Circuit Breakers, Trading Collars, and Volatility Transmission Across Markets: Evidence from NYSE Rule 80A

Michael A. Goldstein*
Babson College

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* Donald P. Babson Professor of Finance, Babson College, Finance Department, 231 Forest Street, Babson Park, MA 02457-0310; Phone: (781) 239-4402; Fax: (781) 239-5004; E-mail: goldstein@babson.edu

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Abstract

The New York Stock Exchange's Rule 80A attempted to de-link the futures and equity markets by limiting index arbitrage trades in the same direction as the last trade to reduce stock market volatility. Rule 80A leads to a small but statistically significant decline in intraday U.S. equity market volatility. In addition, the results are asymmetric: volatility is dampened more in a rising market than in a declining one. These results suggest that, to a limited basis, rule restrictions on trading can sufficiently de-link the futures and equity markets enough to reduce the transmission of volatility.

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1. Introduction

For almost thirty years, a consistent concern for regulators and practitioners alike has been the possibility of the transmission of volatility from the derivatives markets (such as futures market) to the primary market (such as the equity market), and for good reason. The October 19, 1987 Black Monday market crash was blamed on program trading and the selling of stock index futures due to portfolio insurance, some of which was arbitraging the difference in prices between the Chicago futures market and the equity markets in New York.[1] For example, the Presidential Task Force on Market Mechanisms (1988), commonly called the Brady Commission Report, noted that "[s]elling pressure in the futures market was transmitted to the stock market by the mechanism of index arbitrage" (p. v).[2] Over two decades later, the joint report by the Securities and Exchange Commission and the Commodity Futures Trading Commission (2010) notes that the May 10, 2010 Flash Crash was also due to volatility transmission from the SP500 futures market to the equity markets.

The October 1987 Market Crash and the May 2010 Flash Crash demonstrate the notable effects of volatility transmission from the futures markets to the equity markets. Despite the distance between Chicago and New York, the increase use of computerization of the markets and their linkages has caused movements in the Chicago futures markets to impact prices in the New York equity markets with increasing speed. Laughlin, Aguirre, and Grundfest (2014) examine

[1] For example, in Lobb (2007), NYU Professor Richard Sylla noted on the twentieth anniversary of the 1987 Crash: "The internal reasons included innovations with index futures and portfolio insurance. I've seen accounts that maybe roughly half the trading on that day was a small number of institutions with portfolio insurance. Big guys were dumping their stock. Also, the futures market in Chicago was even lower than the stock market, and people tried to arbitrage that. The proper strategy was to buy futures in Chicago and sell in the New York cash market. It made it hard -- the portfolio insurance people were also trying to sell their stock at the same time."

[2] In addition, the Presidential Task Force on Market Mechanisms (1988) emphasized that these markets are linked and integrated: "[f]rom an economic viewpoint, what have been traditionally seen as separate markets — the markets for stocks, stock index futures, and stock options — are in fact one market" (p. vi).

information transmission from the Chicago futures markets to the New York equity markets, and show that in April 2010 (immediately prior to the May 2010 Flash Crash) trades in the futures markets in Chicago impacted equity prices in New York within 7.25 to 8 milliseconds later. They also show that by August 2012 (after the Flash Crash), due to increasingly sophisticated microwave towers that are increasingly better located, the data indicates that this transmission time dropped to 4.2 to 5.2 milliseconds.[3]

Given the impact of the linkages across these markets, an interesting question is whether rules and regulations could de-link the futures and equity markets in such a way to reduce volatility on the equity market. In fact, there was a rule put in place just after the October 1987 market crash that did de-link index arbitrage trades between the futures and equity markets, but was rescinded twenty years later, in October 2007 (SEC 2007), less than three years before the May 2010 Flash Crash. That rule, New York Stock Exchange Rule 80A, is a "trading collar" rule and was one of the two circuit breakers that were put in place after the October 1987 Market Crash.[4] When rescinding the rule in 2007, the New York Stock Exchange ("NYSE") noted that while the trading collar was invoked hundreds of times per year in the late 1990s, due to a rule change in 1999, by the mid 2000's NYSE Rule 80A was rarely invoked; see SEC (2007). The time period while NYSE Rule 80A was in place is therefore bracketed by two major market failures during which actions in the futures markets were clearly transmitted to the NYSE equity markets.

[3] In fact, Laughlin, Aguirre, and Grundfest (2014) suggest that future improvements could drop the time to about 4.03 milliseconds, approaching the theoretical minimum of 3.93 milliseconds that is limited by the speed of light. See Angel (2014) for a further discussion of the impact of regulation related to the intersection of physics and finance.

[4] The other was NYSE Rule 80B, which, was a market-wide circuit breaker that stopped trading in all securities once the Dow Jones Industrial Average dropped by a significant amount. Thus far, it has only been executed once, almost exactly a decade after the October 1987 market crash. 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; see Goldstein and Kavajecz [2004] for an examination of liquidity provision and magnet effects during this event. However, NYSE Rule 80A was also triggered twice that day, for the 263th and 264th time that year alone.

In this paper, I evaluate the effectiveness of NYSE Rule 80A in reducing volatility by examining the rule's effectiveness during the period when the rule was relatively binding. Unlike other studies, I examine periods before and after the implementation of the rule, and, by using a proprietary dataset provided by the NYSE, use a more precise and exact timing when the collar was triggered to increase the ability to detect its effectiveness without having to estimate when the collar was in effect. By examining a period where the rule was a fixed amount and not a percentage, I am able to examine the effectiveness of de-linking rules where the trading collar levels changed as a percentage of the previous day's close.[5] Overall, I find that the rule did have some effect in reducing volatility when the trading collar is in effect. However, the effect is asymmetric; volatility is dampened more in a rising market than in a declining one.

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 was 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 studied in this paper, Rule 80A went into effect whenever the Dow Jones Industrial Average ("DJIA") moves either up or down by 50 or more points from its previous day's close. When in effect, Rule 80A restricted index arbitrage traders from making index arbitrage trades in the equity market that would be destabilizing, i.e., trades that were part of an index arbitrage strategy that would continue to push a falling market down or those that would continue to push a rising market up.

Specifically, during the period studied, Rule 80A required that once the DJIA has advanced (declined) by 50 points or more, all index arbitrage orders to buy (sell) any S&P

[5] Since the collar level was binding but the DJIA base amount changes over the period (both up and down), the collar level expressed as a percentage changed. In that way, one can view this period as if there were a natural experiment in testing the effects under a variety of percentage collars. If NYSE Rule 80A does not affect volatility transmission at all, this will not matter, but if it does so but only on a percentage basis, it would not be clear where that cutoff would be. Since the percentages are changing (due to DJIA level changes) during this period, this will provide additional chance for the tests to find if the rule had an effect.

component stock must be entered as a "buy minus" ("sell plus") order. In this way, an index arbitrage order to sell a certain stock (e.g., IBM) could not be executed if the last trade was a sell, but only if the last trade was a buy (and vice versa for buys). Therefore, once the DJIA had declined by 50 points or more, an index arbitrage trade could not follow any sell order with another sell order (or a buy order with another buy order) that was part of an index arbitrage trade and thus cause a cascading set of orders to push the market in any particular direction. Instead, for the index arbitrage order to be executed, it had to go in the opposite direction of the previous order. In addition, there was a "sidecar" provision under which "program trading orders in stocks in the Standard & Poor's (''S&P'') 500 Stock Price Index [were] temporarily diverted into separate electronic files for a five minute period if the primary S&P 500 futures contract decline[d] by 12 points form [sic] its previous close. If the sidecar [was] triggered, … Rule 80A(b) also impose[d] limitations on the entry of certain types of stop orders or stop limit orders." (SEC 1999, p. 8424).[6] Collectively, NYSE Rule 80A restricted those using an index arbitrage strategy from buying NYSE stocks in a rising market or selling NYSE stocks in a falling market. The rule stayed 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.[7]

The effectiveness of market-wide circuit breakers has been frequently debated. Most studies focus on market-wide halts similar to the ones mandated by NYSE Rule 80B. However, since NYSE Rule 80B has only been triggered on one occasion, examining the effectiveness of

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[6] There are relatively few papers that examine the effects of sidecar provisions on program trades and the stock and futures markets. One notable exception is Jordan, Lee, and Park (2014), who examine the program trading sidecar provisions on the Korean Stock Exchange and find that the spot market is adversely affected when the sidecar is in effect and that order imbalances are improved when the sidecar is not in effect. However, they find that sidecars do help during large market movements.

[7] On December 15, 1998, the NYSE proposed dropping the sidecar provision and changing the collar from a fixed 50/25 point change in the Dow Jones Industrial Average to an amount that was 2%/1% of the level of the DJIA in the previous quarter; see SEC (1998). This change was approved on February 11, 1999; see SEC (1999). This change dropped significantly the number of times Rule 80A was executed. Aradhyula and Ergun (2004) and Ergun (2009) examine the 99 times NYSE Rule 80A was triggered from February 16, 1999 to August 31, 2001 under this different regime of the 2% rule, although they must estimate when the collar is in effect.

this type of circuit breaker on U.S. equity markets is difficult. Most studies rely 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. Ackert, Church, and Jayaraman (2001) examine trading halts and circuit breakers using experimental markets, and find that circuit breakers affect trading activity. Using proprietary NYSE order data, Goldstein and Kavajecz (2004) recreate limit order books surrounding the one triggering of the NYSE 80B market-wide circuit breaker on October 27, 1997, and find support for the magnet effect. In addition, Goldstein and Kavajecz (2004) find that orders moved from the electronic limit order book to the floor as traders valued liquidity.

Others empirically examine the effectiveness of circuit breakers on 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.

Other papers examine the effect of price limits, which, like circuit breakers, are rule based measures that disrupt or halt trading. Price limits are in some sense similar to the trading collars contained in NYSE Rule 80A, in that price limits can be either wide or narrow, although price limits halt trading once a certain boundary is hit, while the trading collar of NYSE Rule 80A just inhibits trading.[8] Price limits are a feature of many stock markets around the world.[9] Bildik and Gulay (2006) examine price limits on the Instanbul Stock Exchange and find that "price limits are ineffective in reducing volatility" (p.385). In contrast, Farag (2013) uses extended EGARCH and PARCH time varying conditional variance models and finds that moving from narrow to wide price limits alter volatility in an examination of three emerging markets. In addition, Farag (2013) finds asymmetric effects, in that negative shocks have a greater impact on conditional volatility than do positive shocks. Farag (2015) examines price limits and circuit breakers on the Egyptian stock market and finds support for the magnitude effect. Kim, Liu, and Yang (2013) examine periods on China's stock markets before and after the imposition of price limits, and suggest that price limits moderate transitory volatility, but do not find support for the magnet effect.

A related literature to price limits is the study of individual stock trading halts. Unlike the market-wide circuit breakers such as NYSE Rule 80A or NYSE Rule 80B, which affects trading in all (NYSE Rule 80B) or S&P 500 component (NYSE Rule 80A) stocks, individual stock trading halts affect only one security. Lee, Ready, and Seguin (1994) find that volume and volatility is increased the day after NYSE individual stock trading halts. Corwin and Lipson (2000) find that market and limit order submissions and cancelations increase during NYSE individual stock trading halts, which may provide information. Christie, Corwin, and Harris (2002) examine delayed openings and intraday trading halts for individual stocks on Nasdaq. Kryzanowski and Nemiroff (2001) examine intraday trading halts on stocks that are interlisted on both the Montreal and Toronto Stock Exchanges and find an increase in information asymmetry before the halt and during the halt but not after the halt. Edelen and Gervais (2003) find a similar result for NYSE individual stock trading halts. Jiang, McInish, and Upson (2009) find that

[8] See Tooma (2005) for a review of regulations related to circuit breakers, trading halts, and price limits around the world, including NYSE Rules 80A and 80B.
[9] In the United States, the Securities and Exchange Commission approved the Limit Up-Limit Down rule on May 31, 2012, to be effective April 8, 2013, for a one-year pilot; see SEC (2012a).

NYSE individual stock trading halts affect other, informationally-related stocks that continue to trade, indicating a common liquidity response even to stocks that did not have the halt.

Previous work has examined Rule 80A empirically, but the results are inconsistent. 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 23 observations in their sample, and only 16 days in which Rule 80A was triggered but CME price limits were not. 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 39 mid-day 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.[10]

Aradhyula and Ergun (2004) use five minute data to examine the effects of the 99 times that Rule 80A was triggered from February 16, 1999 to August 31, 2001, during which the 2% and 1% trading collar levels were used and when the sidecar rule was eliminated. As Ergun (2009) notes, due to the five-minute interval, Aradhyula and Ergun (2004) must estimate when the trading collar limits were breached. Using a polynomial specification and GARCH estimates, Aradhyula and Ergun (2004) find that market volatility is higher during periods the collar is in effect. They also find that in rising markets, the presence of Rule 80A does not affect market volatility, but that market volatility is higher in declining markets. Ergun (2009) examines the

[10] 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.

same time period and also uses five minute returns to estimate volatility and the lead-lag relation between the cash and futures market. Ergun (2009) concludes that "neither market leads the other for more than 5 minutes", although his tests may be unable to detect results due to the speed of the markets due to the level of computerization by 2000 and the relative coarseness of a five-minute interval.

This paper differs from previous work in a number of respects. Using minute by minute data from 1988 to 1997, I examine the effectiveness of Rule 80A in reducing stock market volatility to examine if volatility is dampened during times that NYSE Rule 80A is in effect. While other papers mostly focus on the delinking of the markets, this paper focuses exclusively on the issue of whether Rule 80A dampens volatility, as it was the stated reason as to why the rule is in place. I 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, I 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.

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 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 Presidential Task Force on Market Mechanisms (1988), suggest 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 major developments surrounding the adoption of formal circuit breakers on the NYSE following the crash of 1987 through 2007. 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. NYSE Rule 80B, the market-wide trading halt, has changed over the years and now calls for a trading halt based on a percentage decline in the S&P 500.[11]

Rule 80A was officially adopted in August 1990 with two separate provisions. The first provision entails a restriction on index arbitrage orders that might be destabilizing (buying if the last order was a buy; selling if the last order was a sell) on S&P component stocks when the DJIA moves 50 points in either direction from the previous day's close. Should the DJIA return to within 25 points of the previous day's close, the restrictions are lifted. 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. On December 15, 1998, the NYSE proposed dropping the sidecar provision and changing the collar

[11] Effective April 15, 1998, the Rule 80B trigger levels were 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. As of February 4, 2013, the limits were changed to 7%, 13% and 20% move in the S&P 500; see SEC (2012b).

from a fixed 50/25 point change in the Dow Jones Industrial Average to an amount that was 2%/1% of the level of the DJIA in the previous quarter [SEC (1998)] and the change was approved on February 11, 1999 [SEC (1999)]. On October 31, 2007, Rule 80A was rescinded [SEC (2007)].

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, program trading." [12] 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." [13] Consistent with these statements, an NYSE official stated in Congressional testimony, "The purpose of these Rule 80A provisions is to help decrease market volatility caused by the entry of a large volume of orders 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."[14] 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 more generally whether rules and regulations can inhibit volatility transmission between markets.

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[12] SEC release No. 34-27812, File No. SR-NYSE-90-11 (March 16, 1990), 55 FR 11284 (March 27, 1990).
[13] SEC release No. 34-29308, File No. SR-NYSE-91-21 (June 14, 1991), 56 FR 28428 (June 20, 1991).
[14] 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.

3. Data and descriptive statistics

The data in this analysis are 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 index and the S&P 500 futures index, which trade on the Chicago Mercantile Exchange (CME). In order to remove any effects of the change to the calculation of the trading collar and the removal of the sidecar provision, I use a sample period from prior to the establishment of the NYSE 80A rule through a time period during which the rule was constant at 50 DJIA points and 25 DJIA points. Therefore, the sample period contains all business days from March 1, 1988 through December 31, 1997.[15] Due to the possibility of non-synchronous price data at the opening of the NYSE, the first fifteen observations (corresponding to the first 15 minutes of trading) are eliminated.[16] The last ten minutes of trading are also eliminated, as the NYSE rules restrict destabilizing market-on-close orders during this time period.[17] Finally, I 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.

I obtained from the NYSE 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.[18] Overall, during our sample period, Rule 80A was triggered 549 times. For the empirical analysis, three indicator variables are created to identify each minute when Rule

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[15] 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, was altered from its inception in August 1990 to the end of our sample in December 1997. Changes to a percentage classification occur after the sample period.

[16] During this period, the NYSE required specialists to open each stock within the first fifteen minutes of trading or otherwise seek special authorization. See NYSE Rule 103A.10(B)(i).

[17] The results presented in this paper are robust to alternate 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.

[18] I thank Mark Ventimiglia and the NYSE for providing this data.

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, two additional indicator variables are also created. 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.

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

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

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:[19]

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

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

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[19] As an alternate measure of volatility, the square of the return series was also examined. The results and conclusions presented below are qualitatively similar using this alternative measure.

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

This section presents the results of the tests of the impact of NYSE Rule 80A on stock market volatility. I first present preliminary regression results describing the basic relation between volatility and Rule 80A. Next, stock market volatility is compared before and after the implementation of Rule 80A through a differences-of-differences approach. Finally, additional conditioning variables are included in the regression in an attempt to control for additional cross-sectional and time-series variables which help to forecast volatility.

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; see, for example, Lux and Marchsesi (2000), Jacobsen and Dannenburg (2003), Xue and Gencay (2012), and Ning, Xu, and Wirjanto (2015). 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 are 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, is 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, one choice would be to use GARCH-type models, although these models assume a certain structural form to the variance over time. For example, Ning, Xu, and Wirianto (2015) note that most ARCH models assume symmetric volatility, which is not true for stock market data, and therefore employ a coupla approach. Bauwens and Giot (2001, p 132) also note issues with using ARCH models on intraday data. Ghalanos (2014) suggest "de-seasonalizing" the residuals and reviews the method in Engle and Sokalska (2012), while Andersen and Bollerslev (1997), recommend a Flexible Fourier Form, which was used by Aradhyula and Ergun (2004). In his study of Rule 80A during the 2% rule period, Ergun (2009) fits a GARCH (1,1) on daily estimates, but then applies other transformations, noting "… I let the data determine how much smoothing should be carried out …" (p.1679). It is possible, however, that such smoothing may remove the effect being studied, which may in part explain why Ergun (2009) finds little effect.[20]

[20] Another issue with the use of GARCH is its tendency not to converge on this type of data. In this case, various attempts were made at estimating GARCH and other ARCH models via maximum likelihood on the unsmoothed data in this paper 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. These issues could be due to the bid-ask bounce, or the difficulty of inclusion of overnight returns. I therefore do not employ these models in this study and instead employ a different approach that does not require smoothing or transformation.

To avoid some of the issues related to possible smoothing and to avoid strong assumptions on the structural form of the variance, the minute-by-minute volatility estimates are regressed on their respective fractiles. Due to the non-linearity apparent in Figure 1, the square of the fractile as a variable is also included. Finally, since this study is examining the effect of Rule 80A on volatility, the regression includes a dummy variable indicating when the rule is in effect. Specifically, I 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.[21]

All three variables are highly significant at the 0.01% level (Table 3). In particular, the coefficient on *Fractile* is significant and negative, indicating that downward movements have higher volatilities on average than upward movements. In addition, the coefficient on $Fractile^2$ 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, 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. Overall, the regression suggests that NYSE Rule 80A does help reduce volatility.

The dummy variable *80A_min* is then replaced with separate dummy variables for Rule 80A on the upside (*80A_up*) and on the downside (*80A_down*), resulting in the regression

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

[21] We arrive at qualitatively similar conclusions if the discrete variable $Fractile_t$ and $Fractile_t^2$ are replace 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.

This regression suggests that Rule 80A has an effect that is negative and statistically significant in both directions. Interestingly, the 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, I perform a simple 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). Of particular note is 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.

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.[22] 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 relatively simple 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

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

In order to ensure that the results from Section 4.1 are not due to misspecifiations, additional independent variables are added to the regression to capture other independent effects on volatility that are not related to Rule 80A. First, as shown in Table 1, there is a clear pattern of volatility over the years of our sample, so I include a series of dummy variables for each of the years, $D_{\text{YEAR=1988}}$ through $D_{\text{YEAR=1997}}$, 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 a series of dummy variables, $D_{\text{DAY=Monday}}$ through $D_{\text{DAY=Friday}}$, equal to one if the observation occurs on the corresponding day and zero otherwise is also included. 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. This time-of-day pattern is addressed with a series of 24 intraday dummies, from $D_{\text{Time0[945,\ldots,1000)}}$ through $D_{\text{Time0[1530,\ldots,1545)}}$, 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.

5. Conclusions

This paper examines whether or not regulations on delinking, even temporarily, the cash and futures markets can have an effect on volatility in the cash market. This study examines the effects of NYSE Rule 80A, which went into effect in August 1990, using data both before and after the rule went into effect, and by using a long time period during which the trigger amount of the trading collar stayed constant. Using minute-by-minute data on the DJIA cash index and the S&P cash index and futures price, I 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.

Overall, the evidence suggests that rules that temporarily delink the cash and futures market can have an effect on volatility. While these results are statistically significant, they are relatively small in magnitude. The relatively small magnitude may be why Ergun (2009), which study a later period when the rule was based on a 2% DJIA move, did not find notable effects, perhaps because the 5-minute intervals were too coarse and the time period studied had many fewer times that the rule was triggered. However, this study concurs with Aradhyula and Ergun (2004) that the effects on volatility are asymmetric, and a finding in Ergun (2009) that the leading nature of the futures market over the cash market is stronger during a down market.

Regulations and rules cannot prevent a market from falling (or rising). A different question is whether there should be volatility spillovers from one market to another, and whether rules can affect volatility even temporarily. Using a finer grid than previous work, this study finds some evidence that rules put in place after the 1987 market crash were able to dampen volatility transmission. Given that the May 2010 Flash Crash occurred after this rule was rescinded in October 2007, regulators should consider carefully whether rules that affect linkages across these markets are appropriate.

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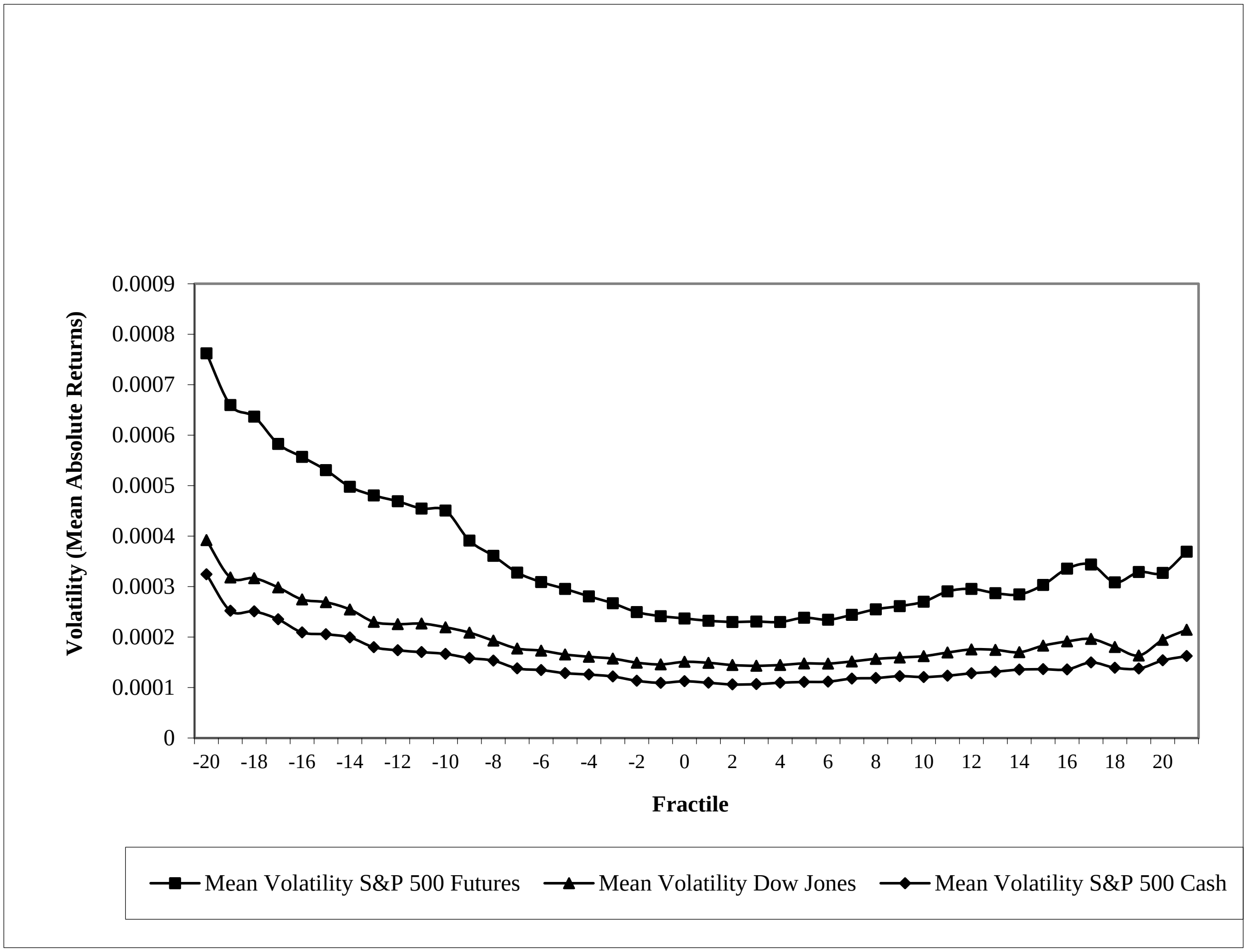

Figure 1. Mean Volatility of Returns for the S&P 500 Cash Index, S&P 500 Futures and the Dow Jones Industrial Average. The average minute-by-minute intraday volatility for the Dow Jones Industrial Average, the S&P 500 index and the S&P 500 futures contract from January 1990 to June 1997. Each minute 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.

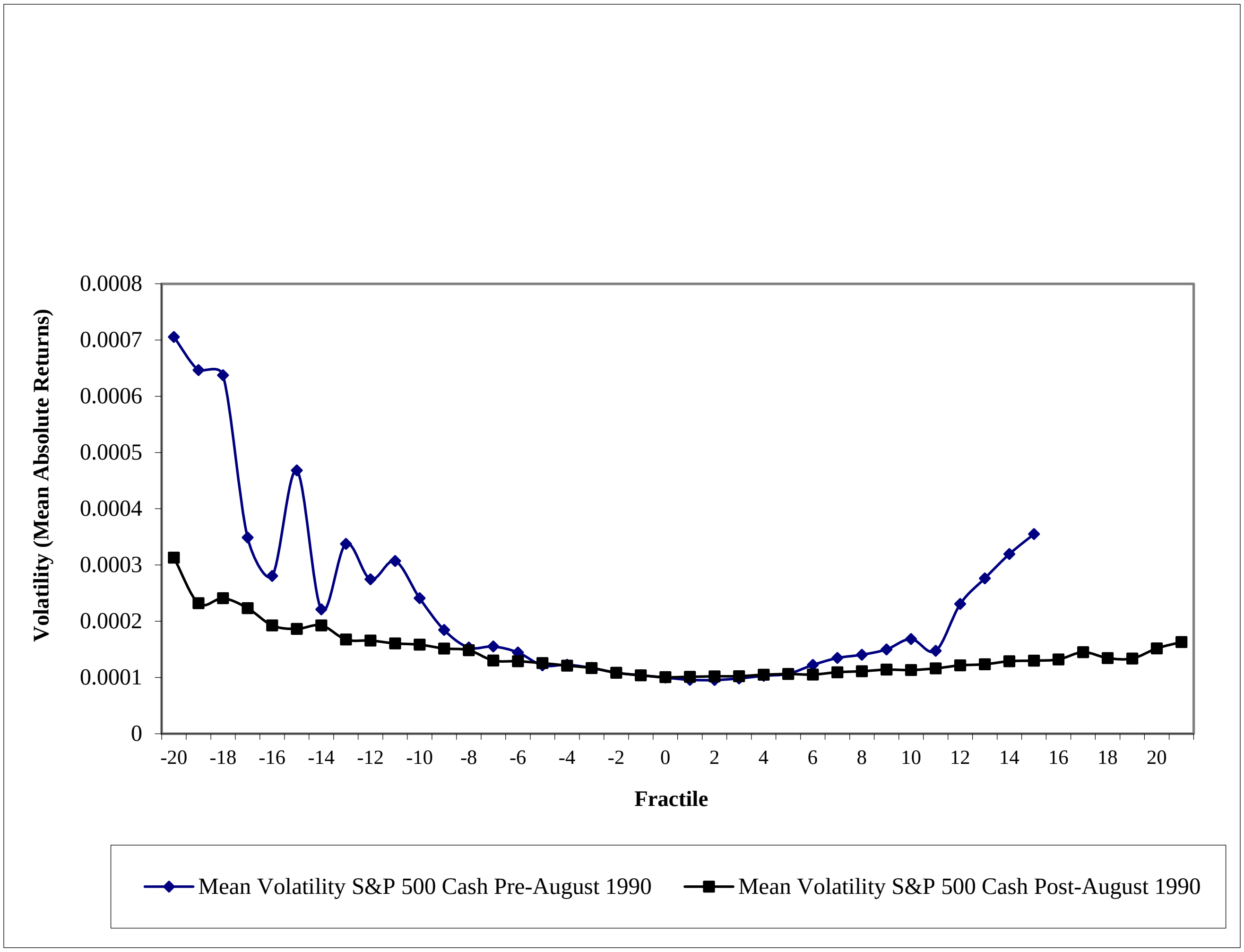

Figure 2. Mean Volatility of Returns for the S&P 500 Cash Index Pre- and Post-August 1990. The average minute-by-minute intraday volatility for the S&P 500 cash index in two sub-periods: from January 1988 to August 1990 and from August 1990 to December 1997. 1997. Each minute was assigned to a fractile 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
Partial Chronology of Circuit Breaker Adoptions and Amendments on the NYSE: 1987 to 2007

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.
01/14/88	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.
02/04/88	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.
08/01/90	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 DJIA move. Unrestricted arbitrage is restored if the DJIA reverses to within 25 points of previous day's close.
07/22/96	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.
02/03/97	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.
04/15/98	NYSE modifies Rule 80B so that trigger levels were 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.
02/11/99	SEC approves the NYSE change to Rule 80A to change the restriction on index arbitrage orders on buying on an uptick (buy minus orders only) and selling on a downtick (sell plus orders) after a 2% change in the DJIA from the previous day's. Unrestricted arbitrage is restored if the DJIA reverses to within 1% of previous day's close. In addition, the sidecar provision is repealed.
10/31/07	SEC approves the NYSE's request to rescind Rule 80A, effective immediately.

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 (8.4413)
Rule 80A off	5318	.00016215	69395	.00014093	.00002122 (18.1942)
Difference in differences:					.00004522 (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:

$$Volatility_t = \alpha_0 + \beta_1 Fractile_t + \beta_2 Fractile_t^2 + \beta_3\, 80A\_up_t + \beta_4\, 80A\_down_t + \Sigma \beta_j D_{YEAR=y} + \Sigma \beta_j D_{DAY\ OF\ THE\ WEEK} + \Sigma \beta_j D_{TIME\ OF\ THE\ DAY} + \varepsilon_t.$$

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.