"Limit Up-Limit Down" Pilot Plan and Extraordinary Transitory Volatility

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ABSTRACT

This paper examines how the mechanisms within the Limit Up-Limit Down ("LULD") National Market System ("NMS") Plan ("LULD Plan") affect extraordinary transitory volatility.[2] We construct measures of the frequency of large, short-term trade-price reversals as proxies for extraordinary transitory volatility. Overall, we find evidence that is consistent with the LULD mechanisms reducing extraordinary transitory volatility. When we specifically compare the mechanisms under the LULD Plan to the mechanisms under the Single-Stock Circuit Breaker ("SSCB") Pilot, we find some evidence that is consistent with the LULD mechanisms reducing extraordinary transitory volatility relative to the SSCB mechanisms. However, the results vary depending on the specific methodology employed.[3]

[1] The U.S. Securities and Exchange Commission ("Commission" or "SEC"), as a matter of policy, disclaims responsibility for any private publication or statement of any of its employees. The views expressed in this White Paper are those of the authors and do not necessarily reflect the views of the Commission or of the authors' colleagues on the staff of the Commission. We prepared this white paper as a part of the Division of Economic and Risk Analysis (DERA) White Paper series. We thank our colleagues in DERA, especially Amy Edwards, for their helpful comments.

[2] See Order Approving, on a Pilot Basis, the National Market System Plan to Address Extraordinary Market Volatility ("Approval Order") by BATS Exchange, Inc., BATS Y-Exchange, Inc., Chicago Board Options Exchange, Incorporated, Chicago Stock Exchange, Inc., EDGA Exchange, Inc., EDGX Exchange, Inc., Financial Industry Regulatory Authority, Inc., NASDAQ OMX BX, Inc., NASDAQ OMX PHLX LLC, The Nasdaq Stock Market LLC, National Stock Exchange, Inc., New York Stock Exchange LLC, NYSE MKT LLC, and NYSE Arca, Inc., Release No. 34-67091 (May 31, 2012), 77 FR 33498 (June 6, 2012) (File No. 4-631), Exhibit A ("The Plan"). Subsequent amendments are available at https://www.sec.gov/rules/sro/nms.htm.

[3] Because we study the frequency of price reversals at a number of different thresholds, we use a number of terms throughout the paper to simplify our discussion and help summarize our findings. We use the term large price reversals as a general term to discuss all of the reversals examined in our analysis. We develop more specific terms that group our price reversal measures into three categories based on the magnitudes of the thresholds and how frequently price reversals exceed the threshold. We define the smaller thresholds as "Moderate" price reversals. We define the middle thresholds as "Big" price reversals. We define the largest thresholds as "Extreme" price reversals.

I. Summary

- Large price reversals for both Tier 1 and Tier 2 securities were less frequent under the LULD Plan than during a time with no individual security price limits or circuit breakers that applied market-wide (i.e. the time period before the SSCB Pilot went into effect).[4]

- The difference between the frequency of large price reversals during the LULD Plan time period and the SSCB Pilot time period depends on the methodology used to categorize the reversal.

- The magnitude of the largest price reversals that occurred each day for both Tier 1 and Tier 2 securities were smaller during the LULD Plan time period than during the SSCB Pilot time period or the time period before the SSCB Pilot went into effect.

- In order to control for confounding factors, we compare the effects of the LULD and SSCB mechanisms on extraordinary transitory volatility over the eight-week staggered phase-in of the LULD Plan for Tier 1 securities, during which time self-regulatory organizations (SROs) transitioned Tier 1 securities from the SSCB Pilot to the LULD Plan. Overall, we find some evidence that is consistent with the LULD mechanisms reducing extraordinary transitory volatility relative to the SSCB mechanisms. However, the results vary depending on the specific methodology employed.

All of these categories are nested in the term large price reversals. See Section V for a more detailed discussion of the categorization.

[4] Tier 1 securities include NMS stocks in the S&P 500 and Russell 1000 indexes and some high volume exchange-traded products (ETPs). Tier 2 securities include the remainder of NMS stocks. See Appendix A of the Approval Order, supra note 2, for the definitions of Tier 1 and Tier 2 securities.

II. Introduction

On May 31, 2012, the Commission approved the National Market System Plan to Address Extraordinary Market Volatility. The Plan provides for a market-wide limit up and limit down mechanism designed to prevent trades in individual NMS securities from occurring outside of specified single-stock price bands. The LULD Plan is designed, among other things, to address the type of sudden price movements that the market experienced during the "Flash Crash" on May 6, 2010. The LULD Plan replaced the Single-Stock Circuit Breaker Pilot, which was an earlier pilot program intended to limit the potential harm from extraordinary price volatility.[5]

Economists differentiate between fundamental and transitory volatility. Fundamental volatility occurs when new information is revealed about a firm's fundamental value and security prices adjust to reflect such new information. Harris (1998) defines transitory volatility as "the tendency of prices to [temporarily] bounce around their fundamental values". Temporary deviations of prices from fundamental values can be caused by trades from uninformed investors (Harris, 1998), liquidity "evaporation" (Nagel, 2012), market-maker inventory problems (Hendershott and Menkveld, 2014; Gissler, 2015), and even rogue trading algorithms and "fat fingers" (Brogaard and Roshak, 2016). Usually, these temporary price deviations reverse quickly.[6] However, occasionally the sudden and unanticipated price movements are so drastic that market orders and stop loss orders face an increased risk of getting executed at prices far away from their fundamental values. A number of features of the LULD Plan, such as the Upper and Lower Price Bands and Limit States,[7] are intended to reduce the frequency of these large, transitory price movements.[8]

Our study attempts to evaluate whether the mechanisms under the LULD Plan reduce extraordinary transitory volatility (i.e. large, temporary deviations of prices from fundamental values).[9] To examine this question, we construct measures of the frequency of large reversals

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[5] See Securities Exchange Act Release Nos. 62251 (June 10, 2010), 75 FR 34183 (June 16, 2010) (SR-FINRA-2010-025); 62883 (September 10, 2010), 75 FR 56608 (September 16, 2010) (SR-FINRA-2010-033).

[6] For example, Angel (2015) argues that "if an institutional trader executes an order in a sloppy manner with a very large short-term price impact, other market participants usually respond quite quickly and push the price back to its appropriate level, making a profit in the process."

[7] Capitalized terms used herein but not otherwise defined shall have the meaning ascribed to such terms in the Plan. See supra note 2

[8] The Plan also incorporates trading pauses in order to accommodate fundamental price movements. See Moise and Flaherty (2017) for a review of the features of the LULD Plan.

[9] Our analysis is restricted to examining extraordinary transitory volatility during the trading day, between 10AM-3:30PM. Restricting our analysis to this time interval gives us long enough time windows during the trading day to construct our metrics and also allows us to directly compare the difference in the effects of the mechanisms of the LULD Plan and SSCB Pilot on extraordinary transitory volatility. See Section V for more details on the time intervals used to calculate our measures.

from transaction price data to serve as proxies for the incidence of extraordinary transitory volatility. We also construct measures of the magnitude of the maximum price reversal that a security experiences each day as proxies for the size of the largest price deviations during periods of transitory volatility. We examine these measures during the time periods the LULD Plan and SSCB Pilot were in effect and also during the time period before the SSCB Pilot was in effect, which is a time period without market-wide individual security price limits or circuit breakers. In addition, we examine these measures during the eight-week phase-in period during which the SROs transition Tier 1 securities from the SSCB Pilot to the LULD Plan.[10] This approach allows us to compare our measures of extraordinary transitory volatility between common stocks trading under the LULD mechanism and common stocks trading under the SSCB mechanism while controlling for common factors such as market volatility.

Overall, we find evidence that is consistent with the LULD mechanisms reducing extraordinary transitory volatility. However, the results vary depending on the specific methodology employed.

Specifically, we compare the frequency of large price reversals under the LULD Plan to the frequency of large price reversals during the time period before the SSCB Pilot goes into effect and find that large price reversals occur less frequently for both Tier 1 and Tier 2 securities under the LULD Plan than during the time period before the SSCB Pilot. We also compare the frequency of these reversals under the LULD Plan to the frequency of these reversals under the SSCB Pilot, but the results we find for the difference in the frequency of large price reversals between the two periods depend on the methodology used to categorize the reversals.

In separate tests we also compare the magnitude of the maximum price reversal that a security experiences each day under the LULD Plan with the magnitude on days under the SSCB Pilot and the magnitude on days during the time period before the SSCB Pilot. We find that the magnitude of the maximum price reversal is smaller on days under the LULD Plan than days during the other two periods.

When we compare the frequency of large reversals between common stocks trading under the LULD mechanism and common stocks trading under the SSCB mechanism during the eight-week phase-in period of the LULD Plan for Tier 1 securities, we find that the LULD mechanisms reduce the frequency of Moderate reversals, but do not find a statistically significant effect on the frequency of larger reversals.[11] When we compare our measures of the magnitude of the maximum price reversals during this time period, we find that the LULD mechanisms reduce the magnitude of the maximum price reversals that occur each day, relative to the SSCB

[10] For details, see https://www.nasdaqtrader.com/content/MarketRegulation/LULD_FAQ.pdf

[11] See supra note 3 and Section V for definitions of Moderate, Big, and Extreme price reversals.

mechanisms. Overall, we find some evidence that is consistent with the LULD Plan reducing extraordinary volatility relative to the SSCB Pilot.

The paper is organized as follows. Section III provides an overview of the LULD Plan and the SSCB Pilot. Section IV briefly reviews other studies that have examined the relationship between price limits and transitory volatility. Section V discusses the sample and price reversal measures used in our analysis. Section VI presents the results of our analysis examining the effects of the LULD Plan on the frequency of large price reversals, and Section VII presents the results of our analysis examining the effects of the LULD Plan on the magnitude of the largest price reversals that occur each day.

III. Overview of LULD Plan and SSCB Pilot

On April 5, 2011, the SROs that oversee the U.S. equity markets filed the LULD Plan with the SEC. On May 31, 2012, the SEC approved the Plan on a pilot basis. The Plan replaced the SSCB Pilot program and aims to mitigate the type of sudden price movements that the market experienced on the afternoon of May 6, 2010. This section briefly reviews the features of the LULD Plan, compares the LULD and the SSCB mechanisms, and describes the timeline of the LULD Plan implementation.

A. LULD Plan Features

The LULD Plan provides for a mechanism designed to prevent trades from occurring at prices that are outside of specified price bands for an individual NMS Stock. The bands are set at prices a certain percentage above and below a dynamic Reference Price.[12] The Reference Price is based on the average trade price of the security over the preceding five-minute period.[13] The price bands are designed to allow trades to occur at quotes between the price bands and prevent trades from occurring at bid or offer quotes outside of the price bands.

Although the Reference Price and the price bands can update as often as every 30 seconds, in practice they change much less frequently because the Reference Price is updated *only if* a Pro-

[12] The percentages vary based on whether a security is in Tier 1 or Tier 2. The Price bands are 5% away from the Reference Price for securities in Tier 1 (NMS stocks in the S&P 500 and Russell 1000 indexes and some high volume ETPs) and 10% away for securities in Tier 2 (the remainder of NMS stocks). Securities whose previous day's closing price was less than or equal to $3.00 have Price bands 20% away from the Reference Price. The percentages are doubled during the first 15 minutes and last 25 minutes of trading. See Appendix A of the Approval Order, supra note 2, for more information on how the percentages are calculated.

[13] The initial Reference Price is the Opening Price of the Security. The Reference Price following a Trading Pause is the price of the reopening auction. See The Plan, supra note 2.

Forma Reference Price is at least 1% away in either direction from the current Reference Price.[14] Angel (2015) examines price band behavior from the implementation of LULD in 2013 until the end of 2014 and finds the average frequency of price band updates is only 6.28 per day.

A security will enter a Limit State when the best quotes on one side of the market for an individual security are equal to the price band on the opposite side of the market (i.e., when the National Best Offer (NBO) is equal to the Lower Price Band or the National Best Bid (NBB) is equal to the Upper Price Band).[15] During a Limit State, market participants can still submit and modify orders, but the Reference Price is not updated and trades can only be executed at a quote that matches the price band.[16] A security can *exit* a Limit State if, within 15 seconds after entering a Limit State, all quotes are executed or canceled at the price band that triggered the Limit State. If the market does not exit a Limit State within 15 consecutive seconds, the primary listing exchange will declare a Trading Pause.[17]

Trading Pauses last for five minutes, during which orders will not execute even though market participants can submit and modify their orders. After five minutes, the primary listing exchange attempts to reopen trading in that security using that exchange's established reopening procedures. If the trading center is unable to reopen trading, it can extend the Trading Pause by another five minutes. After a Trading Pause of at least ten minutes in the security, if the primary listing exchange has not reopened that security, any national securities exchange that trades that security may resume trading.[18]

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[14] The Pro Forma Reference Price is the average price of trades over the previous five minutes. See The Plan supra note 2.

[15] See The Plan supra note 2 for the definitions of a Limit State, Lower Price Band, and Upper Price Band. National Best Bid and National Best Offer are defined under Rule 600(b)(42) of Regulation NMS under the Exchange Act.

[16] For example, if the NBO is equal to the Lower Price Band then the security is in a Limit State and trades from buy orders can only execute against sell orders at the Lower Price Band until the Limit State is exited.

[17] See The Plan supra note 2 for the definition of a Trading Pause.

[18] Amendment 12 to the LULD Plan amended the Plan to provide that a Trading Pause will continue until the Primary Listing Exchange has reopened trading using its established reopening procedures, even if such reopening is more than 10 minutes after the beginning of a Trading Pause. It also amended the LULD Plan to provide that other trading centers may not resume trading in an NMS Stock following a Trading Pause without Price Bands in such NMS Stock. The changes adopted under Amendment 12 are scheduled to be implemented by November 30, 2017. See Order Approving the Twelfth Amendment to the National Market System Plan to Address Extraordinary Market Volatility ("Amendment 12") by Bats BZX Exchange, Inc., Bats BYX Exchange, Inc., Bats EDGA Exchange, Inc., Bats EDGX Exchange, Inc., Chicago Stock Exchange, Inc., Financial Industry Regulatory Authority, Inc., Investors Exchange LLC, NASDAQ BX, Inc., NASDAQ PHLX LLC, The Nasdaq Stock Market LLC, National Stock Exchange, Inc., New York Stock Exchange LLC, NYSE MKT LLC, and NYSE Arca, Inc, Release No. 79845 (January 19, 2017).

The purpose of the price bands and Limit States is to reduce the occurrence of large, sudden price movements. The LULD requirements are coupled with Trading Pauses to accommodate more fundamental price movements. See Moise and Flaherty (2017) for more information regarding the features of the LULD Plan.

B. Implementation of the LULD Plan

The implementation of the LULD pilot occurred in phases. The following table summarizes the implementation schedule.[19]

LULD Plan Implementation Schedule	
Date	
May 31, 2012	The SEC approved the LULD Plan on a pilot basis.
April 8, 2013	The implementation of Phase I of the LULD Plan began. It applied to the S&P 500, the Russell 1000, and some high volume ETPs (**Tier 1** NMS Stocks) from 9:45 am to 3:30 pm. LULD did not operate during the market open and close.
May 31, 2013	The implementation of Phase I was completed.
August 5, 2013	The implementation of the 1st part of Phase II of the LULD Plan (i.e., Phase II.A) began. This part applied the Plan to all NMS Stocks (including both Tier 1 and Tier 2 NMS Stocks) beginning at **9:30 am** and ending at **3:45 pm**. Price Bands were calculated by applying *double* the Percentage Parameters during 9:30-9:45 am and during 3:35-3:45 pm.
September 3, 2013	The implementation of the 1st part of Phase II of the LULD Plan (i.e., Phase II.A) was completed.
February 24, 2014	The implementation of the 2nd part of Phase II of the LULD Plan (i.e., Phase II.B) began. This part added LULD bands for the last 15 minutes of trading from 3:45 pm to **4:00 pm**. Phase II.B applied to securities listed on all exchanges except for Nasdaq.
May 12, 2014	Phase II.B implementation was completed on Nasdaq.

C. Comparison of the SSCB (Single-Stock Circuit Breaker) Pilot and LULD Plan

The LULD Plan replaced the SSCB Pilot, which was an earlier pilot program established after the "Flash Crash" to limit the potential harm from extreme price volatility.[20] Single-stock circuit breakers triggered a five-minute trading pause in an individual security across all exchanges if

[19] The summarization of the implementation schedule does not include information on recent changes made under Amendments 10 and 12 to the LULD Plan. See supra note 2.

[20] See supra note 5.

the security experienced a 10% change in price over the preceding five minutes.[21] After five minutes, the primary listing exchange would attempt to reopen trading in the security using its standard reopening procedures. On June 10, 2010, the SEC approved the SSCB Pilot for stocks in the S&P 500. The SROs extended the SSCB Pilot to include stocks in the Russell 1000 and high volume ETPs on September 10, 2010 and to include remaining NMS securities on June 23, 2011.[22] The SSCB Pilot continued until it was replaced by the LULD Plan.

The primary difference between the SSCB mechanism and the LULD mechanism is that the SSCB mechanism is based on *trades* while the LULD mechanism is based on *quotes*. The SSCB mechanism triggers a trading pause if one or more trades occur at prices outside the price bands. This means, under the SSCB mechanism, if trades occur during momentary gaps in liquidity at prices outside the price bands in a particular stock, these trades would trigger a trading halt for that stock. In contrast, the LULD mechanism is designed to not allow trades to occur outside of the price bands. Instead, an order that would result in a trade occurring outside the price bands under the SSCB mechanism would instead trigger a Limit State under the LULD mechanism. The Limit State would then allow up to fifteen seconds for the order to be modified or canceled before a Trading Pause is triggered. These features could potentially reduce the likelihood of sudden, large price movements caused by momentary liquidity gaps occurring under the LULD Plan, as compared to the SSCB Pilot.

Appendix A highlights the main differences between the operational features of the SSCB Pilot and the LULD Plan.[23]

IV. Review of Price Limit and Volatility Studies

A number of academic studies have examined the effects that price limits and circuit breakers have on volatility. This section briefly summarizes the main findings. For more detailed reviews of the academic literature see Harris (1998), Subrahmanyam (2013), and Moise and Flaherty (2017).

Many stock exchanges around the world impose price limit regulations, which stop trading when prices move outside of some pre-specified range.[24] Unlike the price limits imposed by the

[21] The SSCB 10% trigger is for securities in the S&P 500 and Russell 1000 and certain high volume ETPs. For all other NMS securities, the trading pause trigger is 30% for securities priced above $1 and 50% for securities priced below $1.

[22] See Moise and Flaherty (2017) and Brogaard and Roshak (2016) for more details regarding the implementation of the SSCB Pilot.

[23] See Moise and Flaherty (2017) for a discussion of the differences between the SSCB Pilot and the LULD Plan.

[24] According to Kim and Park (2010), 23 out of 43 stock exchanges around the world impose daily price limits on stock prices.

LULD Plan and SSCB Pilot, which can vary throughout the trading day, the price limits examined in most academic studies are based on the previous trading day's closing price and remain constant throughout the day (Moise and Flaherty (2017)).

The theoretical literature has not reached a consensus about the effects of price limits and trading halts on volatility and market quality. On one hand, a number of models predict that price limits and trading halts will reduce volatility and improve market quality. Kyle (1988) predicts that trading halts would allow market participants time to process information and revise their positions, which would reduce volatility. Greenwald and Stein (1991) predict that properly designed circuit breakers may help the market achieve optimal outcomes by mitigating uncertainty via a reduction in transactional risk, i.e. the risk that orders will be executed at unattractive price levels. Subrahmanyam (1997) argues that price limits would reduce volatility but also decrease price efficiency by causing informed traders to hold back and submit less aggressive orders in order to avoid triggering trading halts.[25]

On the other hand, Subrahmanyam (1994) argues that price limits may *increase* price volatility prior to being triggered due to a "magnet effect," whereby, on volatile days, traders advance purchases or sales of a stock in anticipation of being locked out of the market by a circuit breaker. Chen, Petukhov, and Wang (2017) also predict the presence of downside circuit breakers produces a "magnet effect" and increases conditional and realized volatility by causing optimistic investors to reduce their leverage as the price approaches the circuit breaker limit. Fama (1989) predicts that trading halts harm market quality and do not reduce volatility.[26]

Harris (1998) argues the effects of trading halts on transitory volatility, i.e. temporary deviations of the price from its fundamental value, are unclear. If transitory volatility is caused by an order imbalance from uninformed traders, a trading halt could decrease transitory volatility by allowing time for uninformed traders to modify their orders and time for informed traders to provide liquidity. On the other hand, if traders know they will be notified when a trading halt occurs, trading halts could increase transitory volatility by reducing the incentive for traders to monitor the market and provide liquidity between trading halts.[27]

Similar to the theoretical literature, empirical studies provide mixed evidence regarding the effects of price limits and trading halts on volatility. Some empirical studies provide evidence that price limits reduce stock return volatility. Kim, Liu, and Yang (2013) examine Chinese stock markets and find that price limits moderate transitory volatility. Goldstein (2015) finds that

[25] Also see Kodres and Obrien (1994), Kim and Park (2010), Deb et al (2010), and Westerhoff (2003).

[26] Also see Grossman (1990), Lehmann (1989), and Ackert, Church, and Jayaraman (2001).

[27] Harris (1998) also argues that trading halts could reduce fundamental volatility, i.e. volatility related to information, by delaying price changes associated with new information. This could harm price efficiency by making prices less informative.

circuit breakers (NYSE Rule 80A) lead to a small but statistically significant decline in intraday U.S. equity market volatility. Brogaard and Roshak (2016) examine the effects of the SSCB Pilot price limits on extreme price movements and find that price limits reduce the frequency and severity of extreme price movements, but induce price under-reactions.[28]

On the other hand, some other studies find evidence consistent with a magnet effect. Cho et al. (2003) uses intraday data from Taiwan Stock Exchange (TSE) and find a statistically and economically significant tendency for stock prices to accelerate toward the upper bound. Hautsch and Horvath (2017) study the effects of NASDAQ trading pauses after May 2010 and find that trading pauses increase volatility and trading volume prior to the pause.[29] In addition, some studies conclude that price limits are ineffective in reducing volatility. Kim and Rhee (1997) state that their "evidence supports all three hypotheses suggesting that price limits may be ineffective". Bildik and Gulay (2006), who examine price limits on the Istanbul Stock Exchange, conclude that "price limits are ineffective in reducing volatility."

V. Description of Sample and Measures of Extraordinary Volatility

The LULD Plan is intended, among other things, to limit large, sudden price movements. The purpose of this study is to examine whether the LULD mechanism reduces extraordinary transitory volatility, which is characterized by large, temporary deviations of prices from fundamental values, often caused by temporary gaps in liquidity. In order to examine extraordinary transitory volatility, we focus our analysis on measures of large price reversals, because these reversals may indicate price movements that are temporary and not related to information about the fundamental value of the security. This section describes these price reversal metrics and also provides a brief overview of the sample used in our analysis.

Our sample includes all NMS common stocks and ETFs present in the CRSP database[30] between February 2009 and September 2016.[31] We exclude leveraged ETFs, stock days with missing data, and stock days where the previous or current trading day's closing price or midpoint is below $1.00.[32] We then use the methodology described in Appendix C of this paper to classify

[28] Also see Ma, Rao, and Sears (1989a and 1989b) and Lee and Kim (1995)

[29] Also see Wong, Chang, and Tu, (2009) and Farag (2015).

[30] The sample does not include securities listed on the BATS exchange, because the CRSP database does not include these securities. Most securities listed on BATS are ETPs. However, prior to the implementation of the LULD Plan there were few securities listed on BATS. Based on TAQ data, there were only a total of 17 securities listed on BATS by the end of 2012 and 23 by the end of 2013.

[31] We also exclude the day of the "Flash Crash" (May 6, 2010) from our sample.

[32] Under the SSCB regime, the price range for Tier 2 securities to trigger a trading pause was 50% for securities priced below $1 and 30% for securities priced greater than or equal to $1. Additionally, under Rule 612 of Reg

securities into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks), as defined in the LULD Plan.[33] Further details on the methodology and data sources used to construct our sample and variables are provided in Appendix B of this paper.

Table 1 provides descriptive statistics of the Tier 1 and Tier 2 common stocks and ETFs in our sample.[34] Tier 1 securities have higher average prices and market capitalizations and greater average trading volume than Tier 2 securities. Tier 2 securities have larger average spreads than Tier 1 securities. Common stocks have higher average volatility than ETFs, with Tier 2 common stocks having greater volatility than Tier 1 common stocks.

In order to measure transitory volatility that is not driven by changes in stock prices due to information, the Commission contracted with Cornerstone Research ("Cornerstone"), an economic and financial consulting firm, to construct several metrics of short-term price reversals. We think short-term price reversals are appropriate metrics for measuring transitory volatility, because they are a measure of how far prices deviate from their average values during momentary gaps in liquidity or temporary imbalances in order flow (see Harris, 2003).[35]

Cornerstone constructed their metrics by measuring intraday returns based on transaction prices over three adjacent time intervals. If the return values in two adjacent intervals are of opposite signs (i.e. a positive return followed by a negative return or a negative return followed by a positive return), then a price reversal has occurred and Cornerstone's metrics record the magnitude of the smaller return as the magnitude of the price reversal.[36] Because transitory volatility can occur over different time intervals and there is no precise way to measure it, Cornerstone constructed a number of different price reversal metrics using different prices measured over different frequencies. Specifically, they constructed price reversal metrics separately using the following four types of prices over adjacent intervals measured at frequencies of 1-minute, 5-minutes, 10-minutes, and 30-minutes: [37]

NMS, securities priced under $1.00 have a tick size of $0.0001, while securities priced greater than or equal to $1.00 have a tick size of $0.01.

[33] See Appendix A of the Approval Order, supra note 2, for the definitions of Tier 1 and Tier 2 securities.

[34] See id.

[35] More specifically, Harris (2003) describes short-term price reversals as being associated with the mean reversion in prices caused by the order flow of uninformed traders.

[36] Cornerstone's metrics use the magnitude of the smaller return as the magnitude of the price reversal in order to capture the portion of a price movement that is transitory. For example, if a price movement related to new information overshoots the new fundamental value and then reverses, Cornerstone's metrics will only capture the difference between the overshoot and the new price as the magnitude of the reversal.

[37] There are a total of 16 different price reversals metrics, i.e. four types constructed for each frequency.

- "**Last**" metric: price reversals based on last transaction price in each interval;
- "**VWAP**" metric: price reversals based on the volume-weighted average price in each interval;
- "**Max to Min**" metric: price reversals based on the maximum, minimum, and maximum prices in three consecutive intervals;
- "**Min to Max**" metric: price reversals based on the minimum, maximum, and minimum prices in three consecutive intervals.

Further details on the methodology Cornerstone Research used to construct the price reversal metrics is provided in Appendix D of this paper.

Because SSCB price bands were not in effect from 9:30AM-9:45AM and from 3:35PM-close, we only use price reversal metrics calculated using transactions that occur between 10AM-3:30PM. By restricting our analysis to the time period between 10AM-3:30PM, we can directly compare the difference in the effects of the mechanisms of LULD and SSCB on transitory volatility. However, by limiting the time interval used in our analysis, we are not able to examine the full effect of the LULD Plan on extraordinary transitory volatility. Our analysis does not capture the effects of the LULD Plan on volatility at the beginning of the trading day, i.e. the period immediately following the opening, or at the end of the trading day during the time period preceding the close.[38]

Table 2 summarizes the distribution of the Cornerstone price reversal metrics measured over the entire sample. The table shows the magnitude of the return reversal, in basis points (bps), associated with the given percentile of the distribution. A larger value indicates that the magnitude of the return reversal was greater and transitory volatility was higher. Panels A, B, C, and D each show the distribution of the four different price reversal metrics constructed using 1 minute, 5 minute, 10 minute, and 30 minute time intervals, respectively. The table shows separate distributions based on whether the security is a common stock or ETF and whether it is in Tier 1 or Tier 2.

Based on the distributions, a number of facts are apparent:

[38] The price reversal metrics used in our study would not be appropriate for studying extraordinary volatility near the opening or close, because they rely on trading patterns observed over fixed time intervals. Some of the time intervals used to compute our metrics are longer than the opening and closing intervals during which the SSCB mechanisms were not in effect. Additionally, including time periods before the opening and close to calculate our metrics could result in biased measures, because they are not subject to Regulation NMS and the same trading and quoting restrictions observed during regular trading hours. We would need to use different metrics if we wanted to examine transitory volatility near the opening and close.

1. "No Reversals" shows the percentage of time intervals in which no price reversals occurred. For most price reversal metrics it is usually greater than 50%, which indicates that there are a large number of time periods where no price reversals occur.

2. The magnitudes of the 50th and 99th percentiles across all of the price reversal metrics indicate that Tier 2 securities experience larger reversals than Tier 1 securities, both for common stocks and ETFs.

3. There is significant variation in the magnitude of the price reversals. For example, the interquartile range of the magnitude for the Last price reversal metric for Common Tier 1 stocks in Panel B (5 minute intervals) is only 7.44 bps. However, the magnitude of the maximum reversal for this metric is 1,330 bps, which is over five times larger than the average value (256 bps) of the Tier 1 Common Stock daily high price minus low price volatility measure (*Volatility*) reported in Table 1.[39] Similarly, the magnitude of the 99th and 99.99th percentiles for the Last price reversal metric for Common Tier 1 stocks in Panel B are 47.18 bps and 161.44 bps, respectively.

4. There is also significant variation in the magnitude of the maximum values across the different price reversal metrics. For example, the distribution for the VWAP metric for Common Tier 1 stocks in Panel B (5 minute intervals) has the smallest maximum value, with a magnitude of 1,167 bps. The distribution for the Min to Max metric for Common Tier 2 stocks in Panel D (30 minute intervals) has the largest maximum value, with a magnitude of 68,922 bps. Comparatively, the average difference between Tier 1 and Tier 2 Common Stocks for the daily high price minus low price volatility measure (*Volatility*) reported in Table 1 is 166 bps.

Because the purpose of our analysis is to examine how the LULD Plan influences the incidence of large price reversals, Table 3 examines the distribution of the largest percentiles of the Cornerstone price reversal metrics. Specifically, for each stock, we compute the value of the 99th, 99.9th, 99.99th, and 100th percentiles of the distributions of the Cornerstone price reversal metrics measured over the entire sample period. Table 3 then summarizes the cross-sectional distribution of the percentile of each price reversal measure across the sample of stocks. We can see that there is great variation across stocks for return values in the 99th percentile or higher. For example, if we examine the cross-sectional distribution of the 99th percentile return value calculated using the Last price reversal metric measured over 1 minute intervals, we find that the magnitude of the average 99th percentile return reversal is 162.75 bps. However, 1% of stocks have a 99th percentile return value less than or equal to 9.09 bps and 1% of stocks have a 99th percentile return value greater than or equal to 1,328.13 bps.

[39] See Appendix B for a definition of the *Volatility* measure reported in Table 1.

Given the variation in the distribution of extreme price reversals observed in Table 3, it is not clear that we can identify a precise magnitude for a threshold that constitutes a large price reversal. Therefore, we analyze a number of different thresholds that could constitute a large price reversal to examine the effect the LULD Plan has on extraordinary transitory volatility.

To measure the frequency of large price reversals, for each Cornerstone price reversal metric, we count the number of price reversals whose magnitude exceeds a threshold each stock-day. We construct measures, which we refer to as "**Raw"**, for the number of times the magnitude of a price reversal exceeds fixed thresholds of: 0.5%, 1%, 2%, 3%, 4%, and 5%. We call these measures **Raw 0.5%**, **Raw 1%**, etc.

The magnitude of a price reversal is likely to be greater for securities with higher volatility. Because Tier 2 securities tend to have higher volatilities than Tier 1 securities, Tier 2 securities are more likely to have a higher frequency of large price reversals if the threshold is based on a fixed magnitude. In order to control for volatility and better compare changes in the frequency of large price reversals in Tier 1 and Tier 2 securities over time, we also construct measures, which we refer to as "**Ind**", where the threshold of a large price reversal varies for each stock. Specifically, we construct variables that count the number of times each stock-day a price reversal exceeds the value of the 99th, 99.9th, and 99.99th percentiles of the distribution of the individual stock's price reversals measured over the entire sample period. We call these measures **Ind 99%**, **Ind 99.9%**, and **Ind 99.99%**.

Stock market volatility can vary over time, which means the frequency of large price reversals can vary over time. We attempt to control for time variation in stock volatility by constructing measures, which we refer to as "**Rolling**", where an individual stock's threshold varies through time. Specifically, for each stock-day, Cornerstone calculated the 20-day moving average of the daily standard deviation of the stock's intraday returns. We construct variables that count the number of times each stock-day a price reversal exceeds 10 standard deviations and 25 standard deviations of the 20-day moving average return standard deviation.[40] We call these measures **Rolling 10 SD** and **Rolling 25 SD**.

Because we calculate the frequency of large price reversals separately for each Cornerstone price reversal metric, for each measure and threshold combination we have 16 different metrics for the number of price reversals that exceeded the threshold each stock-day (i.e. **Raw 1%, Ind 99%, Rolling 10 SD,** etc., each have 16 different Cornerstone price reversal metrics counting the number of price reversals that exceed the threshold each stock-day). In order to reduce the

[40] Because this measure is normalized by dividing by the 20 day moving average of a stock's daily standard deviation of intraday returns, it will not detect changes in the standard deviation of the distribution of a stock's price reversals that may occur as a result of the LULD Plan. However, it will detect a change in the kurtosis of a stock's normalized price reversal distribution, after adjusting for how the standard deviation of a stock's price reversals changes over time.

dimensionality of the data, we use Principal Component Analysis (PCA) to transform the 16 different Cornerstone metrics into one variable for each threshold that explains as much of variance in the data as possible. PCA is a statistical procedure that transforms a set of correlated variables into a set of uncorrelated principal components, which are combinations of the original variables. Because PCA usually concentrates the majority of the information in the data in the first few principal components, it can be used as a dimensionality reduction technique. We keep the first principal component for each threshold to use in our analysis. Our principal component measures can be thought of as weighted averages of the 16 different Cornerstone metrics counting the number of price reversals that exceed the threshold each stock-day.[41] See Appendix E for details of the PCA. Throughout the paper, we use the name of the threshold measure (i.e. **Raw 1%**, **Ind. 99%**, **Rolling 10 SD**, etc.) to refer to the first principal component for that threshold.

Because we study the frequency of price reversals at a number of different thresholds, we use a number of terms throughout the paper to simplify our discussion and help summarize our findings. We group our price reversal measures into three categories based on the magnitudes of the thresholds and how frequently price reversals exceed the threshold.

We define the smaller thresholds as "Moderate" price reversals. Specifically, "Moderate" price reversals include the **Raw** reversal thresholds of **Raw 0.5%**, **Raw 1%**, and **Raw 2%** and the **Ind** stock reversal threshold of **Ind 99%**.

We define the middle thresholds as "Big" price reversals. Specifically, "Big" price reversals include **Raw** reversal thresholds of **Raw 3%** and **Raw 4%**, the **Ind** stock reversal threshold of **Ind 99.9%**, and the **Rolling** reversal threshold of **Rolling 10 SD**.

We define the largest thresholds as "Extreme" price reversals. Specifically, "Extreme" price reversals include the **Raw** reversal threshold of **Raw 5%**, the **Ind** stock reversal threshold of **Ind 99.99%**, and the **Rolling** reversal threshold of **Rolling 25 SD**.

Panel A of Table 4 shows the distributions across the entire sample of securities of the stock-day values for the calculated principal components. The table presents separate distributions for Tier 1 and Tier 2 securities for each threshold. A higher value indicates a greater number of price reversals exceeded the specified threshold. From the panel, it is clear that for most of the reversal thresholds, over 50% of the stock-day observations are zeros. For the Extreme thresholds, like **Rolling 25 SD**, over 99% of the observed values are zero.

[41] Because the eigenvectors of the first principal components of our threshold measures are all positive, we can view them as weighted averages of the Cornerstone metrics, See Appendix E for the eigenvectors of the first principal components.

The panel shows that for the **Raw** threshold measures, Tier 2 securities, on average, have a greater frequency of large price reversals. Surprisingly, when the threshold accounts for the volatility of the underlying security, i.e. the **Ind 99%** threshold measures, Tier 1 securities, on average, have a greater frequency of large price reversals than Tier 2 securities.

Panel B of Table 4 shows the average value of the principal components for common stocks based on what tier the stock is in and the stock's average market capitalization quintile during the previous month. The results show that the frequency of large reversals for the **Raw** threshold measures tends to increase as the market capitalization of the stock decreases. On average, the Low market cap quintile for Tier 1 stocks has more reversals that exceed the thresholds than the High quintile for Tier 2 stocks.

VI. Frequency of Extreme Price Reversals

This section presents the results of our analysis examining the effects of the LULD Plan on the frequency of large price reversals. We first present the analysis comparing the frequency of large price reversals during the LULD period with the periods before and during the SSCB Pilot. We then present the results of our difference-in-differences analysis comparing the frequency of large price reversals between stocks operating under the LULD mechanisms with stocks operating under the SSCB mechanisms during the eight-week phase-in period of the LULD Plan for Tier 1 securities.

We find that large price reversals occur less frequently for both Tier 1 and Tier 2 securities under the LULD Plan than during the time period before the SSCB Pilot. However, the results we find when comparing the frequency of large reversals during the LULD period and SSCB Pilot are inconsistent and depend on the methodology used to categorize the reversals.

When we compare the LULD mechanisms to the SSCB mechanisms during the eight-week phase-in period of the LULD Plan for Tier 1 securities, we find that the LULD mechanisms reduce the frequency of Moderate reversals, but do not find a statistically significant effect on the frequency of larger reversals (i.e. Big and Extreme reversals).

A. Univariate Analysis

Table 5 shows the results of a univariate analysis comparing the principal component measures for the frequency of large price reversals during the LULD period with the frequencies during the SSCB and Pre-SSCB periods. All securities are stratified based on whether they would be classified as a Tier 1 or Tier 2 security using the methodology outlined in Appendix C.[42] We

[42] Although securities during the Pre-SSCB period were not formally defined as Tier 1 or Tier 2 securities, we classify them as such using the same methodology as the SSCB and LULD Pilots in order to compare the frequency

define the time periods as follows: the Pre-SSCB period is between February 1, 2009 and June 10, 2010; the SSCB period is between September 14, 2010 and April 5, 2013; the LULD Phase 1 period is between June 3, 2013 and August 2, 2013; and the LULD Phase 2 period is between May 12, 2014 and September 30, 2016.

During the Pre-SSCB period, there are no market-wide individual security price limits or circuit breakers. During the SSCB Period, both Tier 1 and Tier 2 securities operate under the SSCB mechanism. During the LULD Phase 1 period, Tier 1 securities operate under the LULD mechanism and Tier 2 securities operate under the SSCB mechanism. During the LULD Phase 2 period, both Tier 1 and Tier 2 securities operate under the LULD mechanism. We do not include the time periods immediately surrounding the phase-ins for the LULD Plan and the SSCB Pilot in this part of our analysis. Because the securities could be subject to a mix of price band mechanisms during these time periods, including them could bias the results of our tests.

Panel A presents the average value of the principal component measures for the frequency of large reversals during the different time periods. Panel B shows the difference between the average values during the LULD periods and the Pre-SSCB and SSCB periods.[43] The stars and (-)/(+) signs indicate the results of a Wilcoxon rank sum test to show whether the value of an observation during the LULD period is likely to be statistically significantly less or greater than the value of an observation during the Pre-SSCB or SSCB period.[44]

Both Tier 1 and Tier 2 securities experience fewer large reversals during the LULD period than during a time with no individual security price limits or circuit breakers that applied market-wide (i.e the Pre-SSCB period). More specifically, the Wilcoxon rank sum test results are statistically significant at the 1% level for all of the reversal thresholds when comparing the Pre-SSCB period to both the Phase 1 and Phase 2 LULD periods. However, the results should be interpreted with caution, because they are based on univariate tests comparing the frequency of large price reversals across different time periods. The results might not be driven by the LULD mechanism and could be driven by market-wide volatility being lower during Phase 1 and Phase 2 of the LULD Plan than during the Pre-SSCB period.

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of extreme price reversals during the LULD period with the frequency during the pre-SSCB period. See Appendix C for details on the Tier 1 and Tier 2 classification methodology.

[43] The difference is the average value during the LULD period – the average value during the Pre-SSCB/SSCB period.

[44] The Wilcoxon rank sum test is a two sample nonparametric statistical test to test the hypothesis that a randomly selected value from one sample will be equal to a randomly selected value from another sample. See Mann and Whitney (1947).

We find the tests comparing the frequency of large price reversals during the LULD period and SSCB Pilot produce inconsistent results and depend on the methodology used to categorize the reversals.

When we compare the LULD Phase 1 period and the SSCB period, both Tier 1 and Tier 2 securities experience fewer reversals during LULD for all threshold levels of the **Raw** and **Ind** reversal thresholds. However, because Tier 2 stocks operated under the SSCB mechanism during the LULD Phase 1 period, the results could be driven by market-wide volatility being lower during Phase 1 of the LULD Plan than during the SSCB period.

When we compare the LULD Phase 2 period to the SSCB period, the results are mixed. The **Raw** reversal measures indicate that Tier 1 securities experience fewer price reversals at the **Raw 0.5%** and **Raw 1%** thresholds levels and more price reversals at the **Raw 3%**, **Raw 4%, and Raw 5%** threshold levels during the LULD Phase 2 period.[45] The **Ind** reversal measures indicate that Tier 1 securities experienced fewer reversals (at all threshold levels) during the LULD Phase 2 period. The **Rolling** SD reversal measures indicate that Tier 1 securities experience fewer reversals at the **10 Rolling SD** threshold and more reversals at the **25 Rolling SD** threshold during the LULD Phase 2 period.[46] These results could indicate that more volatile Tier 1 securities experienced more large reversals and less volatile Tier 1 securities experienced fewer large reversals during the LULD Phase 2 period compared to the SSCB period.

For Tier 2 securities, the **Raw** reversal measures indicate that Tier 2 securities experienced more reversals (at all threshold levels) during LULD Phase 2 than during the SSCB period.[47] The **Ind** reversal measures indicate Tier 2 securities experienced fewer reversals at the **Ind 99%** and **Ind 99.9%** thresholds and more reversals at the **Ind 99.99%** threshold during the LULD Phase 2 period. The **Rolling** SD reversal measures indicate that Tier 2 securities experienced fewer reversals (at all threshold levels) during the LULD Phase 2 period. These results could indicate

[45] Although the average difference between Tier 1 securities at the **Raw 1%** threshold is positive during the LULD Phase 2 and SSCB periods, the results of the Wilcoxon rank sum test indicates that a randomly sampled reversal from the LULD Phase 2 period is statistically significantly likely to be less than a randomly sampled reversal from the SSCB period. The difference occurs because the table reports the average of the reversals while the Wilcoxon rank sum test is a nonparametric test that tests the probability that an observation from the LULD Phase 2 period is the same as an observation from the SSCB period.

[46] Although the average difference between Tier 2 securities at the **Rolling 10 SD** and **Rolling 25 SD** thresholds and between Tier 1 securities at the **Rolling 10 SD** threshold are positive during the LULD Phase 2 and SSCB periods, the results of the Wilcoxon rank sum test indicate that a randomly sampled reversal from the LULD Phase 2 period is statistically significantly likely to be less than a randomly sampled reversal from the SSCB period.

[47] Although the average difference between Tier 2 securities at the **Raw 4%** and **Raw 5%** thresholds is positive during the LULD Phase 2 and SSCB periods, the results of the Wilcoxon rank sum test indicate that a randomly sampled reversal from the LULD Phase 2 period is statistically significantly likely to be less than a randomly sampled reversal from the SSCB period.

that the volatility of Tier 2 securities increased during the LULD Phase 2 period, but that the frequency of price reversals in the tail of the distributions, after controlling for the change in the standard deviation of the returns, decreased during the LULD Phase 2 period.

B. LULD Phase-in Analysis

One of the limitations of the univariate analysis is that it does not account for possible differences between the time periods that could cause variation in the frequency of large reversals. For example, if market volatility is higher during the SSCB period, the univariate tests would report fewer large reversals during the LULD period, even if the change is caused by the lower volatility and not by the LULD mechanism.

In order to address these issues, we compare the effects of the LULD and SSCB mechanisms on the frequency of large price reversals in a difference-in-differences framework using the staggered phase-in of the LULD Plan for Tier 1 securities.[48] During the phase-in period, Tier 1 securities operated under the LULD mechanism and Tier 2 securities operated under the SSCB mechanism. This approach allows us to directly compare the effects of the LULD and SSCB mechanisms while controlling for certain other confounding factors that might influence the frequency of large price reversals.

One limitation of comparing securities in Tier 1 and Tier 2 to each other is that the securities in Tier 1 are larger and more actively traded, which may affect the frequency of large reversals. In order to ensure our test and control groups are as similar as possible, we select common stocks with smaller market capitalizations from Tier 1 and common stocks with larger market capitalizations from Tier 2 to serve as our test and control stocks. More specifically, our test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1.[49]

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[48] Difference-in-differences is a statistical technique used to mitigate the effects of confounding factors by studying the differential effect of a treatment on a 'treatment group' versus a 'control group' in a quasi-natural experimental setting. In our setting the control group is Tier 2 stocks and the treatment group is Tier 1 stocks. The treatment is a Tier 1 stock trading under the LULD mechanism. The first set of differences are the change in the control groups and test groups after the LULD mechanism was phased in for Tier 1 securities. The second differences is the test group change minus the control group change.

[49] The stocks that move from Tier 1 to Tier 2 when the Russell 1000 Index is reconstituted operate under the LULD Plan mechanism from their activation date through June 27, 2013. When the index is reconstituted on June 28, 2013, they revert to operating under the SSCB method until they are reactivated during the phase-in of the LULD Plan for Tier 2 securities. The stocks that move from Tier 2 to Tier 1 when the index is reconstituted operate under the SSCB mechanism until June 28, 2013, when they begin operating under the LULD Plan mechanism. Including stocks that enter and leave Tier 1 when the Russell 1000 index is reconstituted can better help identify the treatment effect by causing the cross-sectional variation of LULD test stocks and SSCB control stocks to vary more over time.

The control group consists of the 200 common stocks with the largest market capitalizations that remain in Tier 2. The stocks are selected based on market capitalizations computed using prices and shares outstanding from the last trading day in March 2013, shortly before the LULD staggered phase-in for Tier 1 securities begins. We then estimate the effects of the LULD mechanism by comparing the principal components measuring the frequency of price reversals in test and control stocks over the period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013.

Table 6 compares the average stock characteristics from March 2013 of our test and control stocks. From the table, it appears that the test group has a smaller market capitalization, greater trading volume, lower prices, higher volatility, and higher spreads than the control group. The smaller market capitalization is likely driven by the test stocks including Tier 1 securities that switch to Tier 2 when the Russell 1000 index is reconstituted. The stocks are likely to have experienced a decrease in market capitalization over the last year and are smaller in market capitalization than some of the control stocks.

Table 7 compares the average values of the principal component measures of the frequency of large reversals for the test and control stocks during the phase-in. The SSCB period for test stocks is days that they operate under the SSCB mechanism and the LULD period is days that they operate under the LULD mechanism. For control stocks, the Before period is from November 26, 2012 until June 2, 2013, and the After period is from June 3, 2013 until August 2, 2013. Looking at the Diff Test columns, it appears that test stocks experienced a decrease in the frequency of reversals during the LULD period for all threshold measures. Looking at the Diff Control column, it appears the frequency of Big reversals and the frequency of the Extreme reversals decreased for control stocks during the After period, but the frequency of Moderate reversals increased.[50]

The variable of interest in the table is the average treatment effect, meaning the average change in the test stocks minus the average change in the control stocks (Test Diff – Control Diff). The Tobit parameter column tests for the significance of the treatment effect in a censored Tobit regression,[51] while controlling for monthly effects. The parameter is negative and statistically significant for all **Raw** thresholds and for the **Ind 99%** threshold, and insignificant for the remaining thresholds. This indicates that the frequency of Moderate (and **Raw 3%**, **Raw 4%**,

[50] See Section V for the definitions of Extreme, Big, and Moderate price reversals.

[51] The Tobit regression is a censored statistical regression model that describes the relationship between a non-negative dependent variable and a set of independent variables. The model assumes there is a latent variable that is equal to the observed value when it is greater than zero. When the latent variable is less than zero, the observed value is equal to zero.

and **Raw 5%**) price reversals, decreased significantly more for test stocks under the LULD mechanism.

One potential problem with the estimated effects from the analysis in Table 7 is that they could be driven by differences between the Tier 1 and Tier 2 stocks used in the analysis and not by the LULD or SSCB mechanisms. Although we attempt to control for this by restricting our test and control groups to stocks of similar market capitalization, it is still possible that our results are being driven by differences in the types of stocks assigned to Tier 1 and Tier 2. In Table 8 we try to control for this by estimating censored Tobit regressions that attempt to control for daily market wide volatility and also stock specific characteristics. Specifically, we include control variables that account for market-wide returns, market-wide implied and realized volatility and also control variables that account for the stock's price, spread, trading volume, volatility, etc. For the stock-specific control variables, we use the average values from the previous month, because some of the current stock characteristics might be simultaneously determined with the price reversal measures.

The variable of interest in Table 8 is the LULD Active indicator. This variable's parameter indicates the treatment effect, because the indicator is equal to 1 when a test stock is operating under the LULD plan and 0 otherwise. The LULD Active parameters are negative and statistically significant for the **Raw 0.5%**, **Raw 1%**, and **Raw 2%** thresholds and insignificant for the other thresholds. This indicates that, after controlling for stock characteristics, the LULD mechanism decreases the frequency of Moderate price reversals in Tier 1 stocks.

Appendix G repeats this analysis, but uses a sample where the control stocks are matched to test stocks based on characteristics such as spreads, price, volatility, trading volume, etc. The results of the matched sample analysis tend to support the results from the market capitalization difference in difference sample, but show statistical significance at greater thresholds, with the **Raw 3%** and **Raw 4%** treatment effects also being negative and statistically significant in the Tobit regression that controls for stock characteristics.

VII. Magnitude of Extreme Reversals

In addition to examining how the LULD Plan affects the frequency of large reversals, we also examine the effect that it has on the distribution of the magnitude of a stock's maximum price reversal each day. This section presents the results of that analysis. First, we briefly describe the principal component measures we construct for the magnitudes of the maximum price reversal values each stock-day. Then, we compare the value of the principal component measures during the LULD period with the periods before and during the SSCB Pilot. Finally, we present the results of our difference-in-differences analysis comparing the magnitude of the maximum stock-day price reversals under the LULD Plan and the SSCB Pilot during the phase-in period of the LULD Plan for Tier 1 securities.

We find that the magnitude of the maximum daily price reversal is smaller during the LULD Plan than during the SSCB and Pre-SSCB periods. When we compare the magnitude of the maximum daily price reversal during the eight-week phase-in period of the LULD Plan, we find evidence that the magnitude of the maximum daily price reversals are smaller under the LULD mechanism than under the SSCB mechanism.

A. Measures of the Magnitude of Maximum Daily Price Reversal

In order to analyze the effects of the LULD Plan on the magnitude of large price reversals, we examine the distribution of the magnitude of a security's maximum price reversal each day. Specifically, for each stock-day we determine the magnitude of the maximum price reversal that a security experiences for each of the 16 different Cornerstone Research price reversal metrics detailed in Appendix C. We then use Principal Component Analysis to reduce the dimensionality of the data by transforming the 4 price measures (Last, VWAP, Max-to-Min, and Min-to-Max) into one variable for each time interval (**1 minute**, **5 minutes**, **10 minutes**, and **30 minutes**). We keep the first principal component for each time interval to use in our analysis. Our principal component measures can be thought of as weighted averages of the 4 different Cornerstone metrics measuring the magnitude of the largest price reversal that a security experiences each stock-day.[52] Details regarding the construction of the principal component measures for the magnitude of the security's maximum daily price reversal are discussed in Appendix F.

Panel A of Table 9 shows the distributions of the calculated first principal component for each time interval across the entire sample of securities, stratified based on whether a security is in Tier 1 or Tier 2. A larger value for the first principal component indicates that the magnitudes of the maximum price reversals are greater on that stock-day. From the panel, it is clear that Tier 2 securities experience larger reversals than Tier 1 securities. For all time intervals, the mean and median principal component value is greater for Tier 2 securities than Tier 1 securities.

Panel B of Table 9 shows the average value of the time interval principal components for common stocks based on what tier the stock is in and the stock's average market capitalization quintile during the previous month. The results show that the magnitude of the first principal components tends to increase as the market capitalization of the stock decreases. The average magnitude for the Low market cap quintile for Tier 1 common stocks is close to the magnitude of the High quintile for Tier 2 common stocks.

[52] Because the eigenvectors of the first principal components of our measures are all positive, we can view them as weighted averages of the Cornerstone metrics, See Appendix F for the eigenvectors of the first principal components.

B. Univariate Analysis

Table 10 shows the results of a univariate analysis comparing the values of the first principal components for the magnitude of the maximum daily price reversals during the LULD period with the values during the SSCB and Pre-SSCB periods. Similar to the analysis in Section VI.A, we define the time periods as follows: the Pre SSCB period is between February 1, 2009 and June 10, 2010, the SSCB period is between September 14, 2010 and April 5, 2013, the LULD Phase 1 period is between June 3, 2013 and August 2, 2013, and the LULD Phase 2 period is between May 12, 2014 and September 30, 2016. All securities are stratified based on whether they would be classified as a Tier 1 or Tier 2 security using the methodology outlined in Appendix C.

Panel A presents the average value of the first principal components for the magnitude of the maximum daily price reversals during the different time periods. Panel B shows the difference between the average values during the LULD periods and the Pre-SSCB and SSCB periods.[53] The stars and (-)/(+) signs indicate the results of a Wilcoxon rank sum test to show whether the value of an observation during the LULD period is likely to be significantly less or greater than the value of an observation during the Pre-SSCB or SSCB period.

The results indicate that the maximum reversal a security experiences each day is smaller during the LULD period than during the SSCB Period and Pre-SSCB period, which was a time with no market-wide individual security price limits or circuit breakers. Specifically, the results of the Wilcoxon rank sum tests are all negative and statistically significant, which indicates the magnitude of the maximum daily price reversals is smaller during LULD Phase 1 and LULD Phase 2 periods than during the SSCB and Pre-SSCB periods. However, the results should be interpreted with caution, because they are based on univariate tests comparing the magnitude of the maximum daily price reversals across different time periods. For example, the results might not be driven by the LULD mechanism, but instead could be driven by market-wide volatility being lower during the LULD periods.

C. LULD Phase-in Analysis

As discussed in Section VI.B, one of the limitations of the univariate analysis is that it does not account for possible differences between the time periods that could cause variation in the magnitudes of price reversals. In order to address these issues, we use the difference-in-differences sample from Section VI.B to analyze the effect of the LULD Plan on the magnitude

[53] The difference is the average value during the LULD period – the average value during the Pre-SSCB/SSCB period.

of the maximum daily price reversals during the staggered phase-in of the LULD Plan for Tier 1 securities.[54]

Table 11 compares the average values of the first principal component time intervals for the magnitude of the maximum daily price reversals of the test and control stocks during this time period. As discussed in Section VI.B, the SSCB period for test stocks is made up of days on which the stocks operate under the SSCB mechanism and the LULD period is made up of days the stocks operate under the LULD mechanism. For control stocks, the Before period is from November 26, 2012 until June 2, 2013 and the After period is from June 3, 2013 until August 2, 2013. Looking at the Diff Test column, it appears that test stocks experienced a decrease in the magnitude of the maximum daily reversals during the LULD period across all first principal component time intervals. Based on the Diff Control column, it appears that control stocks experienced an increase in the magnitude of the maximum daily reversals during the After period.

The variable of interest in the table is the average treatment effect, meaning the average change in the test stocks minus the average change in the control stocks (Test Diff – Control Diff). The results are negative, indicating the LULD Plan decreases the magnitude of the maximum daily reversals across all principal component time intervals.

If we repeatedly sample the magnitude of price reversals from a security and keep the maximum value each day, then the sample of maximum values will fit a generalized extreme value (GEV) distribution.[55] To confirm the results in the Test Diff – Control Diff column, we estimate a model in which the values of first principal component time intervals for the magnitude of the maximum daily price reversals are drawn from a GEV distribution whose location parameter depends on whether the security is trading under the LULD or SSCB mechanism. More specifically, we model the first principal components, Y_t, for stock i and day t as:

$$Y_{i,t} \sim GEV(\mu(X1_i, X2_{i,t}, Z_t), \sigma, \mathcal{E}),$$

where μ is the location parameter and is given by:

$$\mu(X1_i, X2_{i,t}, Z_t) = \beta_0 + \beta_1 X1_i + \beta_2 X2_{i,t} + \beta_3 Z_t$$

[54] The first set of differences are the change in the first principal components for the magnitude of the maximum daily price reversals for the control groups and test groups after the LULD mechanism was phased in for Tier 1 securities. The second difference is the test group change minus the control group change.

[55] More generally, if we repeatedly sample the maximum value from blocks of independent and identically distributed observations, the sample of maximum values will fit a generalized extreme value distribution. For example, if we measured the depth of a river each hour and only kept the maximum value observed each day, the distribution of maximum values would fit a GEV distribution. In this example, a block would be all measurements taken on one day and the sample would be the set of all maximum values. See Coles (2001) for further details on the GEV distribution.

and $X1_i$ is an indicator variable that equals 1 if a stock is in the test group, $X2_{i,t}$ is an indicator variable that equals 1 if the stock is in the test group and operating under the LULD mechanism, Z_t are month fixed effects, σ is the scale parameter, and $\mathcal{E}$ is the shape parameter.[56]

We are interested in the estimate for parameter β_2, which is the treatment effect. The Extreme Value Parameter and Extreme Value SE columns in Table 11 gives the estimated coefficient and standard error. The coefficients are negative and statistically significant for all time intervals, which indicates the LULD mechanism decreases the magnitude of the maximum daily price reversals relative to the SSCB mechanism.

In order to address the concern that our results are being driven by differences in the types of stocks assigned to Tier 1 and Tier 2, we re-estimate the GEV regression described above and attempt to control for daily market wide volatility and also stock specific characteristics. Specifically, we include control variables in the location parameter equation, μ, that control for market-wide returns, market-wide implied and realized volatility, and also control variables that account for the stock's price, spread, trading volume, volatility, etc. For the stock-specific control variables, we use the average values from the previous month, because some of the current stock characteristics might be simultaneously determined with the price reversal measures.

Table 12 presents the coefficient estimates from these GEV regressions. The variable of interest is the LULD Active indicator variable. This variable's parameter indicates the treatment effect, because the indicator is equal to 1 when a test stock is operating under the LULD plan and 0 otherwise. The LULD Active parameters are negative and statistically significant for the 5 minute, 10 minute, and 30 minute principal component time intervals.[57] These results provide evidence that, after controlling for market conditions and stock characteristics, the LULD mechanism decreases the magnitude of the maximum daily price reversals in Tier 1 stocks relative to the SSCB mechanism.

VIII. Conclusion

This paper examines the effects of the mechanisms within the LULD Plan on extraordinary transitory volatility. We construct measures of the frequency of large price reversals as proxies for the incidence of extraordinary transitory volatility.

Specifically, we combine different measures of intraday transaction price reversals using principal component analysis to create variables that count the frequency with which each stock-

[56] See Coles (2001) for further details on the GEV block maximum model.

[57] The coefficient on the LULD Active parameter is negative, but not statistically significant for the 1 minute time interval.

day experiences reversals that exceed certain thresholds. We compare the frequency of large price reversals during the LULD Plan with the frequency during the time period before the SSCB Pilot goes into effect, which is a time period without market-wide individual security price limits or circuit breakers. We find that large price reversals for both Tier 1 and Tier 2 securities were less frequent under the LULD Plan than during the time period before the SSCB Pilot. These results are consistent with the argument that price limits reduce extraordinary transitory volatility, but they need to be interpreted with caution, because they are based on univariate tests comparing the frequency of large price reversals across different time periods. The results could be driven by differences in market volatility across the two time periods and not by the effects of price limits.

When we compare the frequency of large price reversals during the LULD Plan with the frequency during the SSCB Pilot, the results are mixed, with the difference in the frequency of large reversals between the two periods depending on the methodology used to categorize the reversal.

We also construct measures of the magnitude of the maximum price reversal that a stock experiences each day as proxies for the size of the largest price deviations during periods of transitory volatility. In our univariate analysis, we find that the magnitude of the maximum daily price reversals are smaller under the LULD Plan than during the periods before and during the SSCB Pilot.

In order to control for confounding factors, we use a difference-in-differences design that exploits the staggered rollout of the first phase of the LULD Plan on Tier 1 stocks in order to study the effects of the LULD mechanisms on the frequency of large price reversals, relative to the SSCB mechanisms. We select stocks with similar market capitalizations from Tier 1 and Tier 2 to construct a test and control sample. We find that the LULD mechanisms reduce the frequency of Moderate reversals, but do not find a statistically significant effect on the frequency of larger reversals.[58] We also use a difference-in-differences analysis to examine changes in the magnitude of the largest daily price reversals during the rollout and find evidence that is consistent with the LULD mechanism reducing the magnitude of the maximum price reversals that occur each day, relative to the SSCB mechanism.

Overall, our analysis provides evidence that is consistent with LULD mechanisms reducing extraordinary transitory volatility relative to both the SSCB mechanism and the period before the SSCB Pilot, when no individual security price limits or circuit breakers were applied market-wide. However, the results need to interpreted cautiously, because they vary depending on the specific methodology employed.

[58] See supra note 3 and Section V for definitions of Moderate, Big, and Extreme price reversals.

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Table 1: Sample Descriptive Statistics

The table presents descriptive statistics for the Tier 1 and Tier 2 common stocks and ETFs included in the sample.

The sample includes all common stocks and ETFs present in CRSP between February 2009 and October 2016. Leveraged ETFs and securities not present in TAQ are excluded from the sample. Stock-days where the previous or current trading day's closing price or midpoint is below $1.00 are also excluded from the sample.

Stocks are grouped into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks) using the methodology described in Appendix C.

Number of Unique Securities is the number of unique CRSP PERMNO that fall into the category. **Number of Stock Days** is the number of stock-days present in the sample. ***MktCap, Volume, Price, Volatility, BASpread*** are the daily average of the variables described in Appendix B.

	Common Stock		ETF	
Variable	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**
Number Unique Securities	1,286	4,888	796	1,698
Number Stock-days	1,647,003	5,195,078	812,670	1,062,956
***MktCap* (thousands $)**	17,633,983	614,256	3,067,817	74,824
***Volume* ($)**	146,091,825	6,271,370	142,094,300	776,522
***Price* ($)**	57.02	18.46	55.18	36.01
***Volatility* (%)**	2.56%	4.22%	1.22%	1.03%
***BASpread* (%)**	0.053%	0.865%	0.098%	0.481%

Table 2: Distribution of Price Reversal Measures

This table shows the distributions of the price reversal measures constructed by Cornerstone Research for Tier 1 and Tier 2 common stocks and ETFs in the sample. The price reversal measures are constructed from DTAQ trade data using the methodology described in Appendix D. **No Reversal** is the percentage of periods in which no reversal occurred. All other measures are return values given in basis points (bps).

Last denotes the price reversal metrics constructed using the last transaction price in an interval. **Max to Min** denotes the price reversal metrics constructed using the Maximum – Minimum – Maximum transaction prices in three consecutive time intervals. **Min to Max** denotes the price reversal metrics constructed using the Minimum – Maximum - Minimum prices in three consecutive intervals. **VWAP** denotes the price reversal metrics constructed using the volume weighted average transaction price for a time interval. Panel A, B, C, and D show the distributions for price reversal metrics constructed using time intervals of 1 minute, 5 minutes, 10 minutes, and 30 minutes, respectively.

Panel A: 1 Minute Reversals

Measure	Security Type	No Reversal	Mean	Std Dev	25%	50%	75%	90%	95%	99%	99.90%	99.99%	99.999%	Max
Last	**Common Tier 1**	62.77%	4.56	5.21	1.73	3.11	5.59	9.45	13.05	24.51	54.35	92.76	166.21	1,346.74
Last	**Common Tier 2**	66.16%	14.24	25.10	4.02	7.93	15.81	30.36	45.66	97.09	292.12	683.23	1,363.46	10,452.96
Last	**ETF Tier 1**	59.31%	3.35	4.45	1.01	2.16	4.13	7.36	10.36	19.64	40.29	79.38	224.13	2,115.81
Last	**ETF Tier 2**	60.19%	9.46	16.24	2.46	5.25	11.07	21.02	30.75	64.66	170.64	462.49	954.14	3,962.49
Max to Min	**Common Tier 1**	28.47%	6.78	7.78	2.53	4.56	8.24	14.12	19.58	36.91	76.92	134.53	274.73	7,482.34
Max to Min	**Common Tier 2**	51.42%	15.93	24.66	4.83	9.47	18.40	34.09	49.62	99.01	279.37	633.40	1,221.54	9,921.88
Max to Min	**ETF Tier 1**	42.87%	4.07	5.22	1.35	2.69	5.06	8.74	12.13	22.73	46.57	97.04	292.65	2,507.38
Max to Min	**ETF Tier 2**	58.60%	9.59	16.31	2.54	5.37	11.25	21.26	31.03	65.12	171.23	460.68	977.53	3,235.92
Min to Max	**Common Tier 1**	28.47%	6.78	7.84	2.53	4.56	8.23	14.11	19.59	37.09	77.65	137.61	286.17	6,064.26
Min to Max	**Common Tier 2**	51.48%	15.97	25.63	4.82	9.46	18.42	34.16	49.75	99.01	283.40	664.06	1,346.15	68,155.34
Min to Max	**ETF Tier 1**	42.95%	4.03	5.22	1.33	2.67	5.00	8.66	12.02	22.57	46.40	98.31	296.91	2,556.60
Min to Max	**ETF Tier 2**	58.57%	9.49	17.16	2.50	5.29	11.07	20.96	30.64	64.48	173.27	495.47	1,102.72	6,106.67
VWAP	**Common Tier 1**	56.38%	2.53	3.60	0.60	1.49	3.17	5.80	8.21	15.86	35.65	71.69	163.26	1,743.65
VWAP	**Common Tier 2**	57.65%	9.44	20.31	1.67	4.37	10.10	21.11	33.33	79.01	238.10	572.66	1,160.95	12,449.53
VWAP	**ETF Tier 1**	52.92%	2.44	3.97	0.47	1.32	3.00	5.76	8.43	16.79	36.35	83.85	228.17	1,564.77
VWAP	**ETF Tier 2**	56.62%	8.34	15.03	1.75	4.38	9.78	19.14	28.26	59.98	155.58	415.88	868.43	4,985.68

Panel B: 5 Minute Reversals

Measure	Security Type	No Reversal	Mean	Std Dev	25%	50%	75%	90%	95%	99%	99.90%	99.99%	99.999%	Max
Last	**Common Tier 1**	56.13%	8.15	9.32	2.76	5.40	10.20	17.59	24.21	44.18	87.53	161.44	297.86	1,329.71
Last	**Common Tier 2**	60.97%	20.81	34.77	5.80	11.85	23.67	44.48	66.01	147.49	404.98	880.50	1,673.15	8,804.31
Last	**ETF Tier 1**	54.20%	5.09	6.47	1.52	3.28	6.41	11.40	15.90	29.30	58.37	109.35	285.22	1,798.21
Last	**ETF Tier 2**	57.73%	10.74	17.62	2.86	6.12	12.74	23.84	34.61	71.54	184.55	481.10	1,033.92	3,968.09
Max to Min	**Common Tier 1**	8.33%	14.60	15.38	5.57	10.30	18.29	30.31	41.24	73.30	142.02	264.55	513.20	7,482.34
Max to Min	**Common Tier 2**	31.79%	27.18	36.48	8.82	17.36	32.89	57.80	80.65	162.43	402.68	833.33	1,500.35	9,846.15
Max to Min	**ETF Tier 1**	28.82%	7.51	9.37	2.41	4.89	9.34	16.35	22.76	42.56	86.36	170.61	461.80	2,634.42
Max to Min	**ETF Tier 2**	53.73%	11.48	18.55	3.14	6.68	13.74	25.36	36.63	74.96	191.33	493.84	1,081.08	4,692.01
Min to Max	**Common Tier 1**	8.34%	14.61	15.56	5.57	10.28	18.24	30.27	41.25	73.84	145.33	278.90	550.00	3,333.33
Min to Max	**Common Tier 2**	31.90%	27.37	39.09	8.82	17.35	32.90	58.09	81.30	165.29	424.24	941.70	1,880.00	68,265.80
Min to Max	**ETF Tier 1**	28.93%	7.40	9.32	2.37	4.82	9.19	16.07	22.39	42.02	86.31	173.34	463.14	2,556.60
Min to Max	**ETF Tier 2**	53.79%	11.27	19.54	3.08	6.51	13.37	24.78	35.94	74.02	194.37	548.47	1,213.17	6,106.67
VWAP	**Common Tier 1**	56.14%	5.05	6.66	1.21	3.03	6.42	11.69	16.45	30.72	62.26	120.10	226.68	1,166.58
VWAP	**Common Tier 2**	54.94%	13.70	28.14	2.46	6.47	14.91	30.59	47.49	114.57	335.10	747.20	1,451.47	7,068.67
VWAP	**ETF Tier 1**	51.53%	3.78	5.46	0.78	2.12	4.73	8.96	12.82	24.35	50.02	101.81	249.13	1,564.77
VWAP	**ETF Tier 2**	54.43%	9.29	16.19	1.96	4.95	11.05	21.33	31.30	65.55	167.25	433.65	911.15	4,985.68

Panel C: 10 Minute Reversals

Measure	Security Type	No Reversal	Mean	Std Dev	25%	50%	75%	90%	95%	99%	99.90%	99.99%	99.999%	Max
Last	**Common Tier 1**	54.32%	11.16	13.24	3.51	7.19	13.97	24.50	34.01	62.55	125.00	231.96	421.35	1,329.44
Last	**Common Tier 2**	59.11%	26.29	41.88	7.16	15.05	30.49	57.04	82.74	182.72	474.75	1,001.43	1,875.00	7,783.65
Last	**ETF Tier 1**	52.68%	6.50	8.38	1.85	4.04	8.17	14.69	20.56	38.31	77.02	145.28	320.39	1,795.74
Last	**ETF Tier 2**	57.63%	11.90	19.15	3.19	6.88	14.27	26.46	38.22	77.93	195.77	498.16	1,117.49	3,968.09
Max to Min	**Common Tier 1**	4.40%	21.75	22.65	8.41	15.44	27.20	45.12	61.07	107.96	211.04	387.17	715.79	7,482.34
Max to Min	**Common Tier 2**	24.33%	37.84	47.51	12.76	24.90	46.30	79.68	110.19	218.63	504.59	990.57	1,716.42	9,846.15
Max to Min	**ETF Tier 1**	22.75%	10.58	13.71	3.36	6.88	13.17	23.05	32.21	60.43	123.42	238.31	736.01	4,295.20
Max to Min	**ETF Tier 2**	51.66%	13.45	21.75	3.67	7.91	16.23	29.68	42.65	85.98	213.66	542.44	1,494.85	5,053.27
Min to Max	**Common Tier 1**	4.41%	21.76	23.00	8.41	15.41	27.12	45.03	61.07	108.94	217.29	412.67	786.85	3,060.59
Min to Max	**Common Tier 2**	24.47%	38.29	52.32	12.76	24.90	46.40	80.19	111.37	225.48	551.11	1,202.73	2,429.38	68,265.80
Min to Max	**ETF Tier 1**	22.85%	10.38	13.21	3.31	6.77	12.90	22.51	31.48	59.30	122.32	238.33	632.14	7,424.98
Min to Max	**ETF Tier 2**	51.78%	13.12	22.28	3.59	7.69	15.73	28.82	41.54	84.59	218.39	605.70	1,480.36	6,170.21
VWAP	**Common Tier 1**	56.50%	7.30	9.65	1.74	4.35	9.25	16.93	23.88	44.77	90.91	171.12	314.57	1,310.13
VWAP	**Common Tier 2**	55.08%	17.64	34.01	3.21	8.51	19.63	39.85	61.07	145.13	396.35	848.81	1,600.00	5,662.63
VWAP	**ETF Tier 1**	52.02%	4.78	6.90	1.00	2.71	6.03	11.36	16.19	30.63	61.98	119.65	297.44	1,564.77
VWAP	**ETF Tier 2**	55.01%	10.20	17.43	2.16	5.50	12.22	23.43	34.24	70.95	178.44	455.89	975.82	3,111.40

Panel D: 30 Minute Reversals

Measure	Security Type	No Reversal	Mean	Std Dev	25%	50%	75%	90%	95%	99%	99.90%	99.99%	99.999%	Max
Last	**Common Tier 1**	57.02%	17.81	21.23	5.30	11.45	22.65	39.60	54.64	99.01	199.43	365.89	648.15	1,927.15
Last	**Common Tier 2**	61.44%	38.24	55.87	10.34	22.48	45.80	83.60	121.07	254.78	603.36	1,205.70	2,125.38	13,181.07
Last	**ETF Tier 1**	56.16%	9.62	12.39	2.56	5.85	12.15	21.93	30.78	57.77	115.87	227.00	370.00	1,015.81
Last	**ETF Tier 2**	62.96%	14.62	22.16	3.85	8.58	17.86	32.70	46.73	92.65	225.16	512.17	1,098.40	4,727.83
Max to Min	**Common Tier 1**	10.65%	39.38	38.91	16.01	28.69	49.63	80.59	107.66	186.94	358.42	638.26	1,080.39	7,482.58
Max to Min	**Common Tier 2**	24.51%	65.06	73.02	23.56	44.84	80.82	136.59	186.92	348.55	725.62	1,304.18	2,120.34	9,538.46
Max to Min	**ETF Tier 1**	21.85%	18.53	24.53	5.90	12.27	23.23	40.12	55.59	102.73	205.03	382.11	2,207.79	5,501.39
Max to Min	**ETF Tier 2**	53.32%	19.08	30.49	5.16	11.71	23.44	41.93	59.39	116.58	277.35	649.19	2,980.69	6,371.32
Min to Max	**Common Tier 1**	10.66%	39.42	39.83	15.98	28.58	49.40	80.43	107.97	189.87	374.66	706.52	1,271.32	4,105.96
Min to Max	**Common Tier 2**	24.65%	66.50	83.82	23.60	44.94	81.30	138.63	191.67	369.33	847.46	1,851.85	3,850.93	68,921.57
Min to Max	**ETF Tier 1**	21.96%	17.90	21.16	5.77	11.94	22.39	38.54	53.62	99.98	199.16	363.75	856.20	1,873.80
Min to Max	**ETF Tier 2**	53.58%	18.38	28.47	4.96	11.21	22.40	40.24	57.30	113.78	284.15	701.79	1,791.22	5,505.33
VWAP	**Common Tier 1**	60.83%	12.63	16.04	3.13	7.74	16.21	29.15	40.65	74.62	148.13	274.03	507.04	1,931.77
VWAP	**Common Tier 2**	60.39%	26.81	45.42	5.21	13.78	31.29	61.54	91.93	203.40	500.54	1,018.13	1,819.48	11,580.46
VWAP	**ETF Tier 1**	58.18%	7.14	11.35	1.48	4.04	9.06	16.97	24.11	45.28	89.86	159.89	801.39	3,362.81
VWAP	**ETF Tier 2**	62.16%	12.33	20.44	2.66	6.81	15.02	28.43	41.12	82.92	200.51	479.53	1,447.73	4,758.31

Table 3: Distribution of Extreme Price Reversals

This table shows the distribution of large price reversals. The 99th, 99.9th, 99.99th, and 100th percentile values of the price reversal measures described in Appendix D are calculated for each CRSP PERMNO in the sample over the entire sample period (February 2009 through September 2016). The table shows the cross-sectional distribution of the calculated percentile values across all PERMNOs. For example, in Panel A, the value of 99th percentile of the Last price reversal measure calculated over 1 minute intervals is determined for each PERMNO. The 50% column in the table would then show the median of the calculated 99th percentile values across all PERMNO. All return values are given in basis points (bps).

Last denotes the price reversal metrics constructed using the last transaction price in an interval. **Max to Min** denotes the price reversal metrics constructed using the Maximum – Minimum – Maximum transaction prices in three consecutive time intervals. **Min to Max** denotes the price reversal metrics constructed using the Minimum – Maximum - Minimum prices in three consecutive intervals. **VWAP** denotes the price reversal metrics constructed using the volume weighted average transaction price for a time interval. Permno Percentile is the percentile that is being estimated for each PERMNO. Panel A, B, C, and D show the distributions for price reversal metrics constructed using time intervals of 1 minute, 5 minutes, 10 minutes, and 30 minutes, respectively.

Panel A: 1 Minute Reversals

Measure	Permno Percentile	Mean	Std Dev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Last	**99%**	162.75	304.88	9.09	14.34	18.33	29.59	63.14	166.83	419.16	625.00	1,328.13
Last	**99.90%**	298.58	488.81	16.28	25.15	32.39	52.73	115.27	348.57	786.89	1,149.14	2,210.18
Last	**99.99%**	437.82	602.77	25.94	40.17	52.37	85.64	199.37	559.44	1,132.60	1,607.14	2,800.00
Last	**100%**	561.86	631.78	29.86	72.71	96.91	166.21	336.64	736.66	1,304.40	1,714.29	2,988.05
Max to Min	**99%**	165.74	263.53	11.47	18.68	23.81	36.77	71.43	178.57	428.19	619.47	1,277.22
Max to Min	**99.90%**	306.46	442.68	19.97	33.76	43.36	67.82	138.25	369.50	787.72	1,103.45	2,049.18
Max to Min	**99.99%**	466.37	561.08	29.24	58.48	74.82	117.38	253.57	604.03	1,129.08	1,563.20	2,551.03
Max to Min	**100%**	665.49	588.53	32.76	104.23	161.29	270.61	489.90	897.64	1,379.31	1,768.94	2,747.25
Min to Max	**99%**	170.94	301.47	11.44	18.59	23.65	36.70	71.43	178.95	434.78	640.00	1,270.49
Min to Max	**99.90%**	328.65	519.16	19.86	33.24	43.25	67.91	139.21	375.35	833.33	1,223.47	2,407.42
Min to Max	**99.99%**	517.60	700.00	29.24	57.35	74.59	119.90	261.10	639.34	1,264.50	1,807.23	3,217.67
Min to Max	**100%**	771.60	1,168.55	33.61	105.49	161.24	280.43	532.92	973.15	1,593.75	2,127.66	3,501.00
VWAP	**99%**	136.90	254.25	6.83	10.05	13.23	22.80	51.54	142.75	364.38	535.51	1,116.74
VWAP	**99.90%**	255.02	414.15	12.73	18.88	24.51	41.19	94.88	298.25	682.08	999.50	2,001.28
VWAP	**99.99%**	377.72	520.70	22.47	35.35	44.27	71.06	166.69	481.67	965.61	1,415.30	2,484.27
VWAP	**100%**	508.47	555.09	30.21	73.18	100.59	170.47	322.51	661.70	1,137.50	1,535.43	2,568.81

Panel B: 5 Minute Reversals

Measure	Permno Percentile	Mean	Std Dev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Last	**99%**	183.64	303.87	14.63	24.07	29.65	44.65	79.92	192.64	455.11	666.67	1,462.50
Last	**99.90%**	328.44	478.45	22.66	41.21	51.51	78.77	148.63	380.23	820.82	1,222.17	2,211.78
Last	**99.99%**	477.48	587.83	28.08	65.23	83.96	128.70	251.02	604.03	1,166.67	1,621.29	2,777.62
Last	**100%**	559.81	606.99	30.67	84.64	112.06	183.21	342.85	724.00	1,280.00	1,693.74	2,889.59
Max to Min	**99%**	203.81	271.69	17.01	31.28	40.27	63.13	107.74	227.92	489.13	694.81	1,337.39
Max to Min	**99.90%**	366.40	440.23	26.85	56.34	72.68	112.63	204.08	449.80	879.03	1,214.29	2,119.97
Max to Min	**99.99%**	552.35	549.60	32.27	95.02	126.51	193.68	355.62	726.23	1,268.66	1,643.65	2,506.98
Max to Min	**100%**	720.12	583.92	34.98	113.23	187.56	315.88	551.58	964.63	1,459.85	1,810.54	2,706.29
Min to Max	**99%**	217.35	330.82	16.79	30.70	39.78	62.96	107.93	232.86	512.82	756.30	1,509.97
Min to Max	**99.90%**	416.25	640.83	26.41	55.14	72.40	113.97	208.43	470.96	980.33	1,475.10	2,630.49
Min to Max	**99.99%**	654.45	827.57	33.71	93.40	124.03	194.99	374.51	806.66	1,528.38	2,095.88	3,662.42
Min to Max	**100%**	884.34	1,270.26	38.28	115.38	187.28	326.85	599.86	1,106.93	1,859.19	2,464.23	4,210.53
VWAP	**99%**	148.75	246.79	11.84	18.67	23.21	34.18	61.21	155.60	376.79	557.75	1,175.50
VWAP	**99.90%**	272.22	397.44	19.66	33.33	40.97	61.61	116.51	316.11	691.77	1,007.31	1,979.49
VWAP	**99.99%**	400.58	497.66	26.75	53.55	67.40	101.60	203.31	507.08	982.66	1,415.30	2,427.24
VWAP	**100%**	477.98	516.49	30.21	70.22	93.73	151.11	291.39	614.98	1,100.07	1,506.19	2,488.54

Panel C: 10 Minute Reversals

Measure	Permno Percentile	Mean	Std Dev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Last	**99%**	200.46	290.48	16.06	30.39	37.84	58.23	98.86	215.31	473.87	695.36	1,470.59
Last	**99.90%**	358.09	466.18	21.61	52.11	67.76	104.65	181.94	422.54	856.00	1,249.69	2,331.35
Last	**99.99%**	523.61	581.36	27.33	81.93	111.18	173.32	307.35	659.84	1,220.12	1,637.43	2,857.14
Last	**100%**	585.43	593.88	29.89	90.67	137.78	217.24	378.25	746.54	1,310.34	1,705.88	2,972.43
Max to Min	**99%**	238.25	277.66	19.64	38.75	51.55	86.85	145.21	273.97	536.59	761.06	1,401.27
Max to Min	**99.90%**	425.04	448.09	29.10	70.71	95.49	156.59	269.78	523.56	951.24	1,289.47	2,201.26
Max to Min	**99.99%**	647.69	568.17	32.99	109.20	171.10	271.05	463.77	853.08	1,381.58	1,767.68	2,714.29
Max to Min	**100%**	806.53	618.42	34.93	118.86	217.01	381.50	643.83	1,072.93	1,602.56	2,000.00	2,875.65
Min to Max	**99%**	259.41	360.02	19.19	37.74	50.28	86.25	147.60	285.71	587.49	852.00	1,627.35
Min to Max	**99.90%**	506.34	822.41	29.64	68.99	93.01	156.99	278.88	576.81	1,130.95	1,695.05	3,205.13
Min to Max	**99.99%**	803.42	1,069.05	36.12	110.64	163.15	272.52	485.18	964.28	1,772.00	2,479.34	4,508.92
Min to Max	**100%**	1,024.30	1,453.05	38.33	126.25	218.26	389.45	694.51	1,273.89	2,107.94	2,850.31	5,136.61
VWAP	**99%**	159.90	234.71	13.68	24.44	30.37	45.18	75.71	169.84	388.08	578.91	1,148.24
VWAP	**99.90%**	290.80	379.53	19.89	41.92	53.84	82.31	142.93	339.96	716.61	1,030.13	1,988.60
VWAP	**99.99%**	433.23	488.79	26.54	63.55	84.89	135.55	249.42	542.30	1,010.08	1,428.64	2,405.74
VWAP	**100%**	487.81	499.58	29.14	72.85	100.83	166.35	313.35	626.66	1,105.60	1,477.92	2,419.43

Panel D: 30 Minute Reversals

Measure	Permno Percentile	Mean	Std Dev	1%	5%	10%	25%	50%	75%	90%	95%	99%
Last	**99%**	234.44	291.75	18.16	40.25	52.59	83.15	142.54	267.68	512.13	724.19	1,458.33
Last	**99.90%**	408.76	477.46	24.52	64.80	90.44	145.10	254.72	485.85	900.00	1,267.32	2,320.90
Last	**99.99%**	575.07	537.17	28.07	81.88	141.18	259.53	409.56	721.23	1,210.76	1,590.72	2,568.37
Last	**100%**	575.09	537.15	28.07	81.88	141.29	259.53	409.56	721.23	1,210.76	1,590.72	2,568.37
Max to Min	**99%**	316.81	302.48	24.85	53.70	74.55	136.35	231.94	394.27	645.06	858.17	1,503.01
Max to Min	**99.90%**	547.43	476.03	32.61	89.97	138.05	243.53	411.68	699.30	1,112.99	1,467.89	2,289.26
Max to Min	**99.99%**	825.03	639.56	38.52	114.74	234.23	400.35	653.27	1,084.46	1,617.65	2,000.00	3,095.82
Max to Min	**100%**	910.57	687.58	38.93	117.18	244.59	451.20	758.02	1,202.07	1,735.54	2,176.52	3,323.72
Min to Max	**99%**	355.23	424.72	24.34	51.96	72.19	136.83	236.22	416.67	735.29	1,051.79	2,013.42
Min to Max	**99.90%**	679.69	853.57	32.03	90.05	130.77	244.14	423.98	796.46	1,453.94	2,080.00	4,110.43
Min to Max	**99.99%**	1,064.44	1,436.17	38.90	119.72	202.58	392.45	695.54	1,290.00	2,267.44	3,157.89	5,866.00
Min to Max	**100%**	1,158.28	1,510.17	39.44	123.86	217.32	444.00	783.29	1,428.57	2,443.75	3,333.33	6,076.80
VWAP	**99%**	185.29	231.28	14.92	33.22	43.32	66.31	110.44	206.72	410.01	581.55	1,173.29
VWAP	**99.90%**	329.77	391.52	20.86	54.33	73.30	116.89	200.18	388.48	737.06	1,050.71	1,934.26
VWAP	**99.99%**	471.40	467.13	25.79	73.57	105.97	180.62	323.35	602.12	1,026.70	1,365.09	2,195.76
VWAP	**100%**	471.42	467.11	25.79	73.57	105.97	180.69	323.35	602.12	1,026.70	1,365.09	2,195.76

Table 4: Distribution of Principal Components

This table presents statistics on the distributions of the stock-day frequency of large reversal principle component measures. Panel A presents the distribution of the measures for all common stock and ETF stock-days over the entire sample period, stratified based on whether they belonged in Tier 1 or Tier 2. Panel B sorts all common stocks in Tier 1 and Tier 2 into quintiles based on their average market capitalization during the previous month. It then shows the average value of the frequency of extreme reversal principal components for all common stock-days in the sample based on their tier and market capitalization quintile.

Stocks are grouped into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks) using the methodology described in Appendix C.

Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to principal components with thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns.

Panel A: Distribution of Principal Component Measures

Measure	Tier	Mean	Std Dev	Min	25%	50%	75%	90%	95%	99%	99.90%	99.99%	99.999%	Max
Raw 0.5%	**Tier 1**	0.829	1.883	0.00	0.00	0.18	0.84	2.22	3.70	8.32	24.02	36.09	41.81	49.81
Raw 0.5%	**Tier 2**	2.299	3.481	0.00	0.00	1.04	3.03	6.22	9.03	16.66	28.07	39.21	47.80	56.93
Raw 1%	**Tier 1**	0.285	1.222	0.00	0.00	0.00	0.14	0.57	1.38	4.96	15.64	33.92	58.24	90.59
Raw 1%	**Tier 2**	1.506	3.593	0.00	0.00	0.14	1.36	4.48	7.69	16.62	35.77	70.25	106.09	142.15
Raw 2%	**Tier 1**	0.076	0.735	0.00	0.00	0.00	0.00	0.00	0.31	1.73	9.16	28.09	59.98	106.04
Raw 2%	**Tier 2**	0.861	3.646	0.00	0.00	0.00	0.00	1.64	4.93	16.75	42.10	91.42	154.99	243.52
Raw 3%	**Tier 1**	0.034	0.546	0.00	0.00	0.00	0.00	0.00	0.00	0.59	6.09	22.26	51.85	114.74
Raw 3%	**Tier 2**	0.588	3.636	0.00	0.00	0.00	0.00	0.53	2.13	16.05	46.60	100.65	183.47	312.20
Raw 4%	**Tier 1**	0.019	0.453	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.45	19.45	48.41	98.11
Raw 4%	**Tier 2**	0.434	3.609	0.00	0.00	0.00	0.00	0.00	0.79	13.05	49.44	108.03	204.04	358.35
Raw 5%	**Tier 1**	0.013	0.411	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.74	17.98	46.36	97.99
Raw 5%	**Tier 2**	0.333	3.578	0.00	0.00	0.00	0.00	0.00	0.00	8.62	52.45	117.36	217.69	398.22
Ind 99%	**Tier 1**	1.321	4.223	0.00	0.00	0.00	0.73	3.16	6.60	21.22	48.40	74.24	101.11	121.52
Ind 99%	**Tier 2**	0.764	2.555	0.00	0.00	0.00	0.35	2.06	4.10	11.87	29.88	53.82	85.84	133.95
Ind 99.9%	**Tier 1**	0.584	3.631	0.00	0.00	0.00	0.00	0.58	2.33	13.55	51.22	100.10	171.42	260.15
Ind 99.9%	**Tier 2**	0.330	2.392	0.00	0.00	0.00	0.00	0.00	1.16	8.55	31.50	73.35	149.95	332.20
Ind 99.99%	**Tier 1**	0.251	2.916	0.00	0.00	0.00	0.00	0.00	0.00	6.08	39.63	111.79	194.88	301.63
Ind 99.99%	**Tier 2**	0.156	2.145	0.00	0.00	0.00	0.00	0.00	0.00	4.08	31.28	74.43	154.28	321.68
Rolling 10 SD	**Tier 1**	0.147	2.216	0.00	0.00	0.00	0.00	0.00	0.00	3.00	23.72	88.37	213.49	531.62
Rolling 10 SD	**Tier 2**	0.306	2.710	0.00	0.00	0.00	0.00	0.00	0.85	6.66	32.97	87.40	207.13	1165.08
Rolling 25 SD	**Tier 1**	0.060	2.350	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.96	96.79	279.76	865.17
Rolling 25 SD	**Tier 2**	0.070	2.696	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.96	97.29	273.49	2557.37

Panel B: Distribution of Mean Principal Component Measures for Common Stocks by Market Cap

	Tier 1					Tier 2				
Meaure	**Low**	**2**	**3**	**4**	**High**	**Low**	**2**	**3**	**4**	**High**
Raw 0.5%	1.790	1.117	1.004	0.878	0.671	3.126	3.671	2.948	2.159	1.593
Raw 1%	0.744	0.363	0.314	0.252	0.177	3.448	2.407	1.474	0.913	0.576
Raw 2%	0.233	0.085	0.071	0.051	0.038	2.902	1.172	0.526	0.261	0.138
Raw 3%	0.106	0.034	0.028	0.019	0.017	2.302	0.675	0.253	0.110	0.053
Raw 4%	0.058	0.017	0.015	0.010	0.011	1.827	0.434	0.145	0.058	0.026
Raw 5%	0.037	0.011	0.009	0.006	0.008	1.461	0.297	0.092	0.035	0.015
Ind 99%	1.469	1.235	1.307	1.348	1.447	0.450	0.693	0.844	0.978	1.118
Ind 99.9%	0.659	0.529	0.571	0.586	0.646	0.209	0.295	0.351	0.401	0.461
Ind 99.99%	0.290	0.233	0.256	0.265	0.298	0.127	0.136	0.153	0.169	0.194
Rolling 10 SD	0.124	0.124	0.122	0.130	0.153	0.613	0.400	0.188	0.123	0.108
Rolling 25 SD	0.026	0.030	0.032	0.036	0.056	0.113	0.063	0.030	0.024	0.023

Table 5: Univariate Test of Differences in Frequency of Extreme Reversals

This table reports in Panel A the average value of principal components measuring the frequency of large reversals for Tier 1 and Tier 2 securities during different time periods. Panel B reports the average difference between these measures during the LULD Periods and the Pre-SSCB and SSCB periods. ***, **, * and (-)/(+) indicate that a Wilcoxon signed-rank test indicates the difference between the two periods is negative / positive and statistically significant at the 1, 5 and 10% levels.

Stocks are grouped into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks) using the methodology described in Appendix C.

Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to principal components with thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns.

The Pre SSCB period is defined as the period between February 1, 2009 and June 10,2010. The SSCB period is defined as the period between September 14, 2010 and April 5, 2013. The LULD Phase 1 period is defined as the period between June 3, 2013 and August 2, 2013. The LULD Phase 2 period is defined as the period between May 12, 2014 - September 30, 2016.

Panel A: Average Principal Component Measures by Time Period

	Pre SSCB (February 1, 2009 – June 10,2010)		SSCB (September 14, 2010 – April 5, 2013)		LULD Phase 1 (June 3, 2013 – August 2, 2013)		LULD Phase 2 (May 12, 2014 - September 30, 2016)	
Measure	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**
Raw 0.5%	1.875	3.087	0.715	2.031	0.462	1.769	0.625	2.277
Raw 1%	0.789	2.139	0.203	1.291	0.100	1.047	0.215	1.517
Raw 2%	0.251	1.303	0.042	0.751	0.018	0.583	0.057	0.835
Raw 3%	0.118	0.948	0.016	0.520	0.007	0.401	0.026	0.543
Raw 4%	0.068	0.749	0.008	0.385	0.004	0.290	0.016	0.381
Raw 5%	0.044	0.617	0.005	0.294	0.003	0.212	0.012	0.276
Ind 99%	3.941	1.640	1.020	0.611	0.673	0.397	0.792	0.595
Ind 99.9%	1.789	0.781	0.460	0.252	0.242	0.149	0.340	0.250
Ind 99.99%	0.666	0.350	0.211	0.119	0.110	0.067	0.176	0.132
Rolling 10 SD	0.115	0.283	0.139	0.308	0.136	0.319	0.180	0.323
Rolling 25 SD	0.043	0.066	0.037	0.066	0.042	0.075	0.103	0.081
N	384,044	1,110,960	802,560	2,057,143	56,043	136,405	836,846	1,983,548

Panel B: Distributional Differences

	Distributional Difference between LULD Phase 1 and				Distributional Difference between LULD Phase 2 and			
	Pre SSCB		SSCB		Pre SSCB		SSCB	
Measure	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**
Raw 0.5%	-1.412***(-)	-1.319***(-)	-0.253***(-)	-0.263***(-)	-1.249***(-)	-0.810***(-)	-0.090***(-)	0.246***(+)
Raw 1%	-0.688***(-)	-1.092***(-)	-0.103***(-)	-0.243***(-)	-0.574***(-)	-0.623***(-)	0.011***(-)	0.226***(+)
Raw 2%	-0.233***(-)	-0.721***(-)	-0.024***(-)	-0.169***(-)	-0.193***(-)	-0.469***(-)	0.016	0.083***(+)
Raw 3%	-0.111***(-)	-0.547***(-)	-0.008***(-)	-0.119***(-)	-0.092***(-)	-0.405***(-)	0.011***(+)	0.024***(+)
Raw 4%	-0.064***(-)	-0.459***(-)	-0.003***(-)	-0.095***(-)	-0.052***(-)	-0.368***(-)	0.008***(+)	-0.004***(+)
Raw 5%	-0.042***(-)	-0.405***(-)	-0.002***(-)	-0.082***(-)	-0.033***(-)	-0.341***(-)	0.007***(+)	-0.018***(+)
Ind 99%	-3.268***(-)	-1.243***(-)	-0.348***(-)	-0.214***(-)	-3.149***(-)	-1.045***(-)	-0.229***(-)	-0.016***(-)
Ind 99.9%	-1.546***(-)	-0.632***(-)	-0.218***(-)	-0.103***(-)	-1.449***(-)	-0.531***(-)	-0.120***(-)	-0.002***(-)
Ind 99.99%	-0.557***(-)	-0.283***(-)	-0.101***(-)	-0.052***(-)	-0.490***(-)	-0.218***(-)	-0.034***(-)	0.014***(+)
Rolling 10 SD	0.021***(-)	0.037***(-)	-0.002***(-)	0.011***(-)	0.065***(-)	0.040***(-)	0.042***(-)	0.014***(-)
Rolling 25 SD	-0.001***(-)	0.009***(-)	0.005	0.010*(-)	0.060***(-)	0.014***(-)	0.066***(+)	0.015***(-)

Table 6: Characteristics of Difference in Difference Sample

This table compares the average characteristics of the test and control groups in the difference in difference sample. The **Test** group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The **Control** group consists of the 200 common stocks with the largest market capitalizations that remain in Tier 2. The stocks that are selected based on market capitalizations are selected based on market capitalizations computed using prices and shares outstanding from the last trading day in March 2013, shortly before the LULD staggered phase-in for Tier 1 securities begins.

MktCap is the market capitalization on the last trading day of March 2013. ***Volume*** is a stock's average dollar trading volume during March 2013. ***Volatility*** is a stock's average daily volatility during March 2013, as defined in Appendix A. ***Price*** is a stock's average daily closing price during March 2013. ***BASpread*** is a stock's average percentage bid-ask spread during March 2013, as defined in Appendix A. Average values for each stock are calculated using daily data from March 2013. The table presents the cross-sectional mean of average stock values. **Difference** is the average difference between the **Control** and **Test** groups **(Control – Test)**. ***, **, and * indicate that paired t-test between the Control and Test groups is statistically significant at the 1, 5 and 10% levels.

Characteristic	Control	Test	Difference
MktCap **(thousands $)**	2,646,425	2,447,373	199,053
Volume **($)**	21,862,779	29,490,284	-7,627,504***
Volatility **(%)**	2.15%	2.33%	-0.189%**
Price **($)**	55.79	37.16	18.63
BASpread **(%)**	0.056%	0.066%	-00.010%
N	200	200	

Table 7: Test of Differences of Frequency of Reversal Principal Components for Difference in Difference Sample

This table compares the average values of the frequency of large reversal principal component measures for the test and control stocks in the difference in difference sample during this time period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013. The test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The control group consists of the 200 common stocks with the largest market capitalizations that remain in Tier 2. The stocks that are selected based on market capitalizations are selected based on market capitalizations computed using prices and shares outstanding from the last trading day in March 2013, shortly before the LULD staggered phase-in for Tier 1 securities begins.

The SSCB period for test stocks is days that they operate under the SSCB mechanism and the LULD period is days that they operate under the LULD mechanism. The Before period for control stocks is from November 26, 2012 until June 2, 2013 and the After period is from June 3, 2013 until August 2, 2013. Diff Test is the average values for test stocks during the LULD period minus the average values during the SSCB period. Diff Contol is the average values for the control stocks during the After period minus the average values during the Before period. Test Diff – Contol Diff represents the average treatment effect and is equal to Diff Test minus Diff Control. Tobit Parameter and Tobit SE are estimated from a censored tobit regression and are the parameter value and standard error of an indicator variable that is equal to 1 if a test stock is operating under the LULD mechanism. The tobit regression also includes an indicator variable for is a stock is in the test group and month fixed effects. The standard errors of the regression are clustered by date.

Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to principal components with thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns.

***, **, * indicate statistical significance at the 1, 5 and 10% levels.

Measure	Control Before	Control After	Test SSCB	Test LULD	Diff Test	Diff Control	Test Diff – Control Diff	Tobit Parameter	Tobit SE
Raw 0.5%	0.8575	0.9353	1.0987	0.9826	-0.1161	0.0778	-0.1940	-0.317***	(0.0308)
Raw 1.0%	0.2327	0.2405	0.3535	0.2990	-0.0545	0.0078	-0.0623	-0.334***	(0.0389)
Raw 2.0%	0.0402	0.0396	0.0832	0.0663	-0.0168	-0.0006	-0.0162	-0.609***	(0.100)
Raw 3.0%	0.0135	0.0132	0.0334	0.0260	-0.0074	-0.0003	-0.0071	-0.990***	(0.229)
Raw 4.0%	0.0067	0.0051	0.0166	0.0133	-0.0033	-0.0016	-0.0017	-1.616***	(0.496)
Raw 5.0%	0.0039	0.0018	0.0088	0.0064	-0.0023	-0.0021	-0.0003	-2.379***	(0.882)
Ind 99%	0.4874	0.5556	0.6579	0.6172	-0.0407	0.0682	-0.1090	-0.159**	(0.0684)
Ind 99.9%	0.1945	0.1911	0.3087	0.2815	-0.0272	-0.0034	-0.0238	-0.349	(0.271)
Ind 99.99%	0.0911	0.0736	0.1666	0.1646	-0.0020	-0.0176	0.0155	-1.405	(1.277)
Rolling 10 SD	0.0973	0.0789	0.1536	0.1488	-0.0048	-0.0185	0.0136	-0.298	(0.661)
Rolling 25 SD	0.0115	0.0074	0.0252	0.0239	-0.0013	-0.0041	0.0028	-3.566	(2.961)
N	25,444	8,560	22,418	11,635					

Table 8: Difference in Difference Sample Frequency of Reversal Principal Component Tobit Regressions

This table presents regression results from censored tobit panel regressions on the frequency of large reversal principal component measures for the test and control stocks in the difference in difference sample during this time period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013. The test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The control group consists of the 200 common stocks with the largest market capitalizations that remain in Tier 2. The stocks that are selected based on market capitalizations are selected based on market capitalizations computed using prices and shares outstanding from the last trading day in March 2013, shortly before the LULD staggered phase-in for Tier 1 securities begins.

The dependent variables Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to principal components with thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns.

Explanatory variables include: an indicator if the stock is the test group (**Test Stock**), an indicator if the test stock was operating under the LULD mechanism during the trading day (**LULD Active**), the daily CRSP value weighted market return (**MktReturn**), the daily volatility of the SPY etf (**SPY Volatility**), the opening value of the **VIX**, the natural log of the stock's average price during the previous month (**log(Price)**), the stock's average **Volatility** during the previous month (as defined in Appendix A), the natural log of the stock's average market capitalization (**Log(MktCap)**) during the previous month, the natural log of the stock's average dollar trading volume (**Log (Volume)**) during the previous trading month, the average percentage bid-ask spread (**BASpread**) during the previous month, and the average value of a stock's daily Amihud Illiquidity measure (**ILLQAmihud**) during the previous month. The regressions also include month fixed effects.

Dependent variable observations in the tobit regression are censored at 0. **N Uncensored** gives the number of uncensored observations. ***, **, * indicate statistical significance at the 1, 5 and 10% levels. Standard errors of the regressions are clustered by date.

Variable	Raw 0.5%	Raw 1.0%	Raw 2.0%	Raw 3.0%	Raw 4.0%	Raw 5.0%	Ind 99%	Ind 99.9%	Ind 99.99%	Rolling 10 SD	Rolling 25 SD
Test Stock	0.0457***	0.0370*	0.168***	0.619***	1.244***	1.796***	0.430***	1.458***	5.113***	1.899***	7.033***
	(0.0148)	(0.0210)	(0.0585)	(0.173)	(0.373)	(0.597)	(0.0368)	(0.183)	(0.985)	(0.522)	(2.197)
LULD Active	-0.0876***	-0.0866**	-0.216**	-0.310	-0.440	-1.135	-0.0456	-0.0762	-0.827	-0.316	-4.051
	(0.0254)	(0.0371)	(0.102)	(0.229)	(0.492)	(0.892)	(0.0712)	(0.283)	(1.247)	(0.630)	(3.033)
MktReturn	1.691	4.879	10.01*	16.88	-4.071	-28.75	9.141	44.05	83.55	56.16	168.0
	(2.893)	(3.353)	(5.357)	(10.63)	(21.28)	(34.17)	(6.886)	(31.89)	(119.0)	(72.09)	(155.0)
SPY Volatility	20.25***	14.76*	-4.229	-28.54	-17.34	-117.3	42.55***	124.3**	345.6**	148.0	296.2
	(7.444)	(8.285)	(14.63)	(25.01)	(43.23)	(90.82)	(15.36)	(52.88)	(172.5)	(122.2)	(340.7)
VIX	0.0899***	0.0881***	0.158***	0.215**	0.0648	0.254	0.176***	0.208	-0.331	-0.0988	-0.649
	(0.0274)	(0.0313)	(0.0555)	(0.0986)	(0.164)	(0.252)	(0.0572)	(0.162)	(0.672)	(0.363)	(1.087)
log(Price)	-0.121***	-0.125***	-0.199***	-0.276***	-0.666***	-0.651**	0.188***	0.273**	0.402	0.0805	-4.924**
	(0.00849)	(0.0116)	(0.0354)	(0.101)	(0.233)	(0.327)	(0.0229)	(0.108)	(0.542)	(0.233)	(2.375)
Volatility	86.67***	80.74***	102.8***	130.4***	178.7***	218.2***	63.10***	144.6***	249.2***	42.81	-259.4**
	(1.617)	(2.558)	(5.281)	(9.783)	(19.70)	(28.51)	(2.962)	(12.25)	(46.73)	(28.15)	(132.1)
Log(MktCap)	-0.131***	-0.134***	-0.315***	-0.757***	-0.678*	-0.141	-0.412***	-1.236***	-1.934*	0.801*	1.116
	(0.0190)	(0.0239)	(0.0735)	(0.182)	(0.391)	(0.555)	(0.0420)	(0.180)	(1.069)	(0.430)	(3.118)
Log (Volume)	0.0629***	0.0906***	0.199***	0.292***	0.0840	-0.445	-0.362***	-0.903***	-1.541***	-0.919***	2.837*
	(0.0124)	(0.0137)	(0.0387)	(0.102)	(0.199)	(0.314)	(0.0265)	(0.119)	(0.514)	(0.289)	(1.678)
BASpread	143.3***	126.0***	167.3***	163.6	-199.9	-67.93	-382.8***	-733.4***	-2,329***	1,064***	-3,528
	(10.49)	(17.67)	(55.95)	(147.0)	(247.9)	(384.7)	(34.80)	(143.1)	(783.7)	(239.5)	(5,227)
ILLQAmihud	-2.753e+06**	-1.307e+06	141,838	3.307e+06	1.578e+07*	1.202e+07	5.633e+06***	1.758e+07***	9.229e+07***	-9.104e+06	1.446e+08
	(1.197e+06)	(1.185e+06)	(2.285e+06)	(4.986e+06)	(8.811e+06)	(1.325e+07)	(1.970e+06)	(6.282e+06)	(2.810e+07)	(8.731e+06)	(1.574e+08)
Constant	-1.667***	-3.376***	-7.501***	-9.333***	-13.03**	-22.08**	5.907***	11.62***	-8.001	-25.68***	-119.3***
	(0.448)	(0.530)	(1.196)	(2.411)	(5.338)	(8.591)	(0.925)	(3.236)	(18.20)	(8.650)	(45.02)
Month Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	67,990	67,990	67,990	67,990	67,990	67,990	67,990	67,990	67,990	67,990	67,990
Pseudo-R2	0.153	0.143	0.156	0.143	0.121	0.121	0.0155	0.0147	0.0104	0.0150	0.0253
N Uncensored	60,423	26,276	3,922	983	339	151	31,605	5,673	1,042	1,934	139

Table 9: Distribution of Principal Components for Extreme Values

This table presents statistics on the distributions of the extreme value principle component measures. Panel A presents the distribution of the measures for all common stock and ETF stock-days over the entire sample period, stratified based on whether they belonged in Tier 1 or Tier 2. Panel B sorts all common stocks in Tier 1 and Tier 2 into quintiles based on their average market capitalization during the previous month. It then shows the average value of the extreme value principle component measures for all common stock-days in the sample based on their tier and market capitalization quintile.

Stocks are grouped into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks) using the methodology described in Appendix C.

1 minute, 5 minute, 10 minute, and **30 minute** represent the sampling time interval of the principal component.

Panel A: Distribution of Extreme Value Principal Component Measures

Measure	Tier	Percent Missing	Mean	Std Dev	Min	1%	5%	10%	25%	50%	75%	90%	95%	99%	Max
1 Minute	**Tier 1**	0.51%	0.531	0.477	0.000	0.286	0.420	0.629	0.946	1.240	2.230	5.059	11.530	22.317	33.160
1 Minute	**Tier 2**	12.50%	1.750	2.178	0.000	0.654	1.088	1.966	3.660	5.417	11.173	21.520	34.034	47.900	67.153
5 Minute	**Tier 1**	0.54%	0.751	0.602	0.000	0.402	0.608	0.920	1.368	1.763	2.944	5.858	11.613	19.634	33.993
5 Minute	**Tier 2**	13.39%	1.908	2.121	0.000	0.802	1.306	2.208	3.817	5.478	10.970	20.870	32.647	44.512	61.013
10 Minute	**Tier 1**	0.57%	0.900	0.725	0.000	0.470	0.728	1.113	1.665	2.147	3.559	6.733	12.810	23.551	39.547
10 Minute	**Tier 2**	14.24%	2.011	2.069	0.000	0.887	1.448	2.392	3.958	5.514	10.670	20.025	30.870	42.156	63.750
30 Minute	**Tier 1**	1.25%	1.051	0.855	0.000	0.533	0.847	1.314	1.975	2.546	4.178	7.709	14.248	28.111	49.619
30 Minute	**Tier 2**	17.80%	2.100	1.978	0.000	0.958	1.583	2.577	4.094	5.513	10.103	18.708	28.022	37.451	52.616

Panel B: Distribution of Extreme Value Mean Principal Component Measures for Common Stocks by Market Cap

	Tier 1					Tier 2				
Meaure	**Low**	**2**	**3**	**4**	**High**	**Low**	**2**	**3**	**4**	**High**
1 Minute	0.778	0.605	0.559	0.524	0.482	4.428	2.449	1.583	1.097	0.797
5 Minute	1.116	0.896	0.850	0.803	0.725	4.432	2.542	1.793	1.378	1.105
10 Minute	1.345	1.094	1.042	0.984	0.882	4.342	2.596	1.951	1.589	1.326
30 Minute	1.569	1.285	1.226	1.157	1.029	4.161	2.628	2.123	1.819	1.553

Table 10: Extreme Value Univariate Test of Differences

This table reports in Panel A the average value of extreme value principal components for Tier 1 and Tier 2 securities during different time periods. Panel B reports the average difference between these measures during the LULD Periods and the Pre-SSCB and SSCB periods. ***, **, * and (-)/(+) indicate that a Wilcoxon signed-rank test indicates the difference between the two periods is negative / positive and statistically significant at the 1, 5 and 10% levels.

Stocks are grouped into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks) using the methodology described in Appendix C.
1 minute, 5 minute, 10 minute, and **30 minute** represent the sampling time interval of the principal component.

The Pre SSCB period is defined as the period between February 1, 2009 and June 10,2010. The SSCB period is defined as the period between September 14, 2010 and April 5, 2013. The LULD Phase 1 period is defined as the period between June 3, 2013 and August 2, 2013. The LULD Phase 2 period is defined as the period between May 12, 2014 - September 30, 2016.

Panel A: Average Extreme Value Principal Compent Measures by Time Period

	Pre SSCB		SSCB		LULD Phase 1		LULD Phase 2	
Meaure	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**
1 Minute	0.782	2.247	0.510	1.676	0.464	1.514	0.472	1.639
5 Minute	1.100	2.436	0.723	1.825	0.658	1.622	0.667	1.800
10 Minute	1.329	2.557	0.863	1.911	0.773	1.686	0.801	1.916
30 Minute	1.551	2.657	1.012	1.998	0.891	1.727	0.936	2.014

Panel B: Distributional Differences

	Distributional Difference between LULD Phase 1 and				Distributional Difference between LULD Phase 2 and			
	Pre SSCB		SSCB		Pre SSCB		SSCB	
Measure	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
1 Minute	-0.318***(-)	-0.733***(-)	-0.045***(-)	-0.161***(-)	-0.311***(-)	-0.608***(-)	-0.038***(-)	-0.037***(-)
5 Minute	-0.442***(-)	-0.814***(-)	-0.065***(-)	-0.203***(-)	-0.433***(-)	-0.636***(-)	-0.055***(-)	-0.025***(-)
10 Minute	-0.556***(-)	-0.872***(-)	-0.090***(-)	-0.226***(-)	-0.528***(-)	-0.642***(-)	-0.062***(-)	0.004***(-)
30 Minute	-0.660***(-)	-0.931***(-)	-0.121***(-)	-0.271***(-)	-0.614***(-)	-0.644***(-)	-0.075***(-)	0.016***(-)

Table 11: Test of Differences of Extreme Values Principal Components for Difference in Difference Sample

This table compares the average values of the extreme values principal component measures for the test and control stocks in the difference in difference sample during this time period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013. The test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The control group consists of the 200 common stocks with the largest market capitalizations that remain in Tier 2. The stocks that are selected based on market capitalizations are selected based on market capitalizations computed using prices and shares outstanding from the last trading day in March 2013, shortly before the LULD staggered phase-in for Tier 1 securities begins.

The SSCB period for test stocks is days that they operate under the SSCB mechanism and the LULD period is days that they operate under the LULD mechanism. The Before period for control stocks is from November 26, 2012 until June 2, 2013 and the After period is from June 3, 2013 until August 2, 2013. Diff Test is the average values for test stocks during the LULD period minus the average values during the SSCB period. Diff Control is the average values for the control stocks during the After period minus the average values during the Before period. Test Diff – Control Diff represents the average treatment effect and is equal to Diff Test minus Diff Control. Extreme Value Parameter and Extreme Value SE are estimated from a generalized extreme value (GEV) regression for block maximum and are the parameter value and standard error of an indicator variable that is equal to 1 if a test stock is operating under the LULD mechanism. The GEV regression also includes an indicator variable for is a stock is in the test group and month fixed effects. The standard errors of the regression are clustered by date.

1 minute, 5 minute, 10 minute, and **30 minute** represent the sampling time interval of the principal component.

***, **, * indicate statistical significance at the 1, 5 and 10% levels.

Measure	Control Before	Control After	Test SSCB	Test LULD	Diff Test	Diff Control	Test Diff – Control Diff	Extreme Value Parameter	Extreme Value SE
1 Minute	0.6486	0.6618	0.6928	0.6478	-0.0451	0.0132	-0.0582	-0.0240***	(0.00330)
5 Minute	0.8764	0.9167	0.9559	0.9123	-0.0437	0.0403	-0.0840	-0.0435***	(0.00542)
10 Minute	1.0432	1.0861	1.1362	1.0896	-0.0466	0.0429	-0.0895	-0.0534***	(0.00596)
30 Minute	1.2074	1.2526	1.3113	1.2605	-0.0508	0.0453	-0.0960	-0.0636***	(0.00668)

Table 12: Difference in Difference Sample Extreme Value Principal Component Regressions

This table presents regression results from a generalized extreme value (GEV) regression on extreme value principal component measures for the test and control stocks in the difference in difference sample during this time period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013. The test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The control group consists of the 200 common stocks with the largest market capitalizations that remain in Tier 2. The stocks that are selected based on market capitalizations are selected based on market capitalizations computed using prices and shares outstanding from the last trading day in March 2013, shortly before the LULD staggered phase-in for Tier 1 securities begins.

The dependent variables 1 **minute, 5 minute, 10 minute,** and **30 minute** represent the sampling time interval of the principal component. The model fits the dependent variables to a generalized extreme value (GEV) distribution using maximum likelihood analysis. In the model, the location value of the GEV distribution varies with the explanatory variables.

Explanatory variables include: an indicator if the stock is the test group (**Test Stock**), an indicator if the test stock was operating under the LULD mechanism during the trading day (**LULD Active**), the daily CRSP value weighted market return (**MktReturn**), the daily volatility of the SPY etf (**SPY Volatility**), the opening value of the **VIX**, the natural log of the stock's average price during the previous month (**log(Price)**), the stock's average **Volatility** during the previous month (as defined in Appendix A), the natural log of the stock's average market capitalization (**Log(MktCap)**) during the previous month, the natural log of the stock's average dollar trading volume (**Log (Volume)**) during the previous trading month, the average percentage bid-ask spread (**BASpread**) during the previous month, and the average value of a stock's daily Amihud Illiquidity measure (**ILLQAmihud**) during the previous month. The regressions also include month fixed effects.

***, **, * indicate statistical significance at the 1, 5 and 10% levels. Standard errors of the regressions are clustered by date.

Variable	1 Minute	5 Minute	10 Minute	30 Minute
Test Stock	-0.0124***	-0.00864**	-0.00812	-0.00384
	(0.00308)	(0.00417)	(0.00508)	(0.00546)
LULD Active	-0.00519	-0.0153**	-0.0223***	-0.0342***
	(0.00434)	(0.00648)	(0.00783)	(0.00906)
MktReturn	0.432	0.516	0.574	0.322
	(0.419)	(0.678)	(0.821)	(0.907)
SPY Volatility	3.613***	5.846***	6.397***	5.652**
	(1.020)	(1.683)	(1.822)	(2.248)
VIX	0.0155***	0.0194***	0.0213***	0.0256***
	(0.00313)	(0.00501)	(0.00670)	(0.00735)
log(Price)	0.00109	-0.0221***	-0.0395***	-0.0543***
	(0.00224)	(0.00293)	(0.00317)	(0.00312)
Volatility	10.16***	14.45***	16.78***	17.94***
	(0.502)	(0.493)	(0.523)	(0.645)
Log(MktCap)	-0.0437***	-0.0319***	-0.0275***	-0.0361***
	(0.00654)	(0.00594)	(0.00710)	(0.00755)
Log (Volume)	-0.0133***	0.0266***	0.0420***	0.0596***
	(0.00418)	(0.00388)	(0.00456)	(0.00597)
BASpread	25.23***	35.30***	27.06***	18.46***
	(3.699)	(4.721)	(5.480)	(5.759)
ILLQAmihud	-3.005e+06***	-1.322e+06***	-1.145e+06***	-880,968***
	(606,742)	(243,213)	(278,000)	(262,435)
Constant	0.858***	0.106	-0.107	-0.184
	(0.0722)	(0.0923)	(0.121)	(0.120)
log(σ)	-1.765***	-1.421***	-1.211***	-0.983***
	(0.0122)	(0.0134)	(0.0125)	(0.0112)
ξ	0.167***	0.127***	0.117***	0.102***
	(0.00720)	(0.00692)	(0.00646)	(0.00569)
Month Dummies	Yes	Yes	Yes	Yes
N	67,850	67,845	67,836	67,466

Appendix A. Comparison of SSCB Pilot and LULD Plan Features

Feature	SSCB	LULD
How to calculate ***price bands***?	Under the SSCB regime, "trading in a stock would pause across U.S. equity markets for a rolling five-minute period in the event that the stock experiences a 10 percent change in price over the preceding five minutes". Nasdaq used the following example to illustrate how a trading pause is triggered on Nasdaq under the SSCB: "At 1:30 p.m., ET, the last sale eligible trades on the Consolidated Tape for a single security for the past five minutes were priced within the *range* of $10.00 and $9.50. At 1:30 p.m., if three last sale eligible trades[59] to the tape were 10% or more away from either of the two reference prices of $10.00 or $9.50, a trading pause will be triggered. - An eligible trade at or less than $9.00 [= $10.00 x (1 - 10%)] will trigger a trading pause. - An eligible trade at or greater than $10.45 [= $9.50 x (1 + 10%)] will trigger a trading pause. - In this example the range of the trading pause	Under the LULD regime, the Upper (Lower) Price Bands are computed by adjusting the Reference Price upward (downward) by a certain percentage of the Reference Price, where the Reference Price is the arithmetic mean price of eligible reported transaction over the *past five minutes*. The Reference Price is updated *only if* the Pro-Forma Reference Price[61] is at least 1% away in either direction from the current Reference Price. The initial Reference Price is the Opening Price of the Security. The Reference Price following a trading pause is

[59] If ***three*** prints in the prior five minutes deviate 10% or more from the last print and are **through the National Best Bid or Offer (NBBO)**, a trading pause is initiated by the primary listing market. If a last sale eligible execution is at or higher than the 10% threshold and is also **at or within the NBBO** within the five-minute period, NASDAQ will invoke a trading pause based on that ***single*** transaction. See Nasdaq - Single-Stock Circuit Breakers – FAQ.pdf at https://www.nasdaqtrader.com/content/productsservices/trading/tradingpausefaqs.pdf.

	triggers is [$9.00, $10.45]. [Reference: "Nasdaq - Single-Stock Circuit Breakers – FAQ.pdf"][60]	the price of the reopening auction.
Percentage Bands	Securities in the S&P 500, Russell 100, and high volume ETPs trigger a trading pause for price moves of 10% or more. For Phase III securities (i.e. all other NMS securities), the price move required to trigger a trading pause is 30% or more for securities priced at $1 or higher and 50% or more for securities priced less than $1.	For Tier 1 securities with a Reference Price more than $3.00, the price bands are 5% away from the reference price. For Tier 2 securities with a Reference Price more than $3.00, the price bands are 10% away from the reference price. For Tier 1 and Tier 2 securities whose previous day's closing price is between $0.75 and $3.00, price bands are 20% away from the reference price. For stocks priced less than $0.75, the price bands are the lesser of $0.15 or 75% away from the reference price. For leveraged ETPs the percentage parameter is multiplied by the leverage ratio of the product.

[61] The Pro-Forma Reference Price is average of the previous five-minute trade prices. See The Plan supra note 2.

[60] See id.

		The percentages are doubled from 9:30am to 9:45 am and from 3:35 pm to 4:00 pm.
Trading Pauses	A trading pause is triggered if a single last sale eligible execution is at or higher than the threshold and is also **at or within the NBBO** within the five-minute period. A trading pause is triggered if ***three*** transactions in the prior five minutes deviate 10% or more from the last print and are **through the National Best Bid or Offer (NBBO.**[62] One concern regarding the SSCB expressed by John Comerford, global head of trading research at Instinet is that "Circuit breakers are ***triggered frequently***, *and in most cases they are false positives*."[63] "Angel's report" suggests that the introduction of Limit State helps reduce the frequency of "false positive" trading halts.[64]	A Trading Pause is triggered by the primary listing exchange after a security is in a Limit State for 15 seconds. A Limit State occurs when the best quotes on one side of the market for an individual security are equal to the price band on the opposite side of the market (i.e., when the National Best Offer (NBO) is equal to the Lower Price Band or the National Best Bid (NBB) is equal to the Upper Price Band). A security can *exit* a Limit State if, within 15 seconds after entering a Limit State, all quotes are executed or canceled at the price band that triggered the Limit State.

[62] See supra note 22.

[63] See http://www.wallstreetandtech.com/compliance/is-the-end-of-single-stock-circuit-breakers-near/d/d-id/1266157

[64] Angel (2015) argues that: "One concern about the price bands is whether they exert an impact on liquidity such as a 'gravitational' pull that will trigger the trading pauses. Fortunately, this is not the case with LULD. Rather than exerting a gravitational pull, the price bands exhibit a magnetic repulsion. When a limit state is reached, it is almost immediately exited. As shown below in Table 5, most of the limit states (63.3%) naturally resolve themselves within one second without triggering trading pauses. Only 4.08% of the limit states resulted in trading pauses. It appears that many market participants react to a limit state by cancelling orders. They may be reluctant to trigger a trading pause, or may view the arrival of a limit state as news requiring the reevaluation of their trading strategy."

		The Limit State allows trading to continue for 15 seconds and quote prices to possibly revert to within the price bands before triggering a Trading Pause.
Re-opening process (i.e., Trade Resumption)	After a five minute Trading Pause, the primary listing exchange attempts to reopen trading using normal reopening procedure. If the trading center is unable to reopen trading, it can extend the Trading Pause by another five minutes. After a Trading Pause of at least ten minutes in the security, if the primary listing exchange has not reopened that security, any national securities exchange that trades that security may resume trading	After a five minute Trading Pause, the primary listing exchange attempts to reopen trading using normal reopening procedure. If the trading center is unable to reopen trading, it can extend the Trading Pause by another five minutes. After a Trading Pause of at least ten minutes in the security, if the primary listing exchange has not reopened that security, any national securities exchange that trades that security may resume trading.[65]
Event time	Phase I of the program (which began on June 11, 2010 [66]) included stocks in the S&P 500 Index and Phase II, effective Tuesday, September 14, 2010, included securities in the Russell 1000 Index and select Exchange-Traded Products. On August 8, 2011, the pilot was expanded to the remaining Reg NMS	Phase I implementation of the LULD Plan switched over Tier 1 securities to LULD from April 8, 2013 to May 31, 2013.

[65] See supra note 18 for changes made by Amendment 12 to the LULD Plan to the reopening process following a Trading Pause.

[66] See SEC's press release of the pilot program at http://www.sec.gov/news/press/2010/2010-98.htm. Please also refer to page 8 of Brogaard and Roshak (2016).

	securities (Phase III securities). Effective November 25, 2011, all rights and warrants were excluded from the Single Stock Trading Pause functionality. SSCB ceased operating of a security in 2013 when LULD was activated in its place.	Phase II.A of the implementation of the LULD Plan switched over Tier 2 securities to LULD from August 5, 2013 until September 3, 2013. Phase II.B of the implementation of the LULD Plan extended the price bands until the close of trading day. It was implemented across different exchanges over the period from September 3, 2013 to May 12, 2014. Refer to Section III.B for Implementation Schedule of LULD Plan.
Time of Day Active	SSCB is active from 9:45 am until 3:35 pm.	During Phase I, LULD price bands are active from 9:45 am until 3:35 pm. During Phase II.A, price bands were active from 9:30 am until 3:45 pm. After Phase II.B is complete, price bands are active for the whole trading day.

Appendix B. Data Sources, Sample Construction and Definitions of Control Variables

In this analysis, we use both SRO-provided data and publicly available data from the NYSE's Daily Trade and Quote (DTAQ) database, the Center for Research in Security Prices (CRSP) database, and Bloomberg. The DTAQ database provides intraday transaction and quotation data for all issues traded on NYSE, Nasdaq, and Regional exchanges. The DTAQ was used by Cornerstone Research to construct the measures of transitory price reversals (see the discussions in Appendix D). The CRSP data provides information on security characteristics as well as daily trading volume and prices. We use the CRSP data to identify whether a security is an ETF and also to construct control variables used in the analysis. We use SRO data on the occurrence of each individual Price Band, as described in Appendix B of the Plan, to identify when a security is phased into the LULD Plan and to classify securities into Tier 1 or Tier 2 during the LULD time period. We use data from Bloomberg to identify whether a security is included in the Russell 1000 or S&P 500. We use information from the website: http://etf.stock-encyclopedia.com/category/leveraged-etfs.html to identify leveraged ETFs.

To construct our sample, we include all NMS common stocks and ETFs present in CRSP between February 2009 and September 2016.[67] We eliminate securities with missing data in the aforementioned data sources. We also eliminate the leverage ETFs because they could have wider price bands.[68] We also exclude stock days where the previous or current trading day's closing price or midpoint is below $1.00.[69] We also exclude the day of the "Flash Crash" (May 6, 2010). We then use the methodology described in Appendix C of this paper to classify securities into Tier 1 securities (S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan) and Tier 2 securities (the remainder of NMS stocks). The sample for our difference in difference analysis consists of a subset of the common stocks from our larger sample.

[67] We identify securities in CRSP as common stocks if they have a CRSP share code value of 10 or 11. We identify securities in CRSP as ETFs if they have a CRSP share code value of 73. The sample does not include securities listed on the BATS exchange, because the CRSP database does not include securities. Most securities listed on BATS are ETPs. However, prior to the implementation of the LULD Plan there were few securities listed on BATS.

[68] We identify leveraged ETFs using the SRO price band data and information from the website: http://etf.stock-encyclopedia.com/category/leveraged-etfs.html

[69] Under the SSCB regime, the price range for Tier 2 securities to trigger a trading pause was 50% for securities priced below $1 and 30% for securities priced greater than or equal to $1. Additionally, under Rule 612 of Reg NMS, securities priced under $1.00 have a tick size of $0.0001, while securities priced greater than or equal to $1.00 have a tick size of $0.01.

Variables	Definition	Data Sources
Price	Closing price or the average of closing bid and ask price for a stock on a given date.	CRSP database
MktCap	The market capitalization, defined as *Price* times the number of shares outstanding.	CRSP database
Volume	Dollar trading volume of a stock on a given date. Defined as *Price* times CRSP daily shares traded.	CRSP database
Volatility	Stock price volatility of a stock on a given date, defined as (daily high price – daily low price) / closing price.	CRSP database
BAspread	Closing bid-ask spread (Chung and Zhang, 2014), defined as (closing ask price – closing bid price) / the midpoint of closing ask and bid prices.	CRSP database
ILLQAmihud	Illiquidity measure of Amihud (2002), defined as the absolute value of a stock's daily return divided by this stock's dollar trading volume on a given date.	CRSP database
StockReturn	Daily return of a stock on a given date.	CRSP database
MktReturn	Value-weighted market returns (VWRETD).	CRSP database
VIX	The daily opening Chicago Board Options Exchange (CBOE) volatility index, which is a measure of the *implied* volatility of S&P 500 index options.	CBOE website
SPYvolatility	The price volatility of SPY on a given date, defined as (daily high price – daily low price) / closing price. SPY is an ETF designed to track the S&P 500 stock market index.	CRSP database
Last	The Cornerstone price reversal metrics constructed using the last transaction price during each time interval. See Appendix C for details.	DTAQ database
Max to Min	The Cornerstone price reversal metrics constructed using the maximum, minimum, and maximum prices in three consecutive time intervals. See Appendix C for details.	DTAQ database

Min to Max	The Cornerstone price reversal metrics constructed using the minimum, maximum, and minimum prices in three consecutive time intervals. See Appendix C for details.	DTAQ database
VWAP	The Cornerstone price reversal metrics constructed using the volume-weighted average price during each time interval. See Appendix C for details.	DTAQ database
Raw 0.5%	The principal component for the frequency of price reversals that exceed a fixed threshold of 0.5%. See Appendix E for details.	DTAQ database
Raw 1.0%	The principal component for the frequency of price reversals that exceed a fixed threshold of 1.0%. See Appendix E for details.	DTAQ database
Raw 2.0%	The principal component for the frequency of price reversals that exceed a fixed threshold of 2.0%. See Appendix E for details.	DTAQ database
Raw 3.0%	The principal component for the frequency of price reversals that exceed a fixed threshold of 3.0%. See Appendix E for details.	DTAQ database
Raw 4.0%	The principal component for the frequency of price reversals that exceed a fixed threshold of 4.0%. See Appendix E for details.	DTAQ database
Raw 5.0%	The principal component for the frequency of price reversals that exceed a fixed threshold of 5.0%. See Appendix E for details.	DTAQ database
Ind 99%	The principal component for the frequency of price reversals that exceed the value of the 99th percentile of the distribution of an individual security's price reversal magnitudes. See Appendix E for details.	DTAQ database

Ind 99.9%	The principal component for the frequency of price reversals that exceed the value of the 99.9th percentile of the distribution of an individual security's price reversal magnitudes. See Appendix E for details.	DTAQ database
Ind 99.99%	The principal component for the frequency of price reversals that exceed the value of the 99.99th percentile of the distribution of an individual security's price reversal magnitudes. See Appendix E for details.	DTAQ database
Rolling 10 SD	The principal component for the frequency of price reversals that exceed a threshold of 10 times the 20 day moving average of the daily standard deviation of returns. See Appendix E for details.	DTAQ database
Rolling 25 SD	The principal component for the frequency of price reversals that exceed a threshold of 25 times the 20 day moving average of the daily standard deviation of returns. See Appendix E for details.	DTAQ database
1 Minute	The principal component for the magnitude of the maximum price reversal that occur each stock-day measured over 1 minute time intervals. See Appendix F for details.	DTAQ database
51 Minute	The principal component for the magnitude of the maximum price reversal that occur each stock-day measured over 5 minute time intervals. See Appendix F for details.	DTAQ database
10 Minute	The principal component for the magnitude of the maximum price reversal that occur each stock-day measured over 10 minute time intervals. See Appendix F for details.	DTAQ database
30 Minute	The principal component for the magnitude of the maximum price reversal that occur each stock-day measured over 30 minute time intervals. See Appendix F for details.	DTAQ database

Appendix C. The Classification of Tier 1 and Tier 2 Securities

We classify the NMS securities into Tier 1 and Tier 2 securities using different data sources for different time periods.

Before April 2013, the price band data are not available and thus we classify Tier 1 and Tier 2 securities based on the description in the LULD Plan For the sample prior to April 2013, we defined Tier 1 securities as those included in S&P 500, Russell 1000 Index, and some high volume ETPs as listed in the Plan. Specifically, we classify ETPs that have an average daily trading volume greater than $2,000,000 over the previous six months as Tier 1 securities. Tier 2 securities include the remainder of NMS stocks.

From April 2013 till now, we rely on the price band data to classify securities (with prices more than $3.00) into Tier 1 and Tier 2 and identify the implementation date of LULD for a specific security. We assume that the date on which a security's price band data are available is when the LULD plan was applied to this specific security. Therefore, by using the price-band data, we are able to identify whether the LULD had been implemented for a specific security on a given date.[70]

The following table presents the price-band percentage parameters according to NMS stock tiers and reference prices. It suggests that Tier 1 securities (with reference price greater than $3.00) have a percentage parameter at 5%, while Tier 2 securities (with reference price greater than $3.00) have a percentage parameter at 10%. This difference allows us to more accurately classify securities with reference price greater than $3.00 into Tier 1 and Tier 2 on a daily basis.

Tier	Reference Price	Percentage Parameter
Tier 1–S&P 500, Russell 1000 and selected ETPs	More than $3.00	5%
	$0.75 and up to and including $3.00	20%
	Less than $0.75	Lesser of $0.15 or 75%
Tier 2–All other NMS stocks (provided that all rights and warrants are excluded from the	More than $3.00	10%
	$0.75 and up to and including $3.00	20%

[70] We also verify the LULD phase-in dates identified by the price band data by comparing them with the phase-in dates listed on the SRO websites.

plan)	Less than $0.75	Lesser of $0.15 or 75%
	Leveraged ETP	Percentage above multiplied by the leverage ratio of the product

Using the price-band data, we are not able to classify securities with prices below $3.00 into Tier 1 and Tier 2 securities because their price-band percentage parameters are identical. For example, the price-band percentage parameter for both Tier 1 and Tier 2 securities with references prices above $0.75 and up to $3.00 is 20%. Therefore, we defined a security with a price *below or equal to $3.00* as a Tier 1 security if it is included in S&P 500 Index, Russell 1000 Index, or the LULD Plan's list of high volume ETPs. Tier 2 securities include the remainder of the NMS stocks with prices *below or equal to $3.00*.

Appendix D: Construction of Cornerstone Research Price Reversal Metrics

In order to measure transitory volatility that is not driven by fundamental-value changes, Cornerstone Research used DTAQ data to construct several metrics of short-term price reversals by measuring intraday returns based on transaction prices over different time intervals. Specifically, they construct the following four types of price reversal metrics separately over adjacent 1-minute, 5-minute, 10-minute, and 30-minute intervals: [71]

- price reversals based on last price;
- price reversals based on VWAP (volume-weighted average price);
- price reversals based on Max-Min-Max prices;
- price reversals based on Min-Max-Min prices.

Since LULD price bands were not in effect from 9:30AM-9:45AM and from 3:30PM-close for part of the sample, we only calculate reversal metrics using transactions that occur between 10AM-3:30PM.[72]

(i) Price Reversal Metric based on Last Price

This metric relies on prices from three discrete time points, i.e., the last price of the interval prior to the 1st interval (P_{t-2}), the last price of the 1st interval (P_{t-1}), and the last of price of the 2nd interval (P_t). Then, the following two consecutive returns are calculated: return from *t*-2 to *t*-1 relative to P_{t-2} and return from *t* -1 to *t* relative to P_{t-2}, where the same reference price P_{t-2} is used to ensure comparability. If no intraday trading occurs between two discrete points, the most recent observed price from that day is used for the purpose of calculating a return.

[71] There are a total of 16 different price reversals metrics, i.e. four types constructed for each time interval.

[72] By restricting the analysis to the time period between 10AM-3:30PM, we do not examine the full effect of the LULD Plan on extreme transitory volatility. Our analysis does not capture the effects of the LULD Plan on volatility at the beginning of the trading day, i.e. the period immediately following the opening, or at the end of the trading day during the time period preceding the close. The reason we exclude these time periods is that our analysis focuses on comparing the difference in the effects of the direct mechanisms of LULD and SSCB on transitory volatility. Since, the SSCB mechanism is only active from 9:45-3:35, we directly compare the mechanisms using trades from the beginning and end of the trading day.

A reversal is identified whenever two consecutive returns have opposite signs. The magnitude of the reversal is measured by the minimum of the absolute values of the two consecutive returns:

$$Reversal\_Last = \min(\text{abs}(R_{t-1}), \text{abs}(R_t)),$$

where $R_{t-1} = \frac{P_{t-1}-P_{t-2}}{P_{t-2}}$ and $R_t = \frac{P_t-P_{t-1}}{P_{t-2}}$. Figure D1 illustrates this metric.

(ii) Price Reversal Metric based on VWAP Price

The second metric relies on VWAP (volume-weighted average price) data over 3 consecutive time intervals, so that small trades with extreme prices do not have a disproportionate effect on the returns. That is,

$$VWAP_t = \frac{\sum_i (Q_i \times P_i)}{\sum_i Q_i} \text{ over all trades } i \text{ in the time interval [t, t+1),}$$

Where Q_i is the number of shares executed for trade i and P_i is the execution prices of trade i.

Using the VWAP prices during the three intervals, the following two returns are calculated: price change from $VWAP_{t-2}$ to $VWAP_{t-1}$ scaled by $VWAP_{t-2}$ and price change from $VWAP_{t-1}$ to $VWAP_t$ scaled by $VWAP_{t-2}$.

The magnitude of the reversal is measured by the minimum of the absolute values of the returns:

$$Reversal\_VWAP = \min(\text{abs}(R_{t-1}), \text{abs}(R_t)),$$

where $R_{t-1} = \frac{VWAP_{t-1}-VWAP_{t-2}}{VWAP_{t-2}}$ and $R_t = \frac{VWAP_t-VWAP_{t-1}}{VWAP_{t-2}}$. Figure D2 illustrates this metric.

(iii) Price Reversal Metrics based on Max-Min-Max Prices and Min-Max-Min-Prices

The third and fourth metric are designed to capture the largest possible reversals by computing returns using maximum and minimum prices within three adjacent time intervals. First, a maximum and minimum price is determined in each of three adjacent periods. We denote the lowest price and the highest price over interval [t, t+1) as Min_t and Max_t, respectively.

Then, returns are calculated using alternating maximum and minimum prices (i.e., Max−Min−Max or Min−Max−Min where each price is from a different time interval). Note that the maximum and minimum prices in each period represent three discrete points within respective time intervals, therefore they are usually not equally-spaced. The magnitude of Positive/Negative Reversals are presented below.

$$\textit{Reversal\_Min-Max-Min} = \min(-R_{t-1}, R_t),$$

where $R_{t-1} = \frac{Min_{t-1} - Max_{t-2}}{Max_{t-2}}$, $R_t = \frac{Max_t - Min_{t-1}}{Max_{t-2}}$, and Min_t and Max_t are defined above.

$$\textit{Reversal\_Max-Min-Max} = \min(-R_{t-1}, R_t),$$

where $R_{t-1} = \frac{Max_{t-1} - Min_{t-2}}{Min_{t-2}}$ and $R_t = \frac{Min_t - Max_{t-1}}{Min_{t-2}}$. Figure D3 illustrates how the Max-Min-Max metric is constructed.

Figure D1: Construction of Price Reversal Metric Based on Last Price in Interval

This figure was prepared by Cornerstone Research and shows an example of how the price reversal measure based on the last trade price in each interval (Last) is calculated. The example is based on trade price data taken from DTAQ for Costco Stock on 12/11/2013.

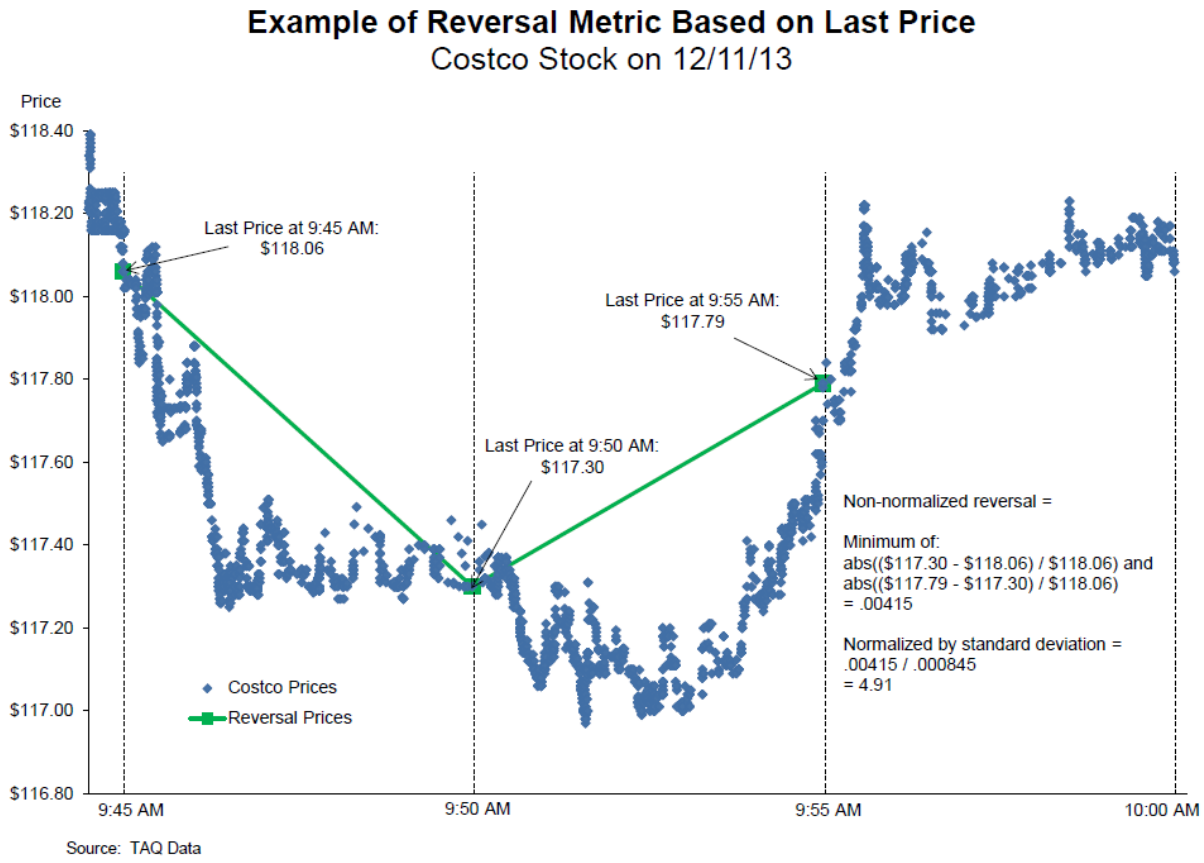


Figure D2: Construction of Price Reversal Metric Based on VWAP Price of Interval

This figure was prepared by Cornerstone Research and shows an example of how the price reversal measure based on volume weighted transaction price in each interval (VWAP) is calculated. The example is based on trade price data taken from DTAQ for Costco Stock on 12/11/2013.

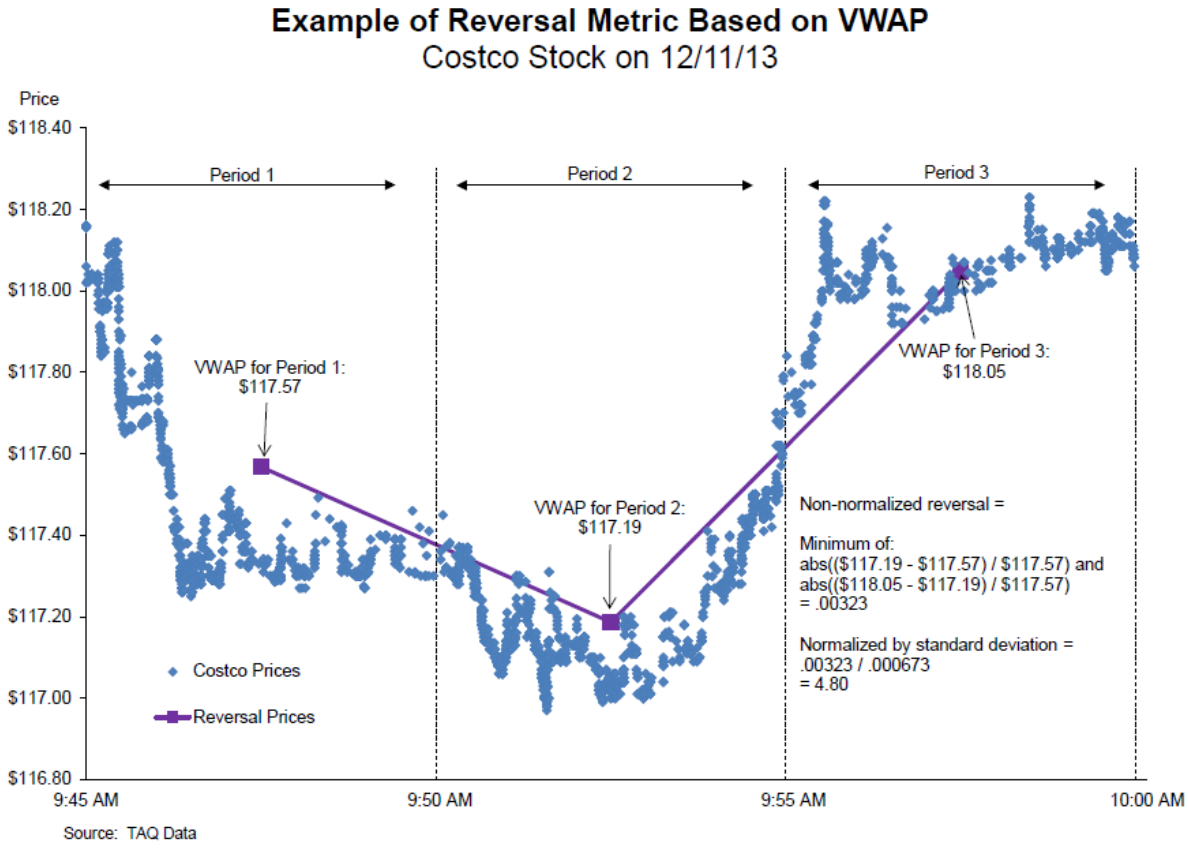
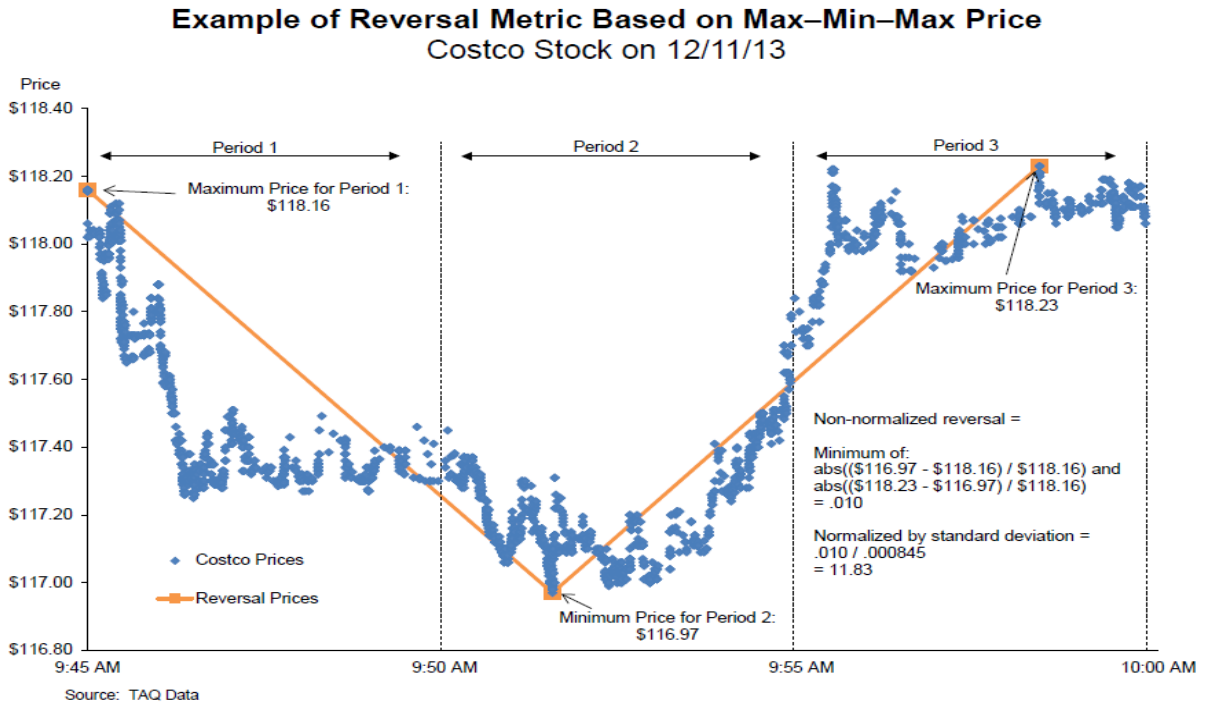


Figure D3: Construction of Price Reversal Metric Based on Max-Min-Max Prices

This figure was prepared by Cornerstone Research and shows an example of how the price reversal measure based on the Maximum-Minimum-Maximum transaction prices in three consecutive intervals (Max-Min-Max) is calculated. The example is based on trade price data taken from DTAQ for Costco Stock on 12/11/2013.



Appendix E: Construction of Principal Components for Frequency of Large Price Reversals

One useful technique for reducing the dimensionality of the data when there are a number of correlated variables is principal component analysis (PCA). PCA is a statistical procedure that linearly transforms a set of correlated variables into a set of orthogonal principal components, which are linear combinations of the original variables. Due to the nature of the transformation, the first principal component has the highest variance and explains the greatest portion of variability in the data. Each subsequent principal component is able to explain less of the variability in the data than the preceding principal component. Since PCA usually concentrates the majority of the information in the data in the first few principal components, it can be used as a dimensionality reduction technique by only keeping the first few components of the PCA. See Mardia, Kent, and Bibby (1979) for an in depth review of PCA.

Since there are 16 variables for each of the thresholds we selected, we reduce the dimensionality of the data using PCA to transform the 16 variables into one variable for each threshold that explains as much of the variance in the data as is possible by keeping the first principal component from the PCA. The principal component measures are used to examine how the frequency of large price reversals changes during different time periods.

Table E1 shows the results of the principal component analysis (PCA) that was performed for each of the stock-day reversal thresholds. Panel A shows the Eigenvalues of each of the principal components and Panel B shows the proportion of variation that each of the principal components explains. These are both measures of how much of the data each principal component explains. The results in Panel A show that the first principal components of the reversal thresholds all have eigenvalues more than three times as large as the second principal components. The results in Panel B show that first principal components of all the Raw reversal metrics explain over 50% of the variation in the data and over 39% of the variation in the data for both the thresholds based on a stock's Individual price reversal distribution and the thresholds based on the stock's normalized reversal distribution (Rolling SD).

Panel C presents the eigenvectors of the first principal components for each of the reversal thresholds. The value of the principal component is determined for each observation by standardizing all of the 16 price reversal variables and then multiplying the 16 standardized variables by their corresponding eigenvector and summing them up. The loadings in each of the eigenvectors in Panel C are all positive, which indicates that our first principal component is a weighted average of price reversal measures.

Table E1: Principal Component Analysis of Frequency of Reversals

This table presents the results of the principal component analysis that was performed for each of the stock-day reversal thresholds. The principal components are constructed from variables that measure the counts of the number of times that a stock-day experienced a price reversal that exceeded the threshold. A variable is constructed for each of the 16 different price reversal measures discussed in Appendix D (Last, Max to Min, Min to Max, and VWAP each measured over 1 minute, 5 minute, 10 minute, and 30 minute intervals). A principle component is formed from the linear combination of the 16 price reversal count variables. Appendix E describes the construction of the principal components. Panel A shows the Eigenvalues of each of the principal components. Panel B shows the proportion of variation that each of the principal components explains. Panel C shows the Eigenvectors of the first principal component of each of the reversal thresholds.

Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns.

Last denotes the price reversal metrics constructed using the last transaction price in an interval. **Max to Min** denotes the price reversal metrics constructed using the Maximum – Minimum – Maximum transaction prices in three consecutive time intervals. **Min to Max** denotes the price reversal metrics constructed using the Minimum – Maximum - Minimum prices in three consecutive intervals. **VWAP** denotes the price reversal metrics constructed using the volume weighted average transaction price for a time interval.

Panel A: Eigenvalues

Principal Component	Raw 0.5%	Raw 1%	Raw 2%	Raw 3%	Raw 4%	Raw 5%	Ind 99%	Ind 99.9%	Ind 99.99%	Rolling 10 SD	Rolling 25 SD
1	10.135	9.992	9.820	9.635	9.440	9.260	9.782	7.841	5.703	6.665	6.776
2	1.818	2.025	1.905	1.916	1.939	1.939	1.337	1.354	1.425	1.909	2.018
3	1.577	1.242	1.209	1.153	1.131	1.130	0.797	0.905	1.236	1.607	1.340
4	0.617	0.591	0.616	0.593	0.570	0.602	0.682	0.824	0.970	1.115	1.073
5	0.444	0.472	0.496	0.526	0.548	0.580	0.602	0.781	0.944	0.879	0.989
6	0.355	0.402	0.441	0.468	0.502	0.546	0.479	0.730	0.880	0.640	0.647
7	0.298	0.288	0.297	0.397	0.480	0.477	0.418	0.646	0.703	0.625	0.578
8	0.223	0.236	0.281	0.302	0.304	0.306	0.410	0.542	0.606	0.542	0.517
9	0.165	0.179	0.226	0.225	0.232	0.239	0.344	0.477	0.585	0.431	0.390
10	0.128	0.155	0.194	0.194	0.208	0.236	0.319	0.449	0.581	0.368	0.362
11	0.067	0.131	0.135	0.175	0.190	0.191	0.254	0.340	0.558	0.317	0.305
12	0.055	0.086	0.129	0.130	0.132	0.134	0.164	0.334	0.504	0.272	0.244
13	0.043	0.070	0.082	0.086	0.099	0.118	0.160	0.285	0.411	0.189	0.233
14	0.041	0.060	0.069	0.081	0.088	0.092	0.142	0.212	0.349	0.173	0.220
15	0.020	0.043	0.061	0.073	0.078	0.083	0.079	0.187	0.307	0.148	0.170
16	0.013	0.028	0.038	0.049	0.058	0.068	0.030	0.094	0.239	0.119	0.140

Panel B: Proportion of Variation Explained

Principal Component	Raw 0.5%	Raw 1%	Raw 2%	Raw 3%	Raw 4%	Raw 5%	Ind 99%	Ind 99.9%	Ind 99.99%	Rolling 10 SD	Rolling 25 SD
1	63.35%	62.45%	61.38%	60.22%	59.00%	57.87%	61.14%	49.00%	35.65%	41.65%	42.35%
2	11.36%	12.66%	11.91%	11.97%	12.12%	12.12%	8.36%	8.46%	8.91%	11.93%	12.61%
3	9.86%	7.76%	7.56%	7.20%	7.07%	7.06%	4.98%	5.66%	7.72%	10.04%	8.37%
4	3.85%	3.69%	3.85%	3.71%	3.56%	3.76%	4.26%	5.15%	6.06%	6.97%	6.71%
5	2.78%	2.95%	3.10%	3.29%	3.42%	3.62%	3.76%	4.88%	5.90%	5.49%	6.18%
6	2.22%	2.51%	2.75%	2.92%	3.14%	3.41%	2.99%	4.56%	5.50%	4.00%	4.04%
7	1.86%	1.80%	1.86%	2.48%	3.00%	2.98%	2.61%	4.04%	4.40%	3.91%	3.61%
8	1.39%	1.48%	1.76%	1.89%	1.90%	1.91%	2.57%	3.39%	3.79%	3.39%	3.23%
9	1.03%	1.12%	1.42%	1.40%	1.45%	1.49%	2.15%	2.98%	3.66%	2.70%	2.44%
10	0.80%	0.97%	1.21%	1.21%	1.30%	1.48%	1.99%	2.80%	3.63%	2.30%	2.26%
11	0.42%	0.82%	0.85%	1.09%	1.19%	1.19%	1.59%	2.12%	3.49%	1.98%	1.90%
12	0.34%	0.54%	0.81%	0.81%	0.83%	0.84%	1.02%	2.09%	3.15%	1.70%	1.53%
13	0.27%	0.44%	0.51%	0.53%	0.62%	0.73%	1.00%	1.78%	2.57%	1.18%	1.46%
14	0.25%	0.37%	0.43%	0.50%	0.55%	0.57%	0.89%	1.32%	2.18%	1.08%	1.37%
15	0.13%	0.27%	0.38%	0.46%	0.49%	0.52%	0.49%	1.17%	1.92%	0.93%	1.06%
16	0.08%	0.18%	0.24%	0.30%	0.37%	0.43%	0.19%	0.59%	1.49%	0.74%	0.88%

Panel C: Eigenvectors of 1st Principal Components

Measure	Raw 0.5%	Raw 1%	Raw 2%	Raw 3%	Raw 4%	Raw 5%	Ind 99%	Ind 99.9%	Ind 99.99%	Rolling 10 SD	Rolling 25 SD
Last 1 min	0.263	0.265	0.266	0.265	0.267	0.268	0.266	0.272	0.274	0.238	0.230
Last 5 min	0.275	0.271	0.270	0.269	0.270	0.272	0.256	0.249	0.257	0.249	0.246
Last 10 min	0.265	0.262	0.259	0.259	0.259	0.260	0.229	0.216	0.226	0.230	0.232
Last 30 min	0.212	0.210	0.208	0.207	0.208	0.209	0.162	0.150	0.151	0.145	0.154
VWAP 1 min	0.243	0.245	0.248	0.250	0.253	0.257	0.259	0.258	0.257	0.228	0.228
VWAP 5 min	0.231	0.244	0.246	0.248	0.250	0.253	0.248	0.238	0.242	0.229	0.248
VWAP 10 min	0.223	0.236	0.236	0.236	0.237	0.240	0.215	0.200	0.201	0.210	0.237
VWAP 30 min	0.183	0.193	0.190	0.189	0.189	0.189	0.147	0.135	0.129	0.142	0.162
Max to Min 1 min	0.237	0.256	0.265	0.271	0.273	0.274	0.269	0.297	0.311	0.302	0.274
Max to Min 5 min	0.287	0.282	0.280	0.279	0.278	0.277	0.293	0.306	0.310	0.310	0.304
Max to Min 10 min	0.279	0.269	0.269	0.267	0.265	0.262	0.283	0.281	0.280	0.284	0.298
Max to Min 30 min	0.237	0.223	0.219	0.218	0.217	0.214	0.235	0.216	0.197	0.220	0.250
Min to Max 1 min	0.237	0.254	0.263	0.267	0.270	0.270	0.269	0.298	0.310	0.303	0.273
Min to Max 5 min	0.286	0.281	0.278	0.275	0.272	0.269	0.293	0.305	0.301	0.313	0.296
Min to Max 10 min	0.279	0.267	0.266	0.262	0.258	0.253	0.284	0.282	0.269	0.290	0.290
Min to Max 30 min	0.237	0.222	0.216	0.215	0.213	0.208	0.238	0.212	0.184	0.221	0.220

Appendix F: Construction of Principal Components for Magnitude of Maximum Stock-Day Price Reversals

According to the Extreme Value Theory discussed in Coles (2001), if we repeatedly sample the maximum value from a block of independent and identically distributed observations, the sample of maximum values will fit a Generalized Extreme Value (GEV) distribution. We use this information to examine how the LULD Plan affects the distribution of the magnitude of a stock's maximum price reversal each day. Specifically, for each stock-day we determine the magnitude of the maximum reversal that a stock experiences for each of its 16 different price reversal measures.

Using the principal component methodology outlined in Appendix E, we construct principle component measures for each of the time intervals (1 minute, 5 minutes, 10 minutes, and 30 minutes) using the maximum values observed for each of the reversal measures (Last, VWAP, Max-to-Min, and Min-to-Max). We reduce the dimensionality of the data using PCA to transform the 4 variables into one variable for each time interval that explains as much of variance in the data as is possible by keeping the first principal component from the PCA.

Table F1 shows the results of the principal component analysis for the magnitude of the maximum daily reversals. Panel A shows the eigenvalues of each principal component and Panel B shows the proportion of variation that each principal component explains. The first principal components explain a great percentage of variation the longer the time intervals are. The 5 minute, 10 minute, and 30 minute interval principal components explain over 50% of the variation, while the 1 minute principal component explains 49% of the variation.

Panel C of Table F1 shows the eigenvector loadings of the first principal components for each of the intervals. The eigenvector components are all positive, which indicates that the first principal component for each interval is a weighted average of the maximum daily reversals of each of the four price reversal measures.

Table F1: Principal Component Analysis for Magnitude of Maximum Stock-Day Price Reversals

This table presents the results of the principal component analysis performed on the maximum values of the price reversal metrics. A principal component analysis is performed for each sampling interval (1 minute, 5 minute, 10 minute, and 30 minute intervals). A principle component is formed from the linear combination of variables that measure the maximum value of each of the price reversals measures discussed in Section IV.A (Last, Max to Min, Min to Max, and VWAP) each stock-day. Appendix F describes the construction of the principal components. Panel A shows the Eigenvalues of each of the principal components. Panel B shows the proportion of variation that each of the principal components explains. Panel C shows the Eigenvectors of the first principal component of each of the time intervals.

1 minute, 5 minute, 10 minute, and **30 minute** represent the sampling time interval. **Last** denotes the price reversal metrics constructed using the last transaction price in an interval. **Max to Min** denotes the price reversal metrics constructed using the Maximum – Minimum – Maximum transaction prices in three consecutive time intervals. **Min to Max** denotes the price reversal metrics constructed using the Minimum – Maximum - Minimum prices in three consecutive intervals. **VWAP** denotes the price reversal metrics constructed using the volume weighted average transaction price for a time interval.

Panel A: Eigenvalues

Principal Component	1 Minute	5 Minute	10 Minute	30 Minute
1	3.666	3.500	3.371	3.133
2	0.162	0.199	0.259	0.343
3	0.102	0.187	0.212	0.278
4	0.070	0.114	0.159	0.247

Panel B: Proportion of Variation Explained

Principal Component	1 Minute	5 Minute	10 Minute	30 Minute
1	91.66%	87.51%	84.27%	78.32%
2	4.04%	4.97%	6.47%	8.58%
3	2.54%	4.69%	5.29%	6.94%
4	1.76%	2.84%	3.97%	6.17%

Panel C: Eigenvectors of 1st Principal Components

Measure	1 Minute	5 Minute	10 Minute	30 Minute
Last	0.506	0.507	0.506	0.497
VWAP	0.506	0.505	0.503	0.498
Max to Min	0.494	0.495	0.497	0.503
Min to Max	0.493	0.493	0.495	0.502

Appendix G: Matched Sample Difference in Difference Analysis

In addition to performing the difference in difference analysis when the control stocks are the 200 Tier 2 common stocks with the largest market capitalizations, we also perform the analysis when we match stocks in the test group to Tier 2 common stocks based on a number of characteristics.

More specifically, for each stock in the 200 test stocks we compute a distance measure between that stock and all Tier 2 common stocks that did not get included in the Russell 1000 index reconstitution on June 28, 2013. The distance measure is calculated using the formula:

$$\sum_{i=1}^{N}\left[\frac{(X_{it}-X_{ic})}{(\frac{X_{it}}{2}+\frac{X_{ic}}{2})}\right]^2$$

Where $X_{it}$and X_{ic} are the *i*th characteristic of the test stock and the Tier 2 common stock it is being compared to. The stock characteristics used to calculate the distance measure are: the market capitalization on the last trading day of March 2013 (***MktCap***), the stock's average dollar trading volume during March 2013 (***Volume***), the stock's average daily volatility during March 2013 (***Volatility)***, the stock's average daily closing price during March 2013 (***Price***), and a stock's average percentage bid-ask spread during March 2013 (***BASpread***).

For each test stock, we pick, with replacement, the matching Tier 2 stock with the shortest distance to serve as our corresponding control stock.

Table G1 reports the average differences between the characteristics of the matched test and control stocks. Compared to the difference in difference sample used in Section VI.B of the study, the matched sample stocks are more similar, with the average differences between all of the characteristics being smaller.

Tables G2 and G3 repeat the difference in difference analysis from Section VI.B for the matched sample. The overall results are similar to the results in Section VI.B, but the coefficients on the LULD Active variable in Table G3 are also negative and significant for the Raw 3% and Raw 4% thresholds, which indicates the LULD plan reduces the frequency of extreme volatility for larger thresholds for the matched sample than for the sample analyzed in Section VI.B.

Table G1: Characteristics of Difference in Difference Matched Sample

This table compares the average characteristics of the test and control groups in the difference in difference matched sample. The **Test** group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The **Control** group is created by selecting, with replacement, for each test stock, the matching Tier 2 stock with the shortest distance measure calculated using the methodology detailed in Appendix G to serve as the corresponding control stock.

MktCap is the market capitalization on the last trading day of March 2013. ***Volume*** is a stock's average dollar trading volume during March 2013. ***Volatility*** is a stock's average daily volatility during March 2013, as defined in Appendix B. ***Price*** is a stock's average daily closing price during March 2013. ***BASpread*** is a stock's average percentage bid-ask spread during March 2013, as defined in Appendix B. Average values for each stock are calculated using daily data from March 2013. The table presents the cross-sectional mean of average stock values. **Difference** is the average difference between the **Control** and **Test** groups **(Control – Test)**. ***, **, and * indicate that paired t-test between the Control and Test groups is statistically significant at the 1, 5 and 10% levels.

Characteristic	Control	Test	Difference
Market Cap	2,230,292	2,447,373	217,081***
Dollar Trading Volume	27,826,843	29,490,284	1,663,441
Volatility	2.36%	2.33%	-0.022%
Price	34.77	37.16	2.40*
Percentage Spread	0.061%	0.066%	00.005%***
N	200	200	

Table G2: Test of Differences of Reversal Principal Components for Difference in Difference Matched Sample

This table compares the average values of the frequency of large reversal principal component measures for the test and control stocks in the difference in difference matched sample during this time period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013. The test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1 The **Control** group is created by selecting, with replacement, for each test stock, the matching Tier 2 stock with the shortest distance measure calculated using the methodology detailed in Appendix G to serve as the corresponding control stock.

The SSCB period for test stocks is days that they operate under the SSCB mechanism and the LULD period is days that they operate under the LULD mechanism. The SSCB period for control stocks is days when the matched test stock operates under the SSCB method and the LULD period for control stocks is days when the matched test stock operates under the LULD mechanism. Diff Test and Diff Control are the average values during the LULD period minus average values during the SSCB period. Test Diff – Control Diff represents the average treatment effect and is equal to Diff Test minus Diff Control. Tobit Parameter and Tobit SE are estimated from a censored tobit regression and are the parameter value and standard error of an indicator variable that is equal to 1 if a test stock is operating under the LULD mechanism. The tobit regression also includes month fixed effects. The standard errors of the regression are clustered by date.

Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to principal components with thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns.

***, **, * indicate statistical significance at the 1, 5 and 10% levels.

Measure	Control SSCB	Control LULD	Test SSCB	Test LULD	Diff Test	Diff Control	Test Diff – Control Diff	Tobit Parameter	Tobit SE
Raw 0.5%	1.1380	1.0994	1.0987	0.9826	-0.1161	-0.0386	-0.0776	-0.347***	(0.0576)
Raw 1.0%	0.3368	0.3051	0.3535	0.2990	-0.0545	-0.0318	-0.0227	-0.217***	(0.0408)
Raw 2.0%	0.0601	0.0471	0.0832	0.0663	-0.0168	-0.0130	-0.0038	-0.0834***	(0.0243)
Raw 3.0%	0.0186	0.0157	0.0334	0.0260	-0.0074	-0.0030	-0.0045	-0.0510***	(0.0149)
Raw 4.0%	0.0090	0.0058	0.0166	0.0133	-0.0033	-0.0032	-0.0001	-0.0321***	(0.0114)
Raw 5.0%	0.0051	0.0029	0.0088	0.0064	-0.0023	-0.0022	-0.0001	-0.0188	(0.0259)
Ind 99%	0.4231	0.4299	0.6579	0.6172	-0.0407	0.0068	-0.0475	-0.178**	(0.0736)
Ind 99.9%	0.1744	0.1437	0.3087	0.2815	-0.0272	-0.0307	0.0035	-0.0941	(0.0712)
Ind 99.99%	0.0926	0.0908	0.1666	0.1646	-0.0020	-0.0018	-0.0002	-0.123*	(0.0724)
Rolling 10 SD	0.1135	0.1025	0.1536	0.1488	-0.0048	-0.0110	0.0062	-0.0370	(0.0479)
Rolling 25 SD	0.0092	0.0247	0.0252	0.0239	-0.0013	0.0155	-0.0168	-0.0500	(0.0590)
N	22,418	11,635	22,418	11,635					

Table G3: Difference in Difference Matched Sample Reversal Principal Component Tobit Regressions

This table presents regression results from censored tobit panel regressions on the difference in frequency of large reversal principal component measures between the test and matched control stocks in the difference in difference matched sample during this time period from November 26, 2012 until August 2, 2013, including during LULD phase-in for Tier 1 securities from April 8, 2013 through June 3, 2013. The test group consists of 25 stocks that switch from Tier 1 to Tier 2 and 25 stocks that switch from Tier 2 to Tier 1 when the Russell 1000 index is reconstituted on June 28, 2013, plus an additional 150 common stocks with the smallest market capitalizations that remain in Tier 1. The control group is created by selecting, with replacement, for each test stock, the matching Tier 2 stock with the shortest distance measure calculated using the methodology detailed in Appendix G to serve as the corresponding control stock.

The dependent variables Raw 0.5%, Raw 1%, Raw 2%, Raw 3%, Raw 4%, and Raw 5% correspond to principal components with thresholds where the magnitude of the reversal exceed 0.5%, 1%, etc. Ind 99%, Ind 99.9%, and Ind 99.99% correspond to thresholds where the reversal exceeds the value of the 99^{th}, 99.9^{th}, and 99.99^{th} percentiles of each stock's reversal distribution measured over the entire sample period. Rolling 10 SD and Rolling 25 SD correspond to thresholds where the price reversal exceeds 10 and 25 times the 20 day moving average of the daily standard deviation of returns. The dependent variables are the stock-day difference between the matched sample test and control stocks for the corresponding principal components.

Explanatory variables include: an indicator if the test stock was operating under the LULD mechanism during the trading day (**LULD Active**), the daily CRSP value weighted market return (**MktReturn**), the daily volatility of the SPY etf (**SPY Volatility**), and the opening value of the **VIX**. Other control variables are the difference between the test and control stocks values for the following variables: the natural log of the stock's average price during the previous month (**log(Price)**), the stock's average **Volatility** during the previous month (as defined in Appendix A), the natural log of the stock's average market capitalization (**Log(MktCap)**) during the previous month, the natural log of the stock's average dollar trading volume (**Log (Volume)**) during the previous trading month, the average percentage bid-ask spread (**BASpread**) during the previous month, and the average value of a stock's daily Amihud Illiquidity measure (**ILLQAmihud**) during the previous month. The regressions also include month fixed effects.

***, **, * indicate statistical significance at the 1, 5 and 10% levels. Standard errors of the regressions are clustered by date.

Variable	Raw 0.5%	Raw 1.0%	Raw 2.0%	Raw 3.0%	Raw 4.0%	Raw 5.0%	Ind 99%	Ind 99.9%	Ind 99.99%	Rolling 10 SD	Rolling 25 SD
LULD Active	-0.221***	-0.150***	-0.0625***	-0.0419***	-0.0270**	-0.0160	-0.146**	-0.0847	-0.120*	-0.0430	-0.0499
	(0.0506)	(0.0374)	(0.0234)	(0.0154)	(0.0110)	(0.0258)	(0.0729)	(0.0695)	(0.0710)	(0.0485)	(0.0594)
MktReturn	1.144	1.053	0.895	0.596	0.344	0.0473	3.627	4.522**	4.971**	3.379	0.602
	(1.743)	(1.152)	(0.641)	(0.372)	(0.295)	(0.301)	(2.408)	(2.109)	(2.330)	(2.528)	(0.764)
SPY Volatility	-7.813**	-3.735	-0.245	-0.267	-0.0409	-0.635	-1.382	-0.277	0.303	-2.387	-2.060
	(3.838)	(2.500)	(1.250)	(1.498)	(0.623)	(0.676)	(5.052)	(3.688)	(4.616)	(4.629)	(1.878)
VIX	-0.0239**	-0.00979	-0.000873	0.00147	0.000179	0.00169	0.000287	0.00300	0.00853	-0.00389	0.00592
	(0.0110)	(0.00673)	(0.00349)	(0.00304)	(0.00188)	(0.00151)	(0.0166)	(0.0128)	(0.0141)	(0.0146)	(0.00428)
log(Price)	-0.153***	0.000161	0.0435**	0.0376**	0.0243**	0.0180*	-0.00463	0.0303	0.0129	0.0692	0.0203
	(0.0472)	(0.0356)	(0.0194)	(0.0187)	(0.00953)	(0.0109)	(0.0618)	(0.0638)	(0.0612)	(0.0597)	(0.0356)
Volatility	78.18***	42.44***	13.50***	5.773***	3.082***	1.601***	22.96***	8.038***	3.478	-1.867	0.652
	(2.698)	(2.352)	(1.225)	(1.062)	(0.508)	(0.291)	(3.006)	(2.561)	(2.187)	(2.230)	(0.769)
Log(MktCap)	0.0371	-0.0357	-0.0507***	-0.0348***	-0.0192**	-0.0137	0.108	0.0659	-0.0243	0.00246	-0.0281
	(0.0560)	(0.0380)	(0.0190)	(0.0130)	(0.00881)	(0.0138)	(0.0690)	(0.0661)	(0.0788)	(0.0642)	(0.0439)
Log (Volume)	-0.183***	-0.118***	-0.0463***	-0.0203**	-0.0117***	-0.00319	-0.167***	-0.0913***	-0.0121	-0.0187	0.00333
	(0.0254)	(0.0170)	(0.00905)	(0.00899)	(0.00364)	(0.00285)	(0.0367)	(0.0339)	(0.0342)	(0.0292)	(0.0104)
BASpread	148.7***	43.97*	-21.00	-16.91	-20.45***	-9.422**	52.52	-18.98	-2.304	-12.98	-4.436
	(31.08)	(24.12)	(18.35)	(36.75)	(6.240)	(4.125)	(37.35)	(34.60)	(36.70)	(28.18)	(8.754)
ILLQAmihud	-6.017e+06***	-7.120e+06***	-3.741e+06***	-392,272	-66,136	441,648	-5.543e+06**	-6.854e+06*	-1.640e+06	378,293	71,472
	(1.942e+06)	(1.023e+06)	(1.445e+06)	(1.703e+06)	(1.208e+06)	(413,437)	(2.729e+06)	(4.060e+06)	(2.836e+06)	(585,947)	(127,819)
Constant	0.351**	0.198**	0.0487	0.00120	0.00642	-0.0151	0.235	0.0958	-0.00612	0.133	-0.0570
	(0.143)	(0.0890)	(0.0469)	(0.0356)	(0.0250)	(0.0192)	(0.208)	(0.165)	(0.172)	(0.176)	(0.0505)
Month Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	33,935	33,935	33,935	33,935	33,935	33,935	33,935	33,935	33,935	33,935	33,935
Pseudo-R2	0.0446	0.0299	0.0179	0.0107	0.0109	-13.49	0.00131	0.000546	0.000226	0.000252	0.000289