade price for the stock, and information about preceding and following stock prices.

An option record had to satisfy the following seven criteria to be included in the study:

1) the option matured after the ex-split date;
2) the option had at least 21 days to maturity;

[6] Daily returns for 30 trading days before the split and 31 trading days following the split were obtained from the CRSP Daily Returns file.

[7] The match had to have a standard deviation of monthly returns within 20% of the split's standard deviation of monthly returns. Within this class, the match with the same first two digit SIC code and closest beta was selected for the control group. However, if the resulting beta of the match was not within 20% of the beta of the split, the matching on the basis of SIC codes was dropped, and the match with the closest beta, within a 20% standard deviation range, was selected for the control group.

[8] Given the large number of data tapes to be searched, a period of one month was chosen as a compromise between a reasonable period for allowing the CBOE to react to the split and cost considerations.

3) $0.85E \leq P \leq 1.15E$, where P denotes the stock price and E the exercise price of the call;
4) the record did not occur in the first 1000 seconds after 9:00 A.M. or in the last 1000 seconds before 3:00 P.M.;
5) the high and low option prices did not differ by more than $0.25;
6) at least three contracts were traded during the constant stock price interval; and
7) at least three raw records were consolidated.

The first condition is necessary for the purpose of the study and needs no discussion. The second criterion eliminates very short maturity calls, and the third eliminates calls that are deep in the money or deep out of the money. These calls are excluded because their implied volatilities are extremely sensitive to small changes in the call price.[9] The remaining four criteria are to ensure that we use records that reflect market prices.[10] The fourth criterion eliminates trades that may have been held over from the previous day and market-maker quotes at the end of the day to influence their margin requirements. The tight option price interval is desirable so as to obtain a relatively accurate option price. The last two criteria ensure that the option is traded in some depth. These sampling restrictions resulted in a total of 20,206 option records in the month around the split announcement and 28,329 observations around the ex-split date.

The interest rate used was the yield to maturity of a Treasury bill with maturity closest to the maturity of the option. Treasury bill yields were obtained from the CRSP Fama Term Structure files. Since these data are recorded on a monthly basis, a simple convex combination was used to interpolate the interest rates between the record dates.[11]

Dividend data were collected from the CRSP Monthly Master file. Past researchers have used actual dividends in the computation of Black-Scholes or Roll values or to obtain ISDs. This study uses the market's expectations of future dividends. Since most stocks that pay dividends seldom change their dividends and tend to pay dividends at the same time (usually the same day of the week) every year, it is reasonable that the market uses the last quarterly (monthly, semi-annual, annual) dividend when a normal quarterly (monthly, etc.) dividend is expected. Therefore, if a dividend is expected but not announced, the last similar announced dividend is used. When a stock follows a predictable pattern with extra or special dividends, these are treated as regular dividends. Other extra dividends are considered only as they are announced.[12]

The Roll (1977) formula strictly applies only to calls with a single dividend

[9] See Schmalensee and Trippi (1978) and Beckers (1981). Butler and Schachter (1984) point out that ISDs are biased estimates of the true standard deviation of stock returns due to the nonlinearity of the Black-Scholes formula in this standard deviation. Nevertheless, their simulations also show that averaging the ISDs from several close-to-the-money calls tends to cancel out the biases in individual ISDs.

[10] These are derived from Rubinstein (1985).

[11] This should not affect the results significantly because the pricing formulas are insensitive to the interest rate.

[12] The effect of the dividend adjustment was checked by repeating part of the analysis with actual dividends. The results did not change significantly.

before maturity. Restricting attention to such calls, however, would have resulted in a very small sample. Therefore, calls with more than one dividend before maturity were included in the sample, but early exercise was considered only at the last ex-dividend date before maturity. This has a negligible effect on ISDs because it is very unlikely that a call will be exercised before the last ex-dividend date before maturity.[13]

Implied standard deviations of daily returns were obtained using numerical search procedures until the resulting call value was within $0.01 of the market price.[14] The market price of the call was computed as the weighted average of the high and low call prices, using contract volumes as weights. If both these volumes were zero, the simple arithmetic average of the high and low prices was used. The ISDs were restricted to the range [0.001, 0.1] because these were felt to be reasonable limits for daily stock return standard deviations. Twenty thousand, one hundred four of the 20,206 option records around the announcement, and 28,149 of the 28,329 records around the ex-date, had convergent solutions.

B. Tests

Because the results may be sensitive to the way ISDs are aggregated, three different measures are used to test the effect of the split announcement and ex-dates on anticipated volatility. The first, σ_1, uses the sample mean of the ISDs of each stock to obtain a single ISD for that stock both before and after the event; e.g., all the ISDs obtained from IBM options in the two weeks before the split announcement are averaged into a single pre-announcement ISD for IBM, and all the ISDs for IBM in the two weeks after the announcement are averaged into a single post-announcement ISD for IBM. Percent changes in σ_1 are then obtained for each stock, and the paired-sample sign test and the Wilcoxon signed-rank test are applied to these percent changes across the sample of stocks. The null hypothesis of no change in ISDs is tested against the one-sided alternative of an increase in ISDs. For example, referring to the first row of Table I, out of 83 stocks announcing splits, there were 62 for which at least one option record passed the data screens in the two weeks before the announcement as well as the two weeks after the announcement, allowing the computation of σ_1 both before and after the announcement. Of the 62 stocks, 39 had positive percent changes in σ_1, with a median change of 2.76% and an associated paired-sample sign test statistic of $\dfrac{(39-0.5) - 62/2}{\sqrt{62/4}} = 1.91$ and a Wilcoxon signed-rank test statistic of 2.4, both of which are significantly positive.

The second measure, σ_2, uses, for each stock, the pre- and post-event sample

[13] Calculations assuming dividends four months and one month before maturity and an annual interest rate of 10% show that a dividend yield in excess of 6.7% is required for early exercise of a deep-in-the-money call at the first dividend date. This is larger than the dividend yield on all of the 30 stocks in the Dow Jones Industrial Average. Thus, with quarterly dividends it is extremely unlikely that a call will be exercised early except at the last ex-dividend date before maturity.

[14] An IMSL routine, MDBNOR, was used to compute the cumulative bivariate normal density for the Roll formula.

Table I

Changes in Implied Standard Deviations (ISDs) of Stock Returns Around Stock Split Announcements

The changes are for 83 stocks that split between December 1, 1976 and December 31, 1983, and for a control group of stocks. The control group is formed by matching each splitting stock with a nonsplitting stock of similar beta and standard deviation of returns. The Roll (1977) formula is used to compute ISDs. σ_1 is the sample mean of the ISDs from all call records on a given stock. σ_2 is the sample mean of the ISDs from call records with $0.95E \leq P \leq 1.05E$ and $\tau > 70$, where E denotes the exercise price, τ the number of days to expiration of the call, and P the stock price. σ_3 is obtained by setting $R_{ij} = 1$ in the OLS regression estimates of $ISD_{ij} = \alpha_i + \beta_i R_{ij}$, where i indexes stocks, j indexes call records on the stock, and R_{ij} is the ratio of the stock price net of escrowed dividends to the present value of the exercise price of the call. For a given stock, each measure is obtained before and after the announcement and the percent change in the measure is computed. Under Splits and Controls: N is the number of stocks for which there were enough call records to allow computation of the given measure, both before and after the announcement. $N+$ is the number of stocks for which the post-announcement ISD measure exceeded the pre-announcement ISD measure. Correlation with Actual Ex-Date Changes is the Spearman rank correlation between the percent changes in the given ISD measure and ex-date changes in standard deviations estimated from daily returns. Under Difference Between . . . : N is the number of observations where there were enough call records for both a split and its control to allow computation of the given ISD measure before and after the announcement. $N+$ is the number of observations where the percent change in a split's ISD exceeded the percent change in the ISD of its control.

	Splits				Controls			Difference Between the Percent Change in the ISD of a Split and the Percent Change in the ISD of Its Control		
Aggregate ISD Measure	N	$N+$	Median % Change	Correlation with Actual Ex-Date Changes	N	$N+$	Median % Change	N	$N+$	Median
σ_1	62	39	2.76[a,b]	−0.06	58	37	2.36[a,b]	49	24	−0.05
σ_2	52	30	2.76[b]	−0.03	46	25	0.98	29	14	−1.71
σ_3	59	34	2.18	−0.05	53	28	1.48	43	21	−0.57

[a,b] Using the paired-sample sign test and the Wilcoxon signed-rank test, respectively, we can reject, at the 5% level, the null hypothesis of 1) no change in the given ISD measure against the one-sided alternative of a positive percent change, for the within-group comparisons and 2) no difference between splits and controls in percent changes in the given ISD measure against the one-sided alternative of a positive difference, for the between-group comparisons.

means of ISDs from options with more than 70 days to maturity and with a ratio of the stock price to the present value of the exercise price between 0.95 and 1.05, i.e., middle to long maturity, very near-the-money calls. These restricted sample means are tested in the same way as σ_1. The number of observations for σ_2 is smaller than that for σ_1 because σ_2 imposes stricter sampling screens on the options data.[15]

For each period, the third method regresses all ISDs of a given stock on the ratio of the stock price (net of escrowed dividends) to the present value of the

[15] Tests based on sample medians, for σ_1 and σ_2, yield similar results.

exercise price used in computing the ISDs. The resulting estimates are used, for each stock, to obtain a pre- and post-event ISD for an at-the-money option, i.e., one for which the above ratio is unity. This last measure, denoted σ_3, is subjected to the same tests as σ_1 and σ_2. The number of observations for σ_3 is smaller than that for σ_1 because σ_3 requires at least two option records for each stock to pass the data screens, both before and after the relevant event, while σ_1 requires only one option record for each stock in each of the two periods.

In addition to testing whether the ISDs of the split or control group increase around the relevant event, I test whether the percent change in an ISD measure (σ_1, σ_2, or σ_3) for a splitting stock is larger than the percent change in the same measure for its control. The number of observations for the between-group comparisons is smaller than that for the within-group comparisons because the between-group comparisons require enough option records to pass the data screens to compute a change in ISDs for both the split and control, while the within-group comparisons require only enough observations for each group separately.

II. Results

A. The Behavior of Implied Volatilities

The behavior of ISDs around split announcements is given in Table I. Both the splits and the controls show increases in implied variances, with σ_1 providing the most significant increase. Comparisons between the two groups show, however, that the percent changes in split ISDs are not significantly different from the percent changes in the ISDs of their controls. Further, as the fifth column of the table shows, there is very low and statistically insignificant Spearman rank correlation between the announcement date percent changes in ISDs of splitting stocks and the ex-date percent changes in their standard deviations estimated from stock return data. The announcement date increase in ISDs thus seems to be due to factors other than anticipation of a post-split variance increase. One possible explanation lies in a negative relationship between maturity and implicit variances, as noted for out-of-the-money options by Rubinstein (1985).

The behavior of ISDs around split ex-dates is given in Table II. All of the three ISD measures increase significantly for the split group. In contrast, the control group exhibits, for the most part, a statistically insignificant decrease in ISDs during the split period. Comparisons between the two groups show that the percent changes in split ISDs are larger than the percent changes in the ISDs of their controls, and significantly so for σ_1 and σ_2.[16] Further, the fifth column of Table II shows that there is a significantly positive correlation between the ex-date percent changes in ISDs of splitting stocks and the ex-date percent changes in their standard deviations estimated from daily returns. Thus, the CBOE picks up the ex-date variance increase as it occurs.[17]

[16] The statistical insignificance of the results for σ_3 may be due to nonlinearities in the relationship between depth in the money and ISDs which are not captured by the linear model employed in this paper.

[17] Interesting details were uncovered by a closer examination of ISD changes over the entire period.

Table II

Changes in Implied Standard Deviations (ISDs) of Stock Returns Around Stock Split Ex-Dates

The changes are for 83 stocks that split between December 1, 1976 and December 31, 1983, and for a control group of stocks. The control group is formed by matching each splitting stock with a nonsplitting stock of similar beta and standard deviation of returns. The Roll (1977) formula is used to compute ISDs. σ_1 is the sample mean of the ISDs from all call records on a given stock. σ_2 is the sample mean of the ISDs from call records with $0.95E \leq P \leq 1.05E$ and $\tau > 70$, where E denotes the exercise price, τ the number of days to expiration of the call, and P the stock price. σ_3 is obtained by setting $R_{ij} = 1$ in the OLS regression estimates of $ISD_{ij} = \alpha_i + \beta_i R_{ij}$, where i indexes stocks, j indexes call records on the stock, and R_{ij} is the ratio of the stock price net of escrowed dividends to the present value of the exercise price of the call. For a given stock, each measure is obtained before and after the ex-date and the percent change in the measure is computed. Under Splits and Controls: N is the number of stocks for which there were enough call records to allow computation of the given measure, both before and after the ex-date. $N+$ is the number of stocks for which the post-split ISD measure exceeded the pre-split ISD measure. Correlation with Actual Ex-Date Changes is the Spearman rank correlation between the percent changes in the given ISD measure and ex-date changes in standard deviations estimated from daily returns. Under Difference Between . . . : N is the number of observations where there were enough call records for both a split and its control to allow computation of the given ISD measure before and after the ex-date. $N+$ is the number of observations where the percent change in a split's ISD exceeded the percent change in the ISD of its control.

	Splits				Controls			Difference Between the Percent Change in the ISD of a Split and the Percent Change in the ISD of Its Control		
Aggregate ISD Measure	N	$N+$	Median % Change	Correlation with Actual Ex-Date Changes	N	$N+$	Median % Change	N	$N+$	Median
σ_1	51	35	5.73[a,b]	0.48[c]	63	22	−3.59[a]	46	32	7.59[a,b]
σ_2	40	28	6.33[a,b]	0.34[c]	43	22	0.014	24	15	6.50[b]
σ_3	48	27	3.97[b]	0.41[c]	58	25	−2.16	41	23	4.17

[a,b] Using the paired-sample sign test and the Wilcoxon signed-rank test, respectively, we can reject, at the 5% level, the null hypothesis of 1) no change in the given ISD measure against the one-sided alternative of a positive percent change, for the within-group comparisons and 2) no difference between splits and controls in percent changes in the given ISD measure against the one-sided alternative of a positive difference, for the between-group comparisons.

[c] Significantly different from zero at the 5% level.

The median difference between splits and controls in percent increases in σ_1 is 7.59% in the month around the split. This difference is less than half the 20.6% median increase in standard deviations estimated from daily returns and is closer to the Ohlson and Penman finding of an 11% increase in estimated

No absolute or relative increase in ISDs of splitting stocks is found between the announcement and the ex-date. A significant absolute and relative increase occurs in just fifteen days around the ex-date, and this increase has a significant positive correlation with the increases in standard deviations estimated from daily returns. Moreover, ISDs of splitting stocks continue to increase relative to the control group beyond the seventh day after the split.

standard deviations of monthly returns. This indicates that part, but not all, of the ex-date increase in estimated standard deviations of daily returns may be due to measurement effects, such as the bid-ask spread and rounding of stock prices to the nearest $0.125, and is consistent with the findings of Lim and Vijh (1986) and Dravid (1988).

B. Economic Significance

The next natural question is: given that the CBOE did not react to the post-split variance increase until the predictable ex-date, were there economic profits to be made? To abstract from the noted increase in the prices of splitting stocks, I study percent changes in the value of the following index:

$$BS = N\left[\frac{\sigma\sqrt{180}}{2}\right] - N\left[\frac{-\sigma\sqrt{180}}{2}\right].$$

This is simply the ratio of the Black-Scholes value of a six-month, at-the-money call to the price of the underlying stock.[18] The value of this index is seen to depend only on the variance of stock returns, and percent changes in BS are indicative of the returns accruing to call options aside from stock price and maturity changes. The index is computed for each stock, both before and after the ex-date, using σ_1, σ_2, and σ_3.

Panel A of Table III contains the median returns from this index around ex-split dates. The median return to the split sample exceeds that of the control group for all three expected volatility measures, with the difference in median returns (over, at most, one month) ranging from 6.08% for σ_3 to 9.28% for σ_1.

Transaction costs, however, allow only market-makers to capture these excess returns. For each split, returns inclusive of transaction costs are obtained for an at-the-money, six-month call. The value of this call is obtained before and after the ex-date using the pre-split median stock price and pre- and post-split values of σ_1. Transaction costs are then added to the value of this call when it is purchased before the split and subtracted when it is sold after the split. Public traders and arbitrageurs are assumed to pay a $0.125 bid-ask spread, while market-makers are assumed to earn the same spread.[19] Commission costs for the public are based on a schedule from Charles Schwab and Co., Inc. Clearing costs are assumed to be $1.50 and $0.50 per contract for arbitrageurs and market-makers, respectively.[20] Panel B of Table III contains the returns based on this

[18] For the index, depth in the money is measured as the ratio of the stock price to the present value of the exercise price.

[19] This assumes that market-makers are able to shift part of their scalping activities to calls on splitting stocks and continue to buy at the bid and sell at the ask. To the extent that they want to ensure their buy orders before the split and sell orders after the split, this may not be possible, and then their returns would be similar to those of arbitrageurs. Nevertheless, given the long time period between split announcement and ex-dates, it is very likely that market-makers can wait to buy at the bid and sell at the ask. Thus, it is reasonable that market-makers could have earned the returns given in Panel B of Table III.

[20] These costs are at the lower end of the ranges given in Phillips and Smith (1980) and represent discounted transaction costs. Nevertheless, costs from the higher end of the range do not change the results significantly.

Table III

Returns to a Call Index Around Ex-Split Dates

The returns are for calls on 83 stocks that split between December 1, 1976 and December 31, 1983, and for calls on a control group of stocks. The control group is formed by matching each splitting stock with a nonsplitting stock of similar beta and standard deviation of returns. The value of the index is computed as $N\left[\frac{\sigma_i\sqrt{180}}{2}\right] - N\left[\frac{-\sigma_i\sqrt{180}}{2}\right]$, where σ_i is one of three aggregate ISD measures. The Roll (1977) formula is used to compute ISDs. σ_1 is the sample mean of the ISDs from all call records on a given stock. σ_2 is the sample mean of the ISDs from call records with $0.95E \leq P \leq 1.05E$ and $\tau > 70$, where E denotes the exercise price, τ the number of days to expiration of the call, and P the stock price. σ_3 is obtained by setting $R_{ij} = 1$ in the OLS regression estimates of $\text{ISD}_{ij} = \alpha_i + \beta_i R_{ij}$, where i indexes stocks, j indexes call records on the stock, and R_{ij} is the ratio of the stock price net of escrowed dividends to the present value of the exercise price of the call. For a given stock, each measure is obtained before and after the ex-date and the percent change in the resulting index value is computed. N is the number of splitting stocks with enough option records to allow the computation of the index before and after the ex-date. $N+$ is the number of splitting stocks with positive index returns.

Panel A: Median Gross Returns, Separately for Each Group

ISD Measure	Splits	Controls
σ_1	5.71%[a]	−3.57%
σ_2	6.29%[a]	0.01%
σ_3	3.94%	−2.14%

Panel B: Transaction Costs Adjusted Returns for Split Group[b]

Trader Group	N	$N+$	Median % Return
Public	51	12	−10.6[a]
Arbitrageurs	51	29	1.8
Market-Makers	51	42	8.7[a]

[a] Significantly different from zero at the 5% level, using the Wilcoxon signed-rank test.

[b] Transaction costs are based on the dollar value of one call contract. For each split, this call value is computed using the median stock price in the 15 days before the split and the pre- and post-split value of σ_1.

procedure. The transaction costs adjusted returns are significantly negative for the public, close to and insignificantly different from zero for arbitrageurs, and high and significantly positive for market-makers. The median return to market-makers is 8.7%, with 42 of 51 splits providing positive returns. Since these returns abstract from stock price movements, the positive variance and stock price effects together should make calls on splitting stocks an unusually attractive investment for market-makers.[21]

[21] Actual returns from buying an at-the-money call ($0.95E \leq P \leq 1.05E$) in the 14 days before the

III. Summary and Conclusion

The results show that the CBOE did not anticipate post-split increases in stock return variances. Although ISDs of splitting stocks increase at both the announcement and the ex-date, the increase at the announcement is not significantly different from the change in ISDs of the control group and is unrelated to the ex-date increase in return variances. On the other hand, the ex-date increase in ISDs of splitting stocks is significantly larger than the change in ISDs of the control group and is significantly correlated with the ex-date increase in return variances. The ex-date increase in ISDs is smaller than the increase in standard deviations estimated from daily returns, indicating that the post-split increase in observed return variances is partly due to measurement effects. The ex-date increase in implied variances translates into excess returns to market-makers from calls on splitting stocks.

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split and holding it for 14 days were computed for the sampled records. The median return was 14.7% for the splits and −8.8% for the controls. The 14-day decrease in maturity implies a decline of 6% in the value of a six-month, at-the-money call. The negative returns to the control group, therefore, are driven largely by maturity changes. Moreover, given the 6% decline due to maturity changes, the return due to volatility and stock price increases is 14.7 + 6 = 20.7% for the splits. Of this, 6.3% (the index return for σ_2 in Table III, Panel A) is due to volatility increases, so that 14.4% is due to stock price increases. The elasticity of an at-the-money, six-month call is about 6, so that the 14.4% call return corresponds to a stock return of 2.4%, which is close to the 1.9% return in the 14 days around stock splits found by Grinblatt, Masulis, and Titman (1984).

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