

Circuit Breakers and Stock Market Volatility

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INTRODUCTION

Circuit breakers were first introduced by the New York Stock Exchange (NYSE) in 1988 in the form of NYSE Rule 80A. The rule imposed restrictions on use of the NYSE Designated Order Turnaround (DOT) System to enter orders involving index arbitrage when the DOW Jones Industrial Average (DJIA) reached a level of 50 or more points above or below its previous closing level.¹

Rule 80A has evolved over time and other rules have been added. The rationale advanced by the NYSE in implementing the rules is "The Exchange and other market centers have been concerned that sophisticated trading strategies related to program trading may create excess volatility that undermines investor confidence in the fairness and orderliness of the securities markets, and may in fact constitute a threat to the viability of American capital markets."² These are strong claims suggesting that the trading strategies increase the variation in securities prices to a level that drives business elsewhere.³

Excess volatility, the notion underlying the rationale for circuit breakers, is a troublesome concept. It suggests there are times when herd instincts cause investors to push prices to levels (either higher or lower) that some cooler heads know are unsupportable.

¹Index arbitrage involves trading on small and short-lived price differences for the same group of stocks in the spot, futures, and options markets. For further discussion see Cinar (1987), Cornell and French (1983), Figlewski (1984), Fortune (1989), Modest and Sundaresan (1983), Stoll (1988), and Stoll and Whaley (1987). However, the NYSE applies Rule 80A to "any trading strategy involving the related purchase or sale of a 'basket' or group of 15 or more stocks having a total market value of \$1 million or more (NYSE Information Memo 88-29, October 19, 1988)." The DOT system is a high-speed, order-routing system that arbitrageurs use to facilitate execution of simultaneous trades in the cash and futures market.

²See for example, Torres (1990) and Torres and Salwen (1990). Program trading is a computer assisted technique used to monitor price differentials between markets and to quickly execute trading strategies. Index arbitrage is a form of program trading.

³They are strong claims because evidence of the effect of trading in stock index futures and options on cash market price volatility is mixed. Some studies have found no effect. See, for example, Schwert (1990), pp. 31-32; Beckeki and Roberts (1990); Fortune (1989); Davis and White (1987); and Santoni (1987). Stoll (1988) finds a statistically significant increase in the variance of stock prices on days futures and options expire ("Triple Witching Days"). See also Herbst and Maberly (1990) on this issue, Harris (1988), Hodrick (1990), Jones and Wilson (1989), Lockwood and Linn (1990), and Edwards (1988a) and (1988b) report mixed results while Lockwood and Linn (1990) conclude that the advent of trading in stock index futures in 1982 coincides with an increase in the variance of cash market returns.

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For some unexplained reason, these better informed individuals fail to take advantage of the profitable trading opportunity.

Circuit breakers are an attempt to prevent "excess price volatility" by preventing or restricting program trading. The advocates of circuit breakers believe they are effective because index arbitrage is thought to be a major source of price volatility.⁴ An alternative view concerning the effect of circuit breakers suggests that program trading has little impact on price volatility so these new trading rules are not likely to be effective. Furthermore, fear that a trading restriction will occur as prices approach known limits may cause an increase in volatility if most investors value liquidity very highly.⁵

This article is an empirical examination of the effect of recent circuit breaker rules on the volatility of prices in the cash market for stocks. Previous work suggests that stock returns sampled at high frequency have a variance that follows an autoregressive conditional heteroskedastic (ARCH) process.⁶ This study estimates this process with an ARCH model for daily data from July, 1962–May, 1991 and tests for structural breaks subsequent to the adoption and revision of the circuit breaker rules. Also, data on the variance of intraday returns on days when circuit breakers are triggered is examined to determine whether this data is consistent with the notion that circuit breakers reduce price volatility.

Previous work on the effects of circuit breakers has concentrated on one type of circuit breaker or has focused on some of the days when circuit breakers have been triggered.⁷ While this work is very useful, it has not controlled for the cyclical pattern in the variance of high frequency returns noted above. This is important because without this control it is difficult to interpret differences in the variance of stock returns observed at different times.

A SUMMARY OF THE CIRCUIT BREAKERS

On February 9, 1988, about 3 months after the October, 1987 crash, the NYSE announced adoption of trading Rule 80A and asked members to voluntarily comply with the new rule pending approval by the Securities and Exchange Commission (SEC). The SEC approved the rule for a 6-month trial period on April 19 and the NYSE made compliance mandatory on May 4. The Rule was the first of a growing list of circuit breakers aimed at reducing the volatility of stock prices. About 2 months later, the Chicago Mercantile Exchange (CME) imposed opening and intraday daily price limits on the Standard and Poor's 500 futures contract. A summary of the provisions of these rules and others along with revisions and amendments is presented in Table I.

When the 6-month trial period for Rule 80A expired on October 19, 1988, the NYSE and CME adopted new rules aimed at coordinating their procedures for handling significant market volatility. The CME imposed a 12-point daily *down* limit on its S&P 500 futures contract. The new rules adopted by the NYSE eliminated the 50-point collar on the DJIA and substituted a "sidecar" procedure (New 80A) for market orders

⁴See Report of the Presidential Task Force on Market Mechanisms (1988), and the U.S. General Accounting Office (1988).

⁵See Schwert (1990), p. 33.

⁶See Mandelbrot (1963), Fama (1965), and Bollerslev (1987).

⁷Kuserk, Locke, and Sayers (1991) and the *Interim Report* of the New York Stock Exchange (1991) examine the July 31, 1990 "up-tick/down-tick" amendment to Rule 80A. On the other hand, Moser (1990) and Kuhn, Kurserk, and Locke (1989) examine the effect of circuit breakers on cash market returns during the October 13, 1989 "mini crash."

Table I
A CHRONOLOGICAL SUMMARY OF THE CIRCUIT BREAKERS^a

Rule	Date Effective	Main Provisions
NYSE 80A(Voluntary) SEC Approval Mandatory CME 4002.J	2/09/88 4/19/88 5/04/88 3/28/88	Restricts use of the NYSE DOT System for purposes of index arbitrage when the DJIA breaches a 50-point collar around its previous day's closing level. ^b Halts trading of the S&P 500 futures contract when its price is more than the daily price limit above or below its previous days's closing level Price Range 0.00-275.00 275.05-325.00 325.05 and up Limit 15.00 points 20.00 points 25.00 points ^c
CME 4002.I	4/01/88	The S&P 500 futures contract may not open 5 points above or below its previous day's closing level. This restriction applies from 8:30-8:40 Chicago time. If the price remains at the limit at 8:40, a further 2-minute halt is declared and a new opening range is established after which trade resumes.
NYSE new 80A supersedes old 80A	10/20/88	Provides priority delivery of simple individual investor orders up to 2099 shares that are entered via the DOT system on any day the DJIA breaches a 25-point collar around its previous day's close. When the nearby S&P 500 futures contract falls 12 points below its previous day's closing level, NYSE market orders pertaining to index arbitrage delivered via the DOT system are routed to a "side-car" for 5 minutes prior execution.

Table I (continued)

Rule	Date Effective	Main Provisions
CME amendment to 4002.I	10/20/88	Amends CME 4002.I to include a 30-minute halt in trading of the S&P 500 futures contract when its price <i>falls</i> 12 points or more below its previous day's closing level. Provides for trading halts coordinated with those on the NYSE.
NYSE 80B	10/20/88	Equity trading on the NYSE is halted for 1 hour if the DJIA <i>falls</i> 250 points or more below its previous close. Equity trading is halted for 2 hours if the DJIA <i>falls</i> 400 points or more below its previous day's closing level.
NYSE amendment to 80A	7/31/90	When the DJIA declines 50 or more points from its previous day's closing level, all index arbitrage orders to sell any component stock of the S&P 500 must be executed on an up-tick in the stock. The reverse applies to 50 point advances in the DJIA.
CME revised 4002.I	12/13/90	Halts trading of the S&P 500 futures contract at a price of 20 points above or below its previous day's closing level.

^aSources: New York Stock Exchange, Information Memos Number 88-12 dated May 4, 1988; Number 88-29 dated October 19, 1988; Number 90-33 dated July 31, 1990; Consolidated Rules of the Chicago Mercantile Exchange, Special Executive Report Number S-2328 dated December 17, 1990.

^bThe DOT system is a high-speed, order-routing system that arbitrageurs use to facilitate execution of simultaneous trades in the cash and futures markets.

^cSubsequently raised to 30 points.

pertaining to index arbitrage whenever the S&P 500 futures contract was offered limit down on the CME. Essentially, the new procedure routes any index arbitrage orders delivered through the DOT system to an undisclosed system file (the sidcar) for a 5-minute period prior to execution. At the same time, the two exchanges adopted procedures for coordinated trading halts during periods of "extraordinary" price volatility.

The 50-point collar on the DJIA was reintroduced in July 1990 by an amendment to Rule 80A. The amendment requires that all index arbitrage orders to *sell* any component stock of the S&P 500 must be executed on an *up-tick* in the price of the stock on days when the DJIA declines by 50 points or more from its previous day's close. On days when the DJIA rises by 50 points or more, all index arbitrage orders to *buy* any component stock of the S&P 500 must be executed on a down-tick in the share price.

In large part, these trading rules are directed at reducing the volatility of stock prices in the cash market by restricting index arbitrage on days when stock prices are moving rapidly. The NYSE *Interim Report* (1991) indicates that the rules are effective in restricting index arbitrage. It also reported that the up-tick/down-tick amendment to Rule 80A increases execution times for index arbitrage orders from about 1.5 minutes to about 30.0 minutes on days when the rule is triggered.⁸ As a result, it is virtually impossible for arbitrageurs to establish simultaneous cash and futures positions. This raises the risk associated with index arbitrage. The increase in risk is not trivial. Index arbitrage activity falls by about 30.0% on days the rule is triggered on the downside and by about 60.0% on days the rule is triggered on the upside. Of course, evidence that circuit breakers disrupt index arbitrage does not imply that they reduce price volatility in the cash market.

STOCK PRICE VOLATILITY AND ARCH

Stock price volatility is generally measured by the variance of the rate of return. When prices are sampled at high frequency, the rate of return is proxied by the percentage change in price. Previous work indicates that the rates of return implicit in the time series of stock prices are serially uncorrelated and well described by a unimodal distribution with fatter tails than the normal.⁹ While uncorrelated, the returns are not independent. In particular, large percentage changes in price tend to be followed by large changes (of either sign); while small changes tend to be followed by small changes.¹⁰ This suggests that the general measure of price volatility is temporally dependent (heteroskedastic). A meaningful comparison of price volatility across different time periods can only be made if the comparison controls for this time dependence.¹¹

This article accounts for the temporal dependence in the variance of stock returns by applying an Autoregressive Conditional Heteroskedastic (ARCH) model to the variance and tests to determine whether the parameters of the model change subsequent to the adoption, revision, or triggering of the various circuit breakers.

The idea underlying the ARCH model is that the variance of the time series is subject to change with the change in period t conditional on the changes in period $t - 1$, $t - 2$, etc. More formally, denote the percentage change in an index of stock prices as Y_t . The

⁸*Ibid.*, p. 6. Execution time is measured from the time the specialist receives the order to the time it is reported as executed.

⁹See Mandelbrot (1963), Fama (1965), and Bollerslev (1987).

¹⁰See Mandelbrot (1963), p. 418; Bollerslev (1987), p. 542; and Diebold (1988), Chapter 2.

¹¹See Diebold (1988), p. 36.

ARCH model can be written in the following form.¹²

$$Y_t = M_t + \varepsilon_t \quad (1)$$

$$\varepsilon_t = u_t h_t^{\frac{1}{2}} \quad (2)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + \dots + \alpha_{p-q} \varepsilon_{t-q}^2 \quad (3)$$

Equation (1) expresses the return, Y_t , in terms of its conditional mean, M_t , and disturbance, ε_t . The model assumes that ε_t is the product of an i.i.d. disturbance, u_t , and a term, $\sqrt{h_t}$, that is a function of past information as in eq. (3). When eq. (3) is respecified as in (4),

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + \dots + \alpha_p \varepsilon_{t-p}^2 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \dots + \beta_q h_{t-q} \quad (4)$$

it is referred to as a Generalized ARCH model or GARCH (p, q). Given restrictions on the parameters of eq. (4), such that h_t is positive, the model has the property that volatility shocks last more than one period with the effect of shocks represented by the expression for the conditional variance, h_t . Once an appropriate GARCH model is estimated, a solution for the implied time series of the conditional variance can be obtained. This yields a meaningful measure of volatility since any uncertainty that can be removed by conditioning on past observations is economically irrelevant.

DAILY DATA AND TESTING FOR ARCH

The daily data used in this article are closing levels of the S&P 500 composite index from July 1962–May 1991. This data set contains roughly 7200 observations. It is used to determine whether the adoption of various circuit breaker rules is associated with a significant reduction in the volatility of stock prices. A subsequent section of the article uses intraday data to examine price volatility on days when circuit breakers are triggered.

Figure 1 plots the first differences of the log of daily closing levels of the S&P 500 composite index multiplied by 100.¹³ The data are approximately daily percentage changes in the index (daily returns). The average daily return for the sample is 0.025 with a standard deviation of 0.898 suggesting that the typical variation in daily returns falls within a range of roughly ± 1.0 percent. However, examination of Figure 1 suggests that variation in daily returns differs over some shorter intervals, i.e., the daily return data are heteroskedastic. Fitting an ARCH model for this process is a way of controlling for the heteroskedasticity that is conditional on past realizations of the series.

To test for the presence of an ARCH process, the squared differences between the daily return data and its mean are regressed on a constant and eight own lags. The test for ARCH is a Lagrange multiplier test of the null hypothesis of no ARCH effects. The test statistic is distributed chi-square with 8 degrees of freedom and is the product of the regression R^2 (0.0499 in this case) and the number of observations in the sample (7168). The calculated test statistic, 357.68, is sufficiently high to reject the null hypothesis at conventional confidence levels. It confirms that a significant ARCH process is present in the daily return data.

¹²See Engle (1982), Bollerslev (1986), Nelson (1991), Greene (1990), and Lamoreux and Lastrapes (1990).

¹³The observations are calculated as follows:

$$\Delta L \eta P_t = L \eta (P_t / P_{t-1}) \times 100$$

where P = the daily closing level of the S&P 500.

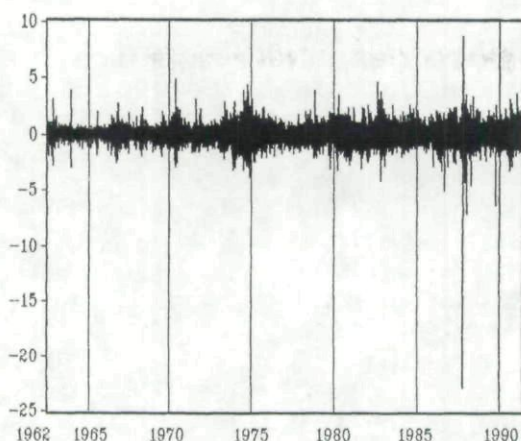


Figure 1

DID ADOPTION OF CIRCUIT BREAKERS REDUCE VOLATILITY?

Table II reports the coefficient estimates of the model given in (1)–(4). The parameters are estimated simultaneously using maximum likelihood techniques.¹⁴ The estimates include a dummy variable (D_o) to control for the unusually large increase in volatility immediately surrounding the October, 1987 crash in stock prices (October–December 1987). The estimated coefficient of the dummy variable is positive and significant and it indicates that the intercept of the estimate is roughly 100 times higher during this time.

The tests for the effect of the circuit breaker rules proceed as follows. Various dummy variables are included in the estimate that correspond to periods following the adoption and revision of circuit breaker rules by the NYSE and CME (see Table I). The dummies are included one at a time in the following order. A dummy Beginning February 9, 1988, and extending through the end of the sample is included to determine whether a significant change in the conditional variance is associated with the initial adoption of Rule 80A. The coefficient of this dummy is positive and significant (t -score = 10.84). Of course, this result may be due to other rules or revisions of 80A that were adopted subsequent to February 9, 1988. To check this the initial dummy is dropped and a dummy is added for February 9, 1988–March 27, 1988, and a dummy is added for March 28, 1988 (when the next circuit breaker was adopted), through the end of the sample.¹⁵ The coefficient of the February 9–March 27 dummy does not differ significantly from zero (t -score = 0.73) in this run, but the coefficient for the March 28, 1988–May 7, 1991 dummy is significantly positive (t -score = 10.78). It seems that the initial voluntary adoption of 80A had no appreciable effect on the conditional variance. February 9–March 27 is dropped from consideration and the marginal contribution of the

¹⁴The estimates of the mean return are less important for the purpose of this study. The estimate of eq. (1) allows first and second order serial correlation in the returns. The parameter estimates and t -scores are:

$$Y_t = 0.0177 + 0.173Y_{t-1} - 0.023Y_{t-2}$$

(2.31) (14.08) (1.78)

The serial correlation of daily returns may seem odd given the Efficient Markets Hypothesis. This result is not unexpected in the presence of ARCH effects even though the series is truly white noise. See Diebold (1988), pp. 27–28.

¹⁵The CME adopted daily price limits for the S&P 500 futures contract on March 28, 1988.

Table II
THE EFFECT OF RULE CHANGES MAXIMUM
LIKELIHOOD ESTIMATES OF GARCH (1, 1) MODEL^a

Estimate	$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \beta_0 D_0 + \gamma_i CB_i, \quad (i = 1 \dots 5)$								
	α_0	α_1	α_2	β_0	γ_1	γ_2	γ_3	γ_4	γ_5
1	0.006 (6.24)	0.086 (18.14)	0.907 (188.74)	1.250 (13.33)	0.018 (2.15)		0.018 (10.53)		
2	0.006 (6.24)	0.086 (18.15)	0.907 (188.76)	1.239 (13.3)		0.018 (2.17)	0.0001 (0.01)		
3	0.006 (6.21)	0.086 (18.12)	0.907 (188.91)	1.252 (13.32)	0.018 (2.14)		0.019 (10.60)	-0.004 (0.46)	
4	0.006 (6.24)	0.086 (18.12)	0.907 (188.68)	1.252 (13.33)	0.018 (2.15)		0.018 (10.55)		-0.0002 (0.02)

Where $D_0 = 1$ from 10/1/87–1/1/88 and zero otherwise.
 $CB_1 = 1$ from 3/28/88–10/19/88 and zero otherwise.
 $CB_2 = 1$ from 3/28/88–5/7/91 and zero otherwise.
 $CB_3 = 1$ from 10/20/88–5/7/91 and zero otherwise.
 $CB_4 = 1$ from 7/31/88–5/7/91 and zero otherwise.
 $CB_5 = 1$ from 12/13/90–5/7/91 and zero otherwise.

^at-scores in parentheses.

March 28–April 19 period is considered.¹⁶ The dummy for this period is significantly positive so it is retained in subsequent tests. The test proceeds in the above fashion through each of periods listed in Table I.¹⁷

The results of the above are shown in the estimates presented in Table II. The events prior to March 28 and between March 28 and October 19 have no marginal impact on the conditional variance. In contrast, the 12-point intraday price limits imposed by the CME on March 28 and the 5-point opening limits that took effect on April 1 are associated with a significant increase in the conditional variance. This result holds for March 28–October 19 as well as for the remainder of the sample. This is clear from the fact that the estimates of γ_1 and γ_3 are virtually identical in estimate 1 and equal to γ_2 in estimate 2 and that γ_3 is statistically insignificant in the second estimate. The coefficients of the dummies for other rule changes in July and December 1990 are not significant.¹⁸

It seems that the adoption of Rule 80A, its various revisions, Rule 80B, and the revision in 4002.I on December 13, 1990 had no appreciable effect on the conditional variance of daily stock price returns. This evidence does not support the notion that circuit breakers reduce the volatility of stock prices day-to-day.

¹⁶Due to the proximity of the two dates, the March 28–April 1 period is not tested.

¹⁷A specification test of the model using the Brock, Dechert, and Scheinkman (BDS) method is conducted also. The BDS test statistic of the standardized residuals, $\varepsilon_t / \sqrt{h_t}$, from the first estimated model are reported in the Appendix (Table AV). Except for some extreme values of m and ε , the statistics are generally less than 1.96 which suggests that the model accurately characterizes the data. See Brock, Dechert, and Scheinkman (1987) and Brock and Dechert (1988).

¹⁸In addition to the results reported in Table II, estimates that control for week-end effects, changes in margin requirements, and the leverage effect (the lagged value of the daily return) are run. None of these additional controls has any qualitative impact on the Table II results.

INTRADAY DATA

Despite the above result, it is possible that intraday volatility is reduced by circuit breakers. Appendix Tables A1 and AII list 28 different days on which various circuit breakers are triggered from May, 1989–December, 1990.¹⁹ In addition to the day, the tables indicate the times during the day when circuit breakers are on. Roughly, circuit breakers are triggered when prices in the cash or futures market breach some specified limit (see Table I). They are lifted when the price moves back within its permitted trading band or when the time limit for the circuit breaker expires.

The remainder of this article focuses on the effect of the tick test rule. We do this because there were relatively few days on which other rules were triggered. Furthermore, it was usually the case that more than one circuit breaker was triggered on these days preventing a clean test of the other rules. In contrast, there are 16 days on which only the tick test was triggered. These days (indicated by an asterisk in Table II) comprise the test sample for this rule.

Unlike the daily data, there is no pattern in the variance of minute-by-minute returns that is consistent across the various days in the sample. For this reason, consideration of the intraday returns focuses on the unconditional variance. The unconditional variance of stock returns in the test sample is compared to the unconditional variance of returns in a control sample. The days included in the control sample are listed in Appendix Table III. These days were selected from the period immediately preceding adoption of the tick test rule (January 1–July 30, 1990). The list includes the days and times during the day when the tick test rule would have triggered had such a rule existed. In addition, the variance of stock returns in the test sample is compared to the variance of returns in a sample of 13 days in 1986 during which the tick test rule would have triggered had the rule existed (See Appendix Table IV). None of the circuit breaker rules were in existence during these 13 days, but program trading was prevalent. Since the results of the two comparisons are virtually identical, only the comparisons between the test sample and the January 1–July 30, 1990 control sample are reported and shown in the following tests.

The intraday return variance on 50-point days is examined to determine whether it is lower after the rule is triggered. This is done by comparing variances during different time intervals before and after the trigger point. Next, the intraday data on 50-point days are examined to determine whether the return variance is lower after adoption of the tick test rule. This is done by comparing the return variances in the test and control samples.

DID VOLATILITY DECLINE WHEN THE TEST TRIGGERED?

Recall that the tick test rule is triggered when the DJIA breaches a 50-point collar around its previous day's closing level. If the lower band of the collar is breached, all index arbitrage orders to sell any component stock of the S&P 500 must be executed on an up-tick in the stock. The reverse applies to 50-point or more advances in the DJIA. The tick test is lifted should the DJIA experience a 25-point intraday reversal. Tables AII–AIV suggest that a reversal of this magnitude is not a frequent occurrence. Once the collar is breached the tick test rule is usually enforced through the close. Table III examines the variance of returns in the test and control samples pre- and post-trigger. The data indicate that the variance of returns in the test sample is 34% lower subsequent to the trigger point through the remainder of the day. In the control sample, return variance is about 30% larger subsequent to the DJIA breaching a 50-point collar around its previous close. This evidence suggests that return variance is lower while the tick test was on.

¹⁹*Interim Report of the New York Stock Exchange* (1991).

Table III
VARIANCE IN THE S&P 500^a

	Variance Pre-Trigger	N	Variance Post-Trigger	N	F-Ratio
Control sample ^b	0.000489	2797	0.000634	861	1.30 ^c
Test sample	0.000788	3817	0.000587	1819	1.34 ^c
F-ratio	1.61 ^c		1.08 ^c		

^aThe data are percentage changes in minute-by-minute observations of the S&P 500 cash market index during the intraday periods subsequent to a trigger of the tick test rule and prior to lifting it.

^bThe observations included in the control sample are for intraday periods when the tick test rule would have been operative had such a rule existed.

^cSignificantly different from one at the 5% level.

Shorter time intervals around the trigger point are examined to determine whether other events may have occurred during the relatively long periods the tick test is on. The data are shown in Table IV.

The tick test rule restricts index arbitrage activity immediately upon being triggered. If index arbitrage is responsible for excess price volatility, a significant reduction in volatility should occur in the period immediately following the trigger point. Panel A of Table IV compares return variances during 5-minute intervals immediately before and after the tick test is triggered. Panel B examines 10-minute intervals. The table also examines similar data for the control sample. If the tick test rule is effective, a significant reduction in return variance should occur in the test sample subsequent to triggering the rule relative to the change that occurs in the control sample. The Table IV data are not consistent with this expectation. Rather, they indicate that no significant changes in return variance occur within either sample in the time intervals immediately surrounding the

Table IV
VARIANCE IN THE S&P 500 PRE- AND POST-TRIGGERING OF THE TICK TEST

Panel A: 5-Minute Interval Pre- and Post-Trigger					
	Variance Pre-Trigger	N	Variance Post-Trigger	N	F-Ratio
Control sample	0.001903	50	0.001524	47	1.26
Test sample	0.003073	75	0.002453	80	1.25
F-ratio	1.62 ^a		1.61 ^a		
Panel B: 10-Minute Interval Pre- and Post-Trigger					
	Variance Pre-Trigger	N	Variance Post-Trigger	N	F-Ratio
Control sample	0.001698	100	0.001247	82	1.36
Test sample	0.001892	150	0.001815	160	1.04
F-ratio	1.11		1.46 ^a		

^aSignificantly different from one at the 5% level.

trigger points. This holds in both panels A and B. These Table IV data conflict with the longer period results shown in Table III. The data regarding the effect on return variance when the rule is triggered are mixed. They indicate that price volatility is lower in the period following the trigger point. However, the decline in volatility is not immediately associated with the trigger point as would be the case if the rule's restriction of index arbitrage were primarily responsible for the decline.

DID THE RULE REDUCE VOLATILITY ON 50-POINT DAYS?

By comparing the variances in the test and control samples, the intraday data can be used to determine whether the variance of returns on 50-point days is lower after adoption of the tick rest rule.

The data in Table V compare the variance in the test and control samples on 50-point days. They indicate that the return variance is 38% higher in the test sample on these days. This observation is difficult to reconcile with the notion that the tick test rule reduces price volatility on 50-point days. Similar results are obtained when comparisons are made across intradaily time intervals. The data in Table III indicate that the return variance is about 60% higher in the test sample than the control sample in the pre-trigger period and 8% lower in the test sample post-trigger. When the shorter time intervals around the trigger point are examined, they indicate that the return variance is higher in the test sample, significantly so in three of the four cases (see Table IV).

The only evidence found that is consistent with the claim that the tick test is effective in reducing volatility is presented in Table III. That evidence indicates that volatility is lower in the test sample subsequent to the trigger point. However, volatility is much higher in the test sample prior to the trigger point. If these differences in volatility between the test and control sample can be attributed to the tick test rule, they suggest the rule buys a slight reduction in volatility after triggering in exchange for a substantial increase in volatility prior to triggering. On the whole, volatility on 50-point days is higher since adoption of the rule (Table V).

CONCLUSION

This article examines the effect of circuit breaker rules on the volatility of prices in the cash market for stocks. Previous work suggests that stock returns sampled at high frequency have a variance that follows an autoregressive conditional heteroskedastic

Table V
VARIANCE IN THE S&P 500: 50-POINT DAYS^a JANUARY 1, 1990–DECEMBER 31, 1990

	Variance	N
Control sample ^b	0.000549	3750
Test sample	0.000759	6000
F-ratio	1.38 ^c	

^aThe data are percentage changes in minute-by-minute observations of the S&P 500 cash market index. The first 15-minute period of each day is excluded to allow for opening lags of some stocks included in the index.

^bThe days included in the control sample are days when the DOW breached a 50-point collar around its previous close during the period January 1, 1990–July 30, 1990. Rule 80A was not operative during this time.

^cSignificantly different from one at the 5% level.

(ARCH) process. This study models this process for daily data from July, 1962–May, 1991 and tests for structural breaks subsequent to adoption and revision of circuit breaker rules. In addition, data on the variance of intraday returns on days when the tick test rule is triggered are examined to determine whether the data are consistent with the notion that this circuit breaker is effective in reducing the variance of minute-by-minute returns.

The daily data analyzed in this article are *not* consistent with the hypothesis that adoption and revision of circuit breaker rules reduces the conditional variance of stock returns. Some evidence suggests the variance of stock returns is lower in the intraday period following a trigger point of the tick test. However, the decline in volatility is not immediately associated with the trigger as would be the case if the restriction of index arbitrage were primarily responsible for the reduced volatility. Furthermore, comparisons of intraday data between the test and control samples is not consistent with the notion that adoption of the tick test rule reduces price volatility on 50-point days.

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Appendix

Table AI

CME 5-Point Opening Limit (N.Y. Time)		
Date	Limit Triggered	Limit Lifted
Oct. 16, 1989	9:30	9:31
Aug. 3, 1990	9:30	9:42
Aug. 6, 1990	9:30	9:42
Aug. 7, 1990	9:30	9:42
Aug. 21, 1990	9:30	9:42
Aug. 23, 1990	9:30	9:42
Aug. 24, 1990	9:30	9:42
Aug. 27, 1990	9:30	9:42
CME 12-Point Price Limit (N.Y. Time)		
Date	Limit Triggered	Limit Lifted
Oct. 13, 1989	3:07	3:37
Oct. 24, 1989	10:33	10:34
Jan. 12, 1990	2:36	2:37
July 23, 1990	10:34	10:50
Aug. 3, 1990	1:23	1:53
Aug. 6, 1990	9:53	10:23
Aug. 21, 1990	10:46	11:13
CME 30-Point Price Limit (N.Y. Time)		
Date	Limit Triggered	Limit Lifted
Oct. 13, 1989	3:45	4:15

Table AII
NYSE 80A TICK TEST AUGUST 1-DECEMBER 31, 1990

Date	Test Triggered	Test Lifted	Type of Test
Aug. 3	9:50	close	sell plus
Aug. 6	9:56	close	sell plus
Aug. 10*	1:38	close	sell plus
Aug. 16*	3:43	close	sell plus
Aug. 17*	12:05	3:44	sell plus
Aug. 21	9:49	12:16	sell plus
Aug. 21	1:18	close	sell plus
Aug. 23	9:54	close	sell plus
Aug. 24	3:50	close	buy minus
Aug. 27	9:39	close	buy minus
Aug. 30*	3:50	close	sell plus
Sept. 20*	3:36	close	sell plus
Sept. 24*	10:53	close	sell plus
Sept. 27*	12:18	3:20	sell plus
Oct. 1*	12:16	close	buy minus
Oct. 5*	9:43	10:51	sell plus
Oct. 9*	2:47	close	sell plus
Oct. 10*	3:31	close	sell plus
Oct. 11*	1:37	close	sell plus
Oct. 18*	12:10	close	buy minus
Oct. 19*	3:44	close	buy minus
Nov. 12*	3:41	close	buy minus
Nov. 30*	2:18	close	buy minus

*Indicates days on which only the tick test was triggered

Table AIII
CONTROL SAMPLE JANUARY 1-JULY 30, 1990

Date	Test Triggered	Test Lifted
Jan. 2	3:59	close
Jan. 22	2:48	close
Jan. 24	9:41	3:07
Jan. 25	3:57	close
Feb. 20	1:27	close
May 11	1:54	close
May 14	1:02	3:21
May 29	3:51	close
June 12	3:36	close
June 18	2:56	close

Table AIV
CONTROL SAMPLE JANUARY 1-DECEMBER 31, 1986

Date	Test Triggered	Test Lifted
Jan. 8	3:40	close
Mar. 11	3:18	close
Apr. 8	3:41	close
Apr. 16	3:43	close
Apr. 30	3:48	close
May 22	3:51	close
June 9	1:49	close
July 7	1:12	close
July 8	1:38	close
July 28	3:38	close
Aug. 26	1:49	close
Sept. 25	1:17	close
Nov. 18	1:06	close

Table AV
BDS TEST STATISTIC^a DAILY DATA

ε	$m = 2$	$m = 3$	$m = 4$	$m = 5$
0.900000	23.365	0.254	0.360	—
0.810000	-24.531	-0.828	-0.585	—
0.729000	-7.170	-0.980	—	-2.891
0.656100	-0.434	-0.308	-0.205	-0.197
0.590490	-0.103	-0.089	-0.097	-0.101
0.531441	-0.040	-0.063	-0.075	-0.088
0.478297	-0.095	-0.110	-0.121	-0.133
0.430467	-0.064	-0.095	-0.123	-0.144
0.387420	-0.033	-0.100	-0.150	-0.197
0.348678	0.334	0.176	0.061	-0.043
0.313810	1.177	0.862	0.618	0.421
0.282429	2.068	1.596	1.20	0.930
0.254186	2.248	1.681	1.22	0.931
0.228768	1.871	1.292	0.830	0.573
0.205891	1.303	0.734	0.298	0.082
0.185302	0.780	0.219	-0.179	-0.352
0.166772	0.259	-0.264	-0.621	-0.735
0.150095	-0.064	-0.537	-0.848	-0.906
0.135085	-0.257	-0.704	-0.989	-1.012
0.121577	-0.390	-0.811	-1.077	-1.073
0.109419	-0.458	-0.838	-1.076	-1.032
0.098477	-0.440	-0.783	-0.997	-0.929
0.088629	-0.422	-0.722	-0.924	-0.836
0.079766	-0.410	-0.652	-0.798	-0.660
0.071790	-0.380	-0.554	-0.669	-0.454
0.064611	-0.310	-0.440	-0.544	-0.316
0.058150	-0.262	-0.375	-0.479	-0.264
0.052335	-0.250	-0.363	-0.437	-0.199
0.047101	-0.216	-0.331	-0.425	-0.260
0.042391	-0.093	-0.210	-0.313	-0.085
0.038152	-0.040	-0.125	-0.292	-0.106
0.034337	0.039	-0.126	-0.221	0.001
0.030903	-0.013	-0.066	-0.294	0.058
0.027813	-0.067	-0.149	-0.535	-0.314
0.025032	-0.028	-0.135	-0.343	-0.070
0.022528	-0.116	-0.110	-0.171	0.092
0.020276	-0.026	0.080	0.111	0.569
0.018248	0.129	0.194	0.041	0.656
0.016423	0.153	0.420	0.133	0.963
0.014781	0.262	0.303	0.277	2.087

^aThe first column are the epsilon is used in the BDS test. The other columns show the BDS test statistic for different embedding diminsins, $m = 2, 3, 4$, and 5.

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