# Circuit Breakers, Volatility, and the U.S. Equity Markets: Evidence from NYSE Rule 80A*

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**Abstract**

After October 1987, the United States equity markets adopted various rules, collectively known as "circuit breakers," to reduce stock market volatility. Most circuit breakers have been triggered only rarely. However, New York Stock Exchange Rule 80A, which limits destabilizing index arbitrage trades, has been triggered frequently, sometimes more than once a day. Using both parametric and non-parametric tests, we compare volatility during periods when Rule 80A is in effect and when it is not. Controlling for other determinants of volatility, we find that Rule 80A leads to a small but statistically significant decline in intraday U.S.

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## 1 Introduction

Circuit breakers in the U.S. equity markets came under a great deal of scrutiny over this past year as sharp drops in the Dow Jones Industrial Average (DJIA) provoked intense debate over their economic usefulness. The 554 point DJIA drop on October 27, 1997 triggered the New York Stock Exchange (NYSE) to halt trading twice that day in accordance with NYSE Rule 80B, marking the first official market-wide halt on the NYSE due to a decrease in stock prices. Despite the attention focused on the market-wide trading halt, another circuit breaker, NYSE Rule 80A, was also triggered twice that day, for the 263$^{th}$ and 264$^{th}$ time that year alone. Since it is difficult to determine the effectiveness of a circuit breaker on the basis of a single day's observation, we examine the effectiveness of NYSE Rule 80A in stemming stock market volatility.

First implemented on August 1, 1990, NYSE Rule 80A was established to reduce excess market volatility by adding frictions to the linkage between the cash and futures markets. Implicitly, it is intended to prevent "the tail from wagging the dog" by preventing index arbitrage traders from further pushing individual stock prices in either rising or declining markets. During the time period of this study, Rule 80A goes into effect whenever the DJIA moves either up or down by 50 or more points from its previous day's close. When in effect, Rule 80A restricts index arbitrage traders from making destabilizing trades.[1] This rule restricts those using an index arbitrage strategy from buying NYSE stocks in a rising market or selling NYSE stocks in a falling market. The rule stays in effect for the remainder of the day unless the DJIA returns to within 25 points of the previous day's close, at which point Rule 80A is lifted.[2]

The effectiveness of circuit breakers has been frequently debated. Most studies have focused on market halts similar to the ones mandated by Rule 80B. However, since Rule 80B has only been triggered on one occasion, examining the effectiveness of this type of circuit breaker on U.S. equity markets is difficult. Most studies have relied upon theoretical models to examine circuit breakers, although their conclusions differ. Greenwald and Stein (1991), for example, develop a model that indicates that properly designed circuit breakers may help the market achieve optimal outcomes by mitigating uncertainty via a reduction in transactional risk. In contrast, Subrahmanyam (1994) argues that the existence of circuit breakers may have the perverse effect of increasing price volatility prior to the triggering due to the "magnet effect," whereby, on volatile days, traders advance purchases or sales of stock in anticipation of being locked out of the market by a circuit breaker.

Others have empirically examined the effectiveness of circuit breakers on

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[1] Specifically, Rule 80A requires that once the DJIA has advanced (declined) by 50 points or more, all index arbitrage orders to buy (sell) any S&P component stock must be entered as a "buy minus" ("sell plus") order.

[2] On February 11, 1999, the U.S. Securities and Exchange Commission allowed the NYSE to change Rule 80A so that it is triggered upon a 2% change in the DJIA. Our study pre-dates this change.

other markets. For example, Lauterbach and Ben-Zion (1993) examine effects of trading halts on the Tel Aviv Stock Exchange during the October 1987 crash, finding that the circuit breakers help reduce the next day price declines but have little long-term effect. In addition, Bertero and Mayer (1990) examine the effects of market structure, including circuit breakers, on stock market performance on 23 markets around the world during the October 1987 crash.

Rule 80A itself has been examined empirically, but again, results are inconsistent, perhaps as a result of the small sample sizes of the previous studies. Santoni and Liu (1993) find mixed results in their study of the effects of Rule 80A on volatility over the pre-May 1991 period. After adjusting for ARCH effects in the returns series, the authors find that unconditional variances decline on days when Rule 80A is triggered. However, in their analysis of minute-to-minute returns, they find that the decline in variance does not appear to be associated with the triggering of Rule 80A, although they had only 28 days in their sample. In a recent paper, Overdahl and McMillan (1997) study the effect of Rule 80A on trading in the cash and futures markets. The authors find that index-arbitrage trading volume significantly declines during the 68 observations in their sample when Rule 80A is triggered (consistent with early work on Rule 80A published by the NYSE (1991)), but prices in the cash and futures markets nonetheless remain linked.[3]

Our paper differs from previous work in a number of respects. Using minute by minute data from 1988 to 1997, we examine the effectiveness of Rule 80A in reducing stock market volatility, using a variety of parametric and non-parametric specifications to examine if volatility is dampened during times that NYSE Rule 80A is in effect. While other papers have mostly focused on the delinking of the markets, we focus exclusively on the issue of whether Rule 80A dampens volatility, as it is the stated reason as to why the rule is in place. We first examine the intra-day patterns of stock market volatility, and then examine the effects of Rule 80A during both up and down movements. Overall, we find that Rule 80A has a small but statistically significant effect in reducing stock market volatility. The effect is asymmetric, however, in that volatility is dampened more in a rising market than in a declining market.

The paper proceeds as follows. Section 2 presents a brief history of circuit breakers on U.S. equity markets. After describing the data in Section 3, we present the results in Section 4. Section 5 concludes the paper.

## 2 Circuit breakers on U.S. equity markets

Prior to the turbulence in the stock market in October 1987, trading restrictions in the U.S. equity markets were available for individual stocks, but not for the

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[3] Kuserk, Locke and Sayers (1992) examine Rule 80A with respect to the pricing and microstructure of the S&P futures market. They examine the S&P futures market using data from January to October 1990. During most of this time, Rule 80A was only voluntary. While unable to find any effects of Rule 80A, Kuserk, Locke and Sayers (1992) frequently note in their paper that this may be due to the extremely small sample size.

market as a whole. For example, when order flow for an individual stock was "one-sided"—in the sense that there were only sellers and no buyers—individual specialists on the floor of the NYSE could delay the opening of, or suspend trading in, individual stocks with the approval of a floor official. However, prior to October 1988, there were no coordinated, market-wide procedures in place in the event of a massive, market-wide decline in stock prices or one-sided order flow. The stock market crash of 1987 prompted widespread concern among regulators, politicians and investors that the existing *ad hoc* trading restrictions were not sufficient to ensure the integrity of the U.S. equity markets. Several studies on the subject of institutional reform, most notably the Brady Report (1988), suggested the adoption of exchange-mandated and exchange-coordinated trading restrictions, commonly known as circuit breakers.

## 2.1 Chronology of circuit breakers on the NYSE

Table 1 provides an outline of the developments surrounding the adoption of formal circuit breakers on the NYSE following the crash of 1987. Rule 80A first went into effect in early 1988 on a voluntary basis, whereby NYSE members were requested to refrain from using the automated trading system known as SuperDOT on volatile days. Later in the year, Rule 80B, originally calling for a temporary halt following a 250- or 400-point drop in the DJIA, was implemented. Rule 80B has changed over the years and currently calls for a trading halt based on a percentage drop in the DJIA.[4]

Rule 80A was officially adopted in August 1990 with two separate provisions. The first provision entails a restriction on destabilizing index arbitrage orders when the DJIA moves 50 points in either direction from the previous day's close. The second provision, more commonly referred to as the "Sidecar Rule," restricts program trading orders on the NYSE from being entered into the SuperDOT system for five minutes when the nearby S&P futures contract declines 12 points from the previous day's settlement price. The orders are placed in a separate file (sidecar file) and released simultaneously after the five-minute window expires. Neither the size of the point change in the DJIA or the S&P futures that triggers Rule 80A, nor the duration of its effects, has been altered from its inception in August 1990 to the end of our sample in December 1997.

## 2.2 Motivation of Rule 80A

The original SEC releases concerning Rule 80A suggested that the rule was implemented because "program trading may create excess volatility," and Rule 80A was designed to "*minimize excess market volatility and promote stabilization of the market*" by "isolat[ing] one of the potential causes of market volatility,

[4] Effective April 15, 1998, the Rule 80B trigger levels are set quarterly and calculated on the basis of a 10, 20 and 30 percent move in the average DJIA closing level of the previous month.

program trading."[5] In response to the 1990 NYSE request for permanent approval of Rule 80A, the SEC stated that the NYSE thought that the rule had been "helpful in *promoting market stability by minimizing excess volatility*" and that the "50-point level appears to be high enough that it is not triggered too frequently, yet low enough to act as a meaningful check on excess market volatility which might be associated with index arbitrage activity."[6] Consistent with these statements, an NYSE official recently stated in Congressional testimony, "The purpose of these Rule 80'A provisions is to help decrease market volatility caused by the entry of a large volume of order by professional traders without restricting the trading of individual investors... Rule 80A's intent from the beginning has been to *minimize excess market volatility and promote stabilization of the market*."[7] The motivation behind this paper is to test whether the effects of Rule 80A on stock market volatility are consistent with the motivation behind its initiation and continued presence. (Emphasis added throughout this paragraph.)

### 2.3 Tests of circuit breaker effects

The stock market volatility that triggers the Rule 80A circuit breaker and the stock market volatility subsequent to the triggering are observed on days that Rule 80A is in effect. To understand the true impact of Rule 80A on volatility, we pose the question: Is volatility after the triggering of the circuit breaker *different than it would have been* in the absence of the circuit breaker? To answer that counter-factual question, we develop models of volatility dynamics that estimate the expected level of volatility after a movement of the magnitude that triggers the circuit breaker. Using a single model to determine the effect of circuit breakers on volatility would be insufficient to make strong conclusions about the effects of the circuit breakers in general, as the result may be due to a misspecified model. Our statistical tests of the effects of circuit breakers are based on a variety of parametric and non-parametric tests of volatility, in order to ensure our results are robust to the particular specification of volatility dynamics that is assumed.

## 3 Data and descriptive statistics

The data in this analysis were obtained from Bridge News Inc., DRI/McGraw-Hill Inc., and the New York Stock Exchange. The primary data set, obtained from Bridge News, consists of one observation per minute for three price series: the Dow Jones Industrial Average (DJIA), the Standard & Poor's 500 (S&P 500) cash

[5] SEC release No. 34-27812, File No. SR-NYSE-90-11 (March 16, 1990), 55 FR 11284 (March 27, 1990).

[6] SEC release No. 34-29308, File No. SR-NYSE-91-21 (June 14, 1991), 56 FR 28428 (June 20, 1991).

[7] James L. Cochrane, Senior Vice President and Chief Economist of the NYSE, on "Trading Halts and Program Trading Restrictions," presented to the Subcommittee on Securities, Committee on Banking, Housing and Urban Affairs, United States Senate, January 29, 1998.

index and the S&P 500 futures index, which is traded on the Chicago Mercantile Exchange (CME). The sample period contains all business days from March 1, 1988 through December 31, 1997. Due to the possibility of non-synchronous price data at the opening of the NYSE, we eliminate the first fifteen observations (corresponding to the first 15 minutes of trading).[8] Similarly, we eliminate the last ten minutes of trading, as the NYSE rules restrict destabilizing market-on-close orders during this time period.[9] Finally, we obtain the daily closing prices for the nearby S&P 500 futures contract, S&P 500 cash index, and the DJIA from DRI/McGraw-Hill.

We obtain the exact times that Rule 80A was in effect during the sample period from the NYSE and the exact times that the sidecar rule was in effect during the sample period from the CME. Overall, during our sample period, Rule 80A was triggered 549 times. This significant increase in observations over an extended period provides us with a much richer data series than any of the previous studies.

For our empirical analysis, we define three indicator variables to identify each minute when Rule 80A is in effect. The first variable, *80A_min*, is defined to be equal to zero when Rule 80A is not in effect and to one when it is in effect. To allow for asymmetric effects of Rule 80A in rising versus declining markets, we define two additional indicator variables. The variable *80A_up* is defined as equal to one when Rule 80A is in effect on the upside (due to an increase in the DJIA) and zero, otherwise. Similarly, the variable *80A_down* is defined as equal to one when Rule 80A is in effect on the downside and zero, otherwise.

We derive a forward-looking return series for each of the three price series. A minute-by-minute *return series* is calculated as the natural log of the subsequent price over the current price:

$$Return(t) = \ln\left(price(t+1) / price(t)\right),$$

where $price(t)$ represents the index or futures price at time $t$. A minute-by-minute *volatility series* is calculated as the absolute value of the return series:[10]

$$Volatility(t) = |\, Return(t) \,|.$$

Summary statistics of the data are presented in Table 2. The total number of

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[8] The NYSE requires their specialists to open each stock within the first fifteen minutes of trading or otherwise seek special authorization. See NYSE Rule 103A.10(B)(i).

[9] The results presented in this paper are robust to alternative specifications of the business day. In addition to the 9:45am to 3:50pm business day results reported, the tests were also performed for the entire business day (from 9:30am to 4:00pm) and from 9:35am to 3:55pm.

[10] As an alternative measure of volatility, we use, but do not report, the square of the return series. The results and conclusions presented below are qualitatively similar using this alternative measure.

days per year that Rule 80A was triggered exhibits a U-shaped pattern over the sample period. In 1990-91, Rule 80A was triggered often (22 and 20 days, respectively), considering Rule 80A was only adopted in August 1990. In 1992-93, Rule 80A was triggered infrequently (16 and 9 days, respectively). The rate of triggering increased to 28 days per year in 1994 and 1995, and increased to 101 and 219 in 1996 and 1997, respectively.

This U-shaped pattern can be traced to two effects. First, the U-shape occurs because Rule 80A is defined by a nominal, and not a percentage, move in the DJIA. As a result, for a fixed volatility in the DJIA, Rule 80A was more likely to be triggered in 1997 with the DJIA at 7000 than in 1990 when the DJIA was at 2700. Second, the U-shaped pattern in volatility over the period as noted in Table 2 also contributes to the U-shaped pattern in the frequency of Rule 80A occurrences. During 1990-91, the volatility of the daily returns was between 14 and 16 percent and subsequently fell to 8 percent in 1993 before rising to 16 percent in 1997.

## 4 Results

In this section, we present the results of our tests of the impact of NYSE Rule 80A on stock market volatility. We first present preliminary regression results describing the basic relationship between volatility and Rule 80A. We then use additional conditioning variables in the regression in an attempt to control for additional cross-sectional and time-series variables which help to forecast volatility. Finally, we propose a non-parametric test comparing stock market volatility during equally volatile periods, some with Rule 80A in effect and others without Rule 80A in effect. While the regression-based models are dependent on the applicability of the assumptions underlying the dynamics of the volatility process, the non-parametric test is designed to be more robust to misspecifications of these volatility dynamics.

### 4.1 Preliminary results

To examine the effects of NYSE Rule 80A on volatility, we first address a well-documented characteristic of stock market returns known as volatility clustering. Future volatility tends to be higher than average after periods of high volatility and lower than average after periods of low volatility. This characterization leads us to partition the data based on the level of the DJIA, comparing each minute's DJIA level to the previous day's closing DJIA. Forty-two fractiles were constructed, each representing a five-point movement of the DJIA. Fractile 1 represents levels of the DJIA that were between the previous day's close and five points above the previous day's close; fractile 2 represents DJIA levels that were between five and ten points above the previous day's close, and so on. Fractile 21, which represents levels 100 points above the previous day's close and beyond, ends the series. Similarly, on the down side, fractile 0 represents levels between the previous day's close and five points below; fractile -1 represents levels that were between five and ten points below the previous day's close, and so on. Fractile -20, which represents drops in the DJIA of greater than 100 points, ends the series on the down side.

Each minute's volatility estimate, defined in Section 3, was then assigned to its respective fractile, based on the level of the DJIA at the beginning of the minute. Figure 1 shows the distribution of the volatility estimates based on their fractiles. It is apparent from Figure 1 that the distribution of volatility across fractiles follows somewhat of a parabolic "smile" pattern. Another area to note is the slight discontinuity in the slope of the S&P future's volatility at fractile -10, which is around when the 80A rule becomes effective for the first time in a day.

To examine the effectiveness of Rule 80A, we regress the minute-by-minute volatility estimates on their respective fractiles. Due to the non-linearity apparent in Figure 1, we also include the square of the fractile as a variable. Finally, since we are interested in the effect of Rule 80A on volatility, we include a dummy variable indicating when the rule is in effect. Specifically, we estimate:

$$Volatility_t = \beta_0 + \beta_1\ Fractile_t + \beta_2\ Fractile_t^2 + \beta_3\ 80A\_min_t + \varepsilon,$$

where, at time $t$, $Volatility_t$ is the absolute value of the price variation for either the DJIA, the S&P 500 index or the S&P 500 futures, $Fractile_t$ is the fractile location at which that price variation took place, $Fractile_t^2$ is the square of the fractile variable, and $80A\_min_t$ is the dummy variable that is one when the rule is in effect and zero otherwise.[11]

We find that all three variables are highly significant at the 0.01% level (Table 3). In particular, we find that the coefficient on *Fractile* is significant and negative, indicating that downward movements have higher volatilities on average than upward movements. We also find that $Fractile^2$ is positive and significant, indicating that this variable is capturing the non-linear effects associated with increasing volatility as the DJIA moves further away from its previous day's close. However, we also find that the coefficient on *80A_min* is negative and significant, indicating that periods when the Rule 80A was in effect had lower volatility than when it was not, controlling for other factors. Therefore, we find some evidence that NYSE Rule 80A does help reduce volatility.

We next replace the dummy variable *80A_min* with separate dummy variables for Rule 80A on the upside (*80A_up*) and on the downside (*80A_down*), running the regression

$$Volatility_t = \beta_0 + \beta_1\ Fractile_t + \beta_2\ Fractile_t^2 + \beta_3\ 80A\_up_t + \beta_4\ 80A\_down_t + \varepsilon.$$

[11] We arrive at qualitatively similar conclusions if the discrete variables $Fractile_t$ and $Fractile_t^2$ are replaced by the continuous variables $DayReturn_t$ and $DayReturn_t^2$, representing the return and squared return, respectively, from the previous day's close to minute $t$.

We find that Rule 80A has an effect that is negative and statistically significant in both directions. Interestingly, Rule 80A has a much greater impact in lowering volatility in a rising market than in a falling market, even though the unconditional volatility rises more sharply in a falling market than in a rising market (from Figure 1).

Finally, we perform a simple nonparametric test of the effects of Rule 80A by comparing the volatility of returns before and after Rule 80A was officially implemented (Figure 2 and Table 4). We observe the volatility on days where the Dow moved 50 points before and after August 1990, which is the date that the NYSE made Rule 80A binding. The volatility when the Dow is between -50 and +50 points from the previous close (i.e., when Rule 80A is generally not in effect in either time period) is remarkably similar during these two periods. However, there is a significant divergence between these data series outside of the bounds noted above (when Rule 80A is in effect in the latter period but not in the former period). The difference between the volatilities during the pre- and post-August 1990 periods is statistically significant for both Rule 80A and non-Rule 80A times. Therefore, to examine whether Rule 80A has an effect on volatility, we compare whether the decrease in volatility during the post-August 1990 period is larger during times that Rule 80A was activated by examining the differences of differences.[12] The difference of differences is positive and significant, implying that there is a greater reduction in volatility during the post-1990 period when Rule 80A was activated than when Rule 80A was not. The results from this nonparametric test are consistent with the results of the parametric regression: there is some evidence that stock market volatility when Rule 80A is in effect is lower than it would have been if Rule 80A did not exist.

## 4.2 Additional independent variables

In order to ensure that the results from Section 4.1 are not due to misspecifications, we add additional independent variables to the regression to capture other independent effects on volatility that are not related to Rule 80A. First, as shown in Table 1, there was a clear pattern of volatility over the years of our sample, so we include a series of dummy variables for each of the years, $D_{\mathrm{YEAR=1988}}$ through $D_{\mathrm{YEAR=1997,}}$ equal to one if the observation occurs within the corresponding year and zero otherwise. Second, there is a clear day-of-the-week pattern in volatilities, so we include a series of dummy variables, $D_{\mathrm{DAY=Monday}}$ through $D_{\mathrm{DAY=Friday,}}$ equal to one if the observation occurs on the corresponding day and zero otherwise. Third, there is a clear and well-documented pattern of intraday volatilities in equity markets, with high volatility in the morning, decreased volatility around noon, and subsequent increased volatility as the close approaches. We address this time-of-day pattern with a series of 24 intraday dummies, from $D_{\mathrm{Time}\in[945,\ldots,1000)}$ through

[12] Using the differences in differences allows us to adjust for any difference in the base volatility across the two time periods.

$D_{\mathrm{Time} \in [1530,\ldots,1545)}$, equal to one if the time of the observation occurs within the corresponding range and zero otherwise.

Table 5 shows the results of the regression

$$Volatility_t = \beta_0 + \beta_1\, Fractile_t + \beta_2\, Fractile_t^2 + \beta_3\, 80A\_up_t + \beta_4\, 80A\_down_t +$$
$$\Sigma\, \beta j\, D_{YEAR} + \Sigma\, \beta_j\, D_{DAY\ OF\ THE\ WEEK} + \Sigma\, \beta j\, D_{TIME\ OF\ THE\ DAY} + \varepsilon_t.$$

The results of this regression support the simpler specification from Section 4.1. With these additional control variables, the regression continues to yield negative and significant coefficients on the *80A_up* and *80A_down* dummy variables, suggesting that there is a small but statistically significant decrease in minute-to-minute volatility when Rule 80A is in effect. The coefficient on *Fractile* remains negative and significant and the coefficient on $Fractile^2$ remains positive and significant. In addition, *F*-tests (not reported) show that the coefficients on each set of dummy variables (for the year, the day of the week, and the time of day) were significant in explaining the volatility of minute-to-minute stock market returns.

## 4.3 Consideration of various ARCH specifications

A well-documented characterization of equity market volatility is the "ARCH effects" in the time series of equity returns: volatility is autoregressive and conditionally heteroskedastic. This characterization implies that volatility changes in a particular pattern, where periods of high volatility tend to be followed by additional periods of high volatility and periods of low volatility tend to followed by periods of low volatility, and that volatility tends to revert (or autoregress) to a long-run mean. One common implementation of this ARCH effect is with a GARCH (generalized ARCH) model, where the volatility at time *t*, denoted as $\sigma_t$, develops over time according to the equation

$$\sigma^2_t = a + b\, \sigma^2_{t-1} + c\, r^2_t\,,$$

where *a*, *b* and *c* are the GARCH parameters. One period's estimated variance is a constant plus a weighted sum of last period's estimated variance and the most recent squared return. This model of variance dynamics captures a changing volatility structure where volatility levels tend to cluster in time but also tend to revert over time to a long-run mean.

Various attempts at estimating this equation (and alternate ARCH-family specifications) via maximum likelihood were deemed unreliable. When the equation was estimated using intraday data, the estimation procedure often did not converge (in over 30 percent of the cases) or yielded estimates where $(b+c) > 1$, which implies that volatility explodes over time instead of mean reverting (this occurred in about 20 percent of the cases). In the cases where the procedure converged and yielded economically feasible parameter estimates, the variance of the estimates over time was so great, even on consecutive days, as to make any inference from their use untenable.

The lack of usefulness in GARCH estimation with intraday data is consistent with existing literature, which finds only limited applicability of GARCH estimation using intraday data. One potential source of noise that makes intraday GARCH untenable is the bid-ask bounce, which is present but small in daily data but is dominating in intraday data. Another problem with intraday data is the issue of how to handle the overnight change. With daily data, the time between observations is assumed to be constant, even if some time changes include a weekend while other do not; this simplification appears to be innocuous. However, for intraday data, the change from one day's close to the next day's open is orders of magnitude greater than minute-to-minute changes, and at the same time, it seems to be too important a piece of information not to include in estimating future volatility. However, there is no obvious way to incorporate this overnight change into an intraday GARCH-type framework.

## 4.4 Non-parametric test

The final test of the effects of Rule 80A on stock market volatility takes advantage of the fact that Rule 80A has been defined as an absolute point move, and not a percentage move, from its inception in 1990 to the end of the sample in 1997. For example, as shown in Table 2, a 50-point move in the DJIA in 1990 corresponded to an approximate 2% move, but the same 50-point move in 1997 corresponded to an approximate 0.7% move. The idea behind this non-parametric test is to select matched pairs of days with equivalent percentage moves from the previous day's close, but where one day's move triggered Rule 80A but the other day did not. For example, a 1% change in the DJIA on a day in 1997 would have triggered Rule 80A, but a 1% change in the DJIA on a day in 1990 would not have. We attempt to control for the time-of-day and day-of-the-week effects that were alluded to earlier, by matching days in later years with days in earlier year on three dimensions: percent change from the previous day's close, the time of day and the day of the week.

Table 6 shows the results of this final non-parametric test. We match 37 observations from 1997 with 37 observations from the early 1990s, where the DJIA moved by a similar percentage (approximately one percent) at a similar time (fifteen minute interval) on the same day of the week. In 1997, a one percentage point move triggered Rule 80A, while in the early 1990s, a one percentage point move did not. The average volatility on the nearby S&P 500 futures contract over the next 30 minutes was then calculated for each pair of observations, and these averages were then compared. Over the 37 paired observations in our sample, the volatility over the subsequent half-hour was significantly less in the 1997 sample, when Rule 80A was triggered, than in the earlier sample, when Rule 80A was not triggered. It is impossible to know whether the matching criteria that were used to match these pairs of observations are capturing all of the important determinants of volatility. However, this nonparametric result does provide additional evidence to complement the parametric results presented earlier that Rule 80A appears to have a small but measurable impact on the volatility of stock market prices.

## 5 Conclusions

This paper examines the effects of NYSE Rule 80A, which went into effect in August 1990. Using minute-by-minute data on the DJIA cash index and the S&P cash index and futures price, we find that although overall minute-by-minute volatility is higher as the DJIA moves further from its previous day's close, NYSE Rule 80A does help reduce volatility. The decrease in volatility is found in each of the three series examined: the S&P 500 cash index, the S&P 500 futures index, and the level of the Dow Jones Industrial Average.

While these results are statistically significant, we also note that they are relatively small in magnitude. Over time, Rule 80A has been triggered more and more frequently. Unlike Rule 80B, the price limits for Rule 80A have not been readjusted over time, although the DJIA has increased three-fold since its inception. As it gets triggered more often, it may lose its effectiveness and significance.

Therefore, it is questionable whether Rule 80A should continue to exist in its current form. Under the theory that there is evidence that Rule 80A reduces volatility, one option might be to make it effective over the entire day. Alternatively, another option would entail the removal of the rule entirely, under the theory that the reduction in volatility is insufficient to warrant the delinking of the markets. Still another option would be to reset the 80A price limits periodically based on the level of the DJIA, basing Rule 80A triggering levels on a percentage DJIA move instead of a nominal DJIA move. Ultimately, it is a policy decision as to whether Rule 80A reduces volatility sufficiently to warrant the costs associated with its implementation.

**Figure 1: Mean volatility of returns for the S&P 500 cash index, S&P 500 futures and the Dow Jones**

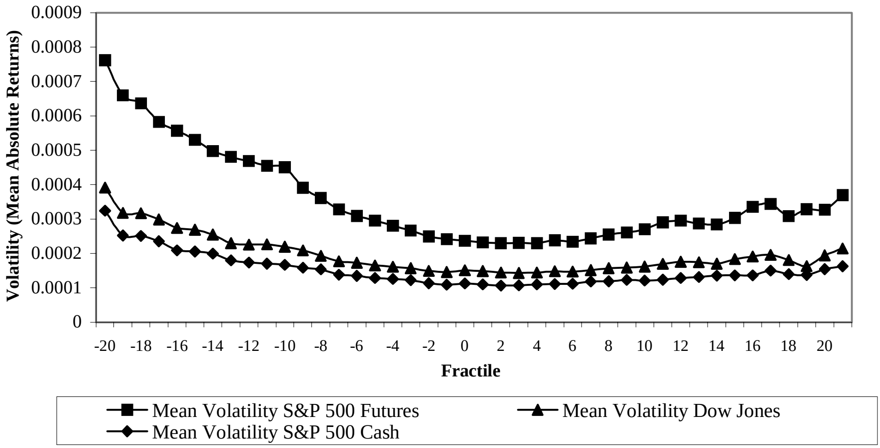


**Figure 1.** The average minute-by-minute intraday volatility for the Dow Jones Industrial Average, the S&P 500 index and the S&P 500 futures contract from January 1990 to June 1997. Each minute was assigned to a fractile representing a five point movement in the Dow Jones Industrial Average. The zero fractile represents movements in the Dow Jones Industrial Average from the previous day's close to five points below the previous day's close.

**Figure 2: Mean volatility of returns for the S&P 500 cash index pre- and post-August 1990**

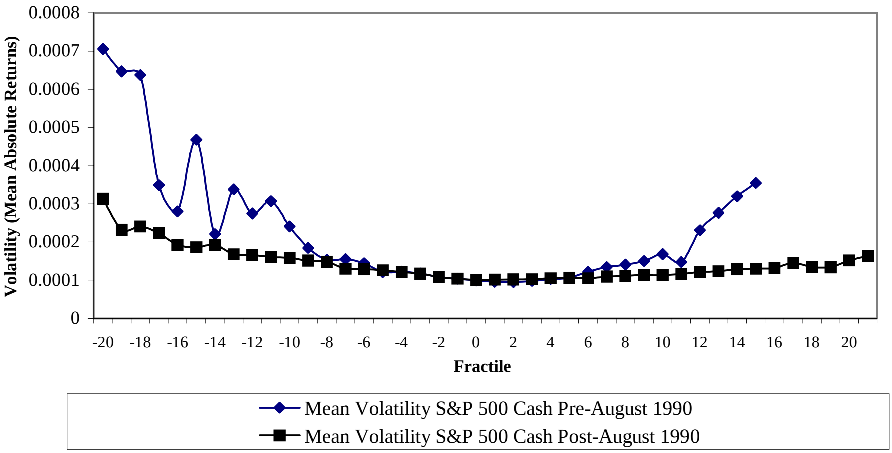


**Figure 2.** The average minute-by-minute intraday volatility for the S&P 500 cash index in two sub-periods: from January 1988 to August 1990 and from August 1990 to December 1997. Each minute was assigned to a fractile representing a five point movement in the Dow Jones Industrial Average. The zero fractile represents movements in the Dow Jones Industrial Average from the previous day's close to five points below the previous day's close.

**Table 1: Chronology of circuit breaker adoptions and amendments on the NYSE**

| Date | NYSE Limits |
|---|---|
| 10/22/87 | No official limits in period immediately following the crash of 1987. Individual stocks can have delayed openings or halts due to order imbalances. |
| 1/14/88 | NYSE implements a 75-point collar on a voluntary basis by asking firms not to use SuperDOT system in the event of a 75-point move. |
| 2/4/88 | NYSE changes voluntary collar to 50 points. Submits it as Rule 80A. |
| 10/20/88 | NYSE institutes Rule 80B that calls for a 1 hour trading halt if the DJIA drops 250 points or a 2 hour halt if it drops 400 points. Rule 80A modified to include a 5-minute sidecar for program trades after 12 point S&P 500 drop. Sidecar does not apply during last 35 minutes of trading. |
| 8/1/90 | NYSE officially implements Rule 80A restricting index arbitrage orders from buying on an uptick (buy minus orders only) and selling on a downtick (sell plus orders) after 50 point move. Unrestricted arbitrage is restored if the DJIA reverses to within 25 points of previous day's close. |
| 7/22/96 | NYSE modifies the Rule 80B trading halt by cutting the time of the halt in half, to one half hour for a 250 point DJIA drop, and to one hour for a 400 point drop. |
| 2/3/97 | NYSE modifies Rule 80B again by raising the trading halt trigger points to 350 points for a half-hour halt and to 550 for a one-hour halt. |

**Table 2: Rule 80A summary statistics**

This table provides yearly statistics on Rule 80A triggerings for the period August 1990 to year-end 1997. The data are broken down by year, by the direction of the move, and the frequency with which it was triggered more than once in a day. It also provides yearly statistics on the level and volatility of the DJIA.

| | 1990* | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Rule 80A Triggered: | | | | | | | | | |
| On a down move | 15 | 8 | 8 | 5 | 19 | 14 | 51 | 113 | 233 |
| On an up move | 7 | 12 | 8 | 4 | 9 | 14 | 53 | 125 | 232 |
| Twice in a day | 1 | 0 | 0 | 0 | 2 | 1 | 16 | 55 | 75 |
| 3 or more in a day | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 | 14 |
| Total triggers/year | 23 | 20 | 16 | 9 | 30 | 29 | 119 | 303 | 549 |
| Total days | 22 | 20 | 16 | 9 | 28 | 28 | 101 | 219 | 443 |
| Standard deviation of DJIA closing prices | 16.3 | 14.6 | 10.4 | 8.2 | 11.0 | 8.8 | 11.7 | 16.1 | 12.1 |
| Ave. DJIA closing price | 2679 | 2929 | 3284 | 3525 | 3794 | 4494 | 5740 | 7002 | 4049 |
| 80A move as % of average DJIA | 1.9 | 1.7 | 1.5 | 1.4 | 1.3 | 1.1 | 0.9 | 0.7 | |

*Rule 80A went into effect August 1, 1990.
Source: NYSE

**Table 3: Volatility regression results**

This table presents OLS regression results on intraday volatility estimates for the Dow Jones Industrial Average (DJIA), the S&P 500 index and S&P 500 futures based on minute by minute data for these three series from January 1990 to June 1997. The absolute value of the price variation per minute was determined for each series. Forty-two fractiles were created representing 5 point movements in the level of the DJIA; twenty-one above the previous day's close, twenty below the previous day's close, and one representing a zero to five point decrease in the DJIA. Each minute's variation was then assigned to the fractile during which it occurred. The following regression was then run:

$$Volatility = \beta_0 + \beta_1\, Fractile + \beta_2\, Fractile^2 + \beta_3\, 80A + \varepsilon$$

where *Fractile* is the appropriate fractile, $Fractile^2$ is the square of the fractile (to control for non-linearities), and *80A* is a dummy variable which is one when NYSE Rule 80A is in effect and zero otherwise. (Each coefficient and standard error estimate has been multiplied by $10^6$ for legibility.)

| | Intercept | *Fractile* | $Fractile^2$ | *80A* | Adjusted $R^2$ |
|---|---|---|---|---|---|
| DJIA | 148* | -2.46* | 0.37* | -6.36* | 0.93% |
| | (0.21) | (0.04) | (0.01) | (1.21) | |
| S&P500 index | 111* | -2.20* | 0.34* | -11.53* | 0.99% |
| | (0.17) | (0.04) | (0.01) | (1.01) | |
| S&P500 Futures | 240* | -6.93* | 0.89* | -10.65* | 2.36% |
| | (0.33) | (0.07) | (0.01) | (1.93) | |

* indicates significance at the 0.01% level.

**Table 4: Stock price volatility, by fractile, before and after the adoption of Rule 80A**

This table presents the volatility of stock prices (as measured by the absolute value of price returns) conditioned on two states. Across the columns are the pre-August 1990 (when Rule 80A was not in effect) and post-August 1980. Across the rows are the periods when Rule 80A had been triggered (or would have been triggered, for the pre-August 1990 period) and periods when Rule 80A had not been triggered. The differences across years are presented in the last column and the difference of differences is presented in the last row. (*t*-statistics under the null hypothesis of no differences in means are provided in parentheses.)

| | Pre-August 1990 | | Post-August 1990 | | |
|---|---|---|---|---|---|
| | **Sample size** | **Average volatility** | **Sample size** | **Average volatility** | **Difference in volatility** |
| **Rule 80A on** | 2734 | .00021056 | 45484 | .00014412 | .00006644<br>(8.4413) |
| **Rule 80A off** | 5318 | .00016215 | 69395 | .00014093 | .00002122<br>(18.1942) |
| **Difference of differences:** | | | | | .00004522<br>(42.968) |

**Table 5: Volatility regression results for augmented regression**

This table presents OLS regression results on intraday volatility estimates for the Dow Jones Industrial Average (DJIA), the S&P 500 index and S&P 500 futures based on minute by minute data for these three series from January 1990 to June 1997. The absolute value of the price variation per minute was determined for each series. Forty-two fractiles were created representing 5 point movements in the level of the DJIA; twenty-one above the previous day's close, twenty below the previous day's close, and one representing a zero to five point decrease in the DJIA. Each minute's variation was then assigned to the fractile during which it occurred. Additional dummy variables were added for the day of the week, the time of day and the year that the observation occurred. The following regression was then run:

$$Volatility_t = \beta_0 + \beta_1\, Fractile_t + \beta_2\, Fractile_t^2 + \beta_3\, 80A\_up_t + \beta_4\, 80A\_down_t +$$
$$\Sigma\, \beta j\, D_{YEAR=y} + \Sigma\, \beta_j\, D_{DAY\ OF\ THE\ WEEK} + \Sigma\, \beta j\, D_{TIME\ OF\ THE\ DAY} + \varepsilon,$$

where *Fractile* is the appropriate fractile, $Fractile^2$ is the square of the fractile (to control for non-linearities), *80A* is a dummy variable which is one when NYSE Rule 80A is in effect and zero otherwise, $D_{YEAR}$ is equal to one if the observation occurs in year y and zero otherwise, $D_{DAY\ OF\ THE\ WEEK=d}$ is equal to one if the day of the week equals d and zero otherwise, and $D_{TIME\ OF\ THE\ DAY=f}$ is equal to one if the time falls into fractile *f* (described in the text) and zero otherwise. Coefficients for the day of the week, the time of day and year are not reported, for space considerations, but F-tests for each set of coefficients indicate that each set is statistically significant in explaining the volatility of stock market returns.

(Each coefficient and standard error estimate has been multiplied by $10^6$ for legibility.)

| | Intercept | *Fractile* | $Fractile^2$ | *80A_down* | *80A_up* | Adjusted $R^2$ |
|---|---|---|---|---|---|---|
| DJIA | 121* | -2.20* | 0.36* | -6.51* | -23.22* | 46.4% |
| | (0.56) | (0.05) | (0.01) | (1.46) | (1.48) | |
| S&P500 index | 108* | -2.00* | 0.31* | -12.93* | -26.00* | 39.9% |
| | (0.50) | (0.04) | (0.01) | (1.25) | (1.28) | |
| S&P500 Futures | 272* | -6.15* | 0.85* | -6.15* | -22.03* | 47.7% |
| | (0.91) | (0.09) | (0.01) | (2.47) | (1.93) | |

* indicates significance at the 0.01% level.

**Table 6: Nonparametric test for volatility effects of Rule 80A**

This table show the results of a match pair comparison of stock market volatilities for the nearby S&P 500 futures contract. Days in the early 1990s were paired with days in 1997, with similar percent volatilities from the previous day's close (1%) by 12:00 noon, and matched on other determinants of volatilities (such as the day of the week). A one percent move in the early 1990s did not result in the triggering of Rule 80A, while a one percent move in 1997 did result in such a triggering. We report the number of observations, the average minute-to-minute volatility in the thirty minutes after the one-percentage point move, the difference, and the t-statistic associated with the difference.

(The average minute-to-minute volatility is multiplied by $10^6$ for enhanced readability.)

| No. of observations | Volatility after 1% move: Early 1990s, Rule 80A not triggered | Volatility after 1% move: 1997, Rule 80A triggered | Difference | t-statistic |
|---|---|---|---|---|
| 37 | 4.18 | 3.73 | -0.45 | -2.27 |

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