MEMORANDUM

TO: FILE

FROM: DIVISION OF ECONOMIC AND RISK ANALYSIS ("DERA")[1]

SUBJECT: CORNERSTONE ANALYSIS OF LONG-LASTING STRADDLE STATES

DATE: December 2017

The Division of Economic and Risk Analysis ("DERA") contracted with Cornerstone Research ("Cornerstone"), an economic and financial consulting firm, to conduct analyses related to investigating the occurrence of long-lasting "Straddle States" under the Limit Up-Limit Down ("LULD") National Market System ("NMS") Plan (the "LULD Plan" or "Plan").[2,3] Under the LULD Plan, a Straddle State occurs when the National Best Bid (Offer) is below (above) the lower (upper) Price Band and the NMS Stock is not in a Limit State. A Straddle State restricts trading from occurring on the side of the quote that is outside the Price Bands.[4] The Cornerstone analysis defines a long-lasting Straddle State as a Straddle State that lasts at least 5 minutes.[5]

The Cornerstone analysis was commissioned by DERA as a result of the Notice of Filing of the Twelfth Amendment to the LULD Plan, in which the Participants proposed eliminating the definition of Straddle State from the Plan and the ability of a Primary Listing Exchange to declare a Trading Pause while a security was in a Straddle State.[6,7] In the Notice of Filing of the

[1] This is a memo by the Staff of the Division of Economic and Risk Analysis of the U.S. Securities and Exchange Commission. The Commission has expressed no view regarding the analysis, findings or conclusions contained herein.

[2] See Order Approving, on a Pilot Basis, the National Market System Plan to Address Extraordinary Market Volatility 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. (altogether, the "Participants") ("Approval Order"), Release No. 34-67091 (May 31, 2012), 77 FR 33498 (June 6, 2012) (File No. 4-631). The original text of the Plan is attached to the Approval Order as Exhibit A ("The Plan"). Subsequent amendments are available at https://www.sec.gov/rules/sro/nms.htm.

[3] Capitalized terms used herein but not otherwise defined shall have the meaning ascribed to such terms in the Plan.

[4] See supra note 2.

[5] In some of the analysis, Cornerstone alternatively defines a long-lasting Straddle State as a Straddle State lasting at least 30 minutes.

[6] See Notice of Filing of the Twelfth Amendment to the National Market System Plan to Address Extraordinary Market Volatility 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.,

Twelfth Amendment, the Commission noted that Commission staff had conducted an analysis of Straddle States under the Plan over the period from May 12, 2014 to August 29, 2014.[8] The staff analysis found that 2,073,497 Straddle States occurred in Tier 2 securities over this time period and the vast majority of Straddle States lasted less than five minutes. However, more than 4,000 Straddle States lasted between five and 30 minutes, and more than 4,000 Straddle States lasted longer than 30 minutes.[9] Unlike Limit States, which can last up to 15 seconds, Straddle States can last indefinitely, unless the Primary Listing Exchange declares a Trading Pause in accordance to its policies and procedures pursuant to Section VII(A)(2) of the Plan.[10] This means that there may be a long period of time during which one or both quotes are non-executable (i.e. cannot be traded against).

The Cornerstone analysis is meant to provide further details on these long-lasting Straddle States, which could help inform future changes to the Plan. In particular, the Cornerstone analysis investigates the frequency of occurrence of long-lasting Straddle States, factors that influence the occurrence of long-lasting Straddle States, market activity during and after long-lasting Straddle States, and the impact of the Tenth Amendment of the LULD Plan on the occurrence of long-lasting Straddle States and Trading Pauses.[11]

New York Stock Exchange LLC, NYSE MKT LLC, and NYSE Arca, Inc. ("Twelfth Amendment Notice of Filing"), "), Release No. 34-79410 (November 28, 2016).

[7] On January 17, 2017, the Participants submitted a letter to the Commission related to the Twelfth Amendment to the LULD Plan, which requested that the Commission modify the Twelfth Amendment to retain provisions in the Plan related to Straddle States. The modified version of Amendment 12 was approved on January 19, 2017. See Securities Exchange Act Release No. 79845 (January 19, 2017).

[8] See supra note 6.

[9] The results and additional analysis concerning Straddle States are also presented in the DERA White Paper entitled "Limit Up-Limit Down Pilot Plan and Associated Events" by Claudia Moise and Paca Flaherty (2017). Available at https://www.sec.gov/files/dera-luld-white-paper.pdf.

[10] However, in the Notice of Filing of the Twelfth Amendment it states that there have not been any Trading Pauses declared following a Straddle State. See supra note 6.

[11] Amendment 10 revised the methodology for determining the initial Reference Price when there is not trading volume in the opening auction. The new methodology uses the closing price of the NMS Stock on the primary listing exchange on the previous trading day, or if no such closing price exists, the last sale on the primary listing exchange, as the initial Reference Price, instead of the midpoint of the opening auction. The changes in Amendment 10 were made based on analysis The Participants presented in a Transmittal Letter and in The Supplemental Joint Assessment that showed using the midpoint of the opening bid and ask when no trading occurred in the opening auction often resulted in what the Participants believe was a skewed initial Reference Price. The Participant's analysis also showed that most Trading Halts occurred in securities that did not have a trade in the opening auction. Amendment 10 was implemented on July 18, 2016. *See* Plan to Address Extraordinary Market Volatility as amended by SEC Approval Order: Rel. No. 34-77679 (Amendment 10), available at https://www.sec.gov/rules/sro/nms/2016/34-77679.pdf. Also *see* Limit Up – Limit Down: National Market System Plan Assessment To Address Extraordinary Market Volatility (the "Supplemental Joint Assessment" or "Assessment"), available at https://www.sec.gov/comments/4-631/4631-39.pdf , and see Letter from Paul Roland,

Overall, the Cornerstone analysis finds that between August 1, 2014 and December 31, 2016, on average, over 140 long-lasting Straddle States occurred each day. It also finds that they are more likely to occur in securities with lower trading volume, higher volatility, and smaller market capitalizations and on days when no trade occurs during the opening. DERA believes that the methodology employed by Cornerstone in the analysis is appropriate to address the questions presented and agrees with the conclusions drawn by Cornerstone based on that analysis. Below, we summarize the main findings presented in the Cornerstone analysis.

Overview of Analysis:

The Cornerstone analysis examines a sample of U.S. stocks and exchange traded products during the period from August 1, 2014 to December 31, 2016 (609 trading days).[12] The analysis focuses on long-lasting Straddle States, which the analysis defines as Straddle States lasting at least 5 minutes.[13] Below, we summarize the main findings from the Cornerstone Analysis regarding the frequency of occurrence of long-lasting Straddle States, factors that influence the occurrence of long-lasting Straddle States, market activity during and after the occurrence of long-lasting Straddle States, and the impact of Tenth Amendment of the LULD Plan on the occurrence of long-lasting Straddle States and Trading Halts

1. Frequency of Occurrence of Long-Lasting Straddle States

The Cornerstone analysis examines how frequently long-lasting Straddle States occur. It finds that, each day, an average of 84 symbols experience 141 long-lasting Straddle States, which is five times more frequent than the rate at which Moise and Flaherty (2017) estimate Trading Pauses occur.[14,15] However, the analysis finds that this represents a small percentage of Straddle States, with over 98% of Straddle States lasting less than 5 minutes.

The analysis examines how frequently long-lasting Straddle States reoccur within the same trading day and finds that the majority of symbols experience only one long-lasting Straddle State during the same trading day.[16]

Principal, U.S. Equities, Nasdaq, to Brent Fields, Secretary, Commission, dated February 18, 2016. ("Transmittal Letter").

[12] Most of the analysis excludes August 24, 2015. Cornerstone does provide some analysis for August 24, 2015.

[13] See supra note 5.

[14] The Cornerstone analysis also examines the duration of long-lasting Straddles States and finds that 53.1% of long-lasting straddle states last between 5 and 30 minutes, 11.8% last between 30 minutes and 1 hour, 15.1% last between 1 and 3 hours, 6.2% last between 3 and 5 hours, and 13.8% last between 5 and 6.5 hours.

[15] Moise and Flaherty (2017) find that an average of 29.4 Trading Pauses occur each day (2295 Trading Pauses/78 days) during the period following the Phase-in of LULD for Tier II stocks. See supra note 9.

[16] The analysis also finds that 29.5% of symbols that experience a long-lasting Straddle State experience at least two long-lasting Straddles States in the same day and 12.8% experience at least three long-lasting Straddle States in the same day.

The analysis also examines how frequently long-lasting Straddle States recur across days and finds that long-lasting Straddle States do not frequently recur in most symbols that experience at least one long-lasting Straddle State.[17] However, the analysis also finds that a small group of 30 symbols frequently experience long-lasting Straddle States, with these symbols experiencing long-lasting Straddle States on more than 200 days out of the 609-day sample period.[18]

2. Factors that Influence the Occurrence of Long-Lasting Straddle States

The Cornerstone analysis examines the factors that influence the occurrence of long-lasting Straddle States. In our opinion, the results suggest that long-lasting Straddle States are mainly associated with thin trading and gaps in liquidity (i.e. instances in which the depletion of liquidity results in large price changes that revert once liquidity is restored). The analysis finds that long-lasting Straddle States are more likely to occur in securities with lower trading volume, higher volatility, and smaller market capitalizations.[19] The analysis also finds that long-lasting Straddle States are more likely to occur on days when market volatility is high, i.e. days the market experiences relatively large positive or negative returns or days when the VIX volatility index is high. Additionally, the majority of long-lasting Straddle States occur in securities that did not experience a trade during the opening, with the majority beginning at either 9:30am (the start of trading) or 9:45am (when the LULD Price Bands narrow from double width).

3. Activity During and After the Occurrence of Long-Lasting Straddle States

The Cornerstone analysis examines trading and quoting activity during long-lasting Straddle States and finds little trading activity occurs during most long-lasting Straddle States and finds that quotes tend to be wider during most long-lasting Straddle States than under normal trading conditions. Specifically, the analysis finds that no trades occur in over 75% of all long-lasting Straddle States and that 95% of long-lasting Straddle States have quoted spreads that are wider than the spreads during the control period.[20]

The analysis also finds that the quoted spreads are wider than the Price Bands in 39% of long-lasting Straddle States and that both the bid and ask quotes are outside the Price Bands in 24% of long-lasting Straddle States. These results could indicate that the Price Bands are not wide enough in these securities.

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[17] 2,364 unique symbols in the sample experience at least one long-lasting Straddle State. Over half of these symbols experience long-lasting Straddle States on 5 or fewer days out of the 609 day sample period.

[18] The analysis also finds a group of 83 symbols experience long-lasting Straddle States for a total of 101 to 200 days out of the 609 day sample period.

[19] These types of securities are also more likely to have wider bid-ask spreads.

[20] The Cornerstone analysis compares the period during a long-lasting Straddles State to a control period, which is constructed by taking the time window corresponding to the Straddle State on the five trading days prior to the event.

The Cornerstone analysis examines how long-lasting Straddle States end.[21] The analysis finds that while the majority of long-lasting Straddle States end with both quotes inside the price bands, 11% of long-lasting Straddle States end by entering a Limit State and 22% immediately reenter another Straddle State.[22,23] Moreover, although the majority of long-lasting Straddle States end with both quotes inside the price bands, the Cornerstone analysis finds that 54% of long-lasting Straddle States eventually reenter another Straddle State on the same day.[24]

4. Impact of the Tenth Amendment of the LULD Plan on Long-Lasting Straddle States and Trading Halts

The Cornerstone analysis examines the impact of the Tenth Amendment on the occurrence of long-lasting Straddle States and Trading Pauses.[25] The results of the Cornerstone analysis suggest that, after the implementation of Amendment 10, long-lasting Straddle States are substituting for some situations that previously would have resulted in a Trading Pause. Specifically, the analysis finds that Trading Pauses are less likely to occur and long-lasting Straddle States are more likely to occur in securities with no opening trade after the implementation of the Tenth Amendment.[26]

[21] According to the Plan, the primary listing exchange has the discretion to declare a Trading Pause in order to resolve a Straddle State. However, as discussed in the Notice of Filing of the Twelfth Amendment to the LULD Plan, a primary listing exchange has never declared a Trading Pause while a security was in a Straddle State. See supra note 6.

[22] Of the 11% of long-lasting Straddle States that enter a Limit State, 7% end in a Trading Pauses.

[23] Of the 22% of long-lasting Straddle States that immediately reenter another Straddle State, 7% immediately reenter another long-lasting Straddle State and 15% immediately reenter another Straddle-State lasting less than five minutes.

[24] Specifically, the analysis finds that 54.4% of long-lasting Straddle States are eventually followed by another Straddle State on the same trading day. Among these follow-up Straddle States, 32.4% are long-lasting Straddle States and 67.6% last less than five minutes.

[25] See supra note **Error! Bookmark not defined.**

[26] The Cornerstone analysis also finds that the majority of long-lasting Straddle States occur in securities that did not experience a trade during the opening. See Section III of the Cornerstone analysis.

MEMORANDUM

DATE: Friday, July 21, 2017

TO: Amy Edwards, Office of Markets, Division of Economic and Risk Analysis

FROM: Stewart Mayhew, Cornerstone Research

RE: Long-Lasting Straddle States

This memo summarizes research we have conducted pursuant to your request under Contract SECHQ1-16-C-0024, related to straddle states[1] under the Limit Up/Limit Down (LULD) rules.

Specifically, this memo provides a summary overview of economic analysis investigating the frequency of "long lasting" straddle states (defined as LULD straddle states lasting at least five minutes or at least 30 minutes), the characteristics of the securities experiencing such long-lasting straddle states, and other aspects of market conditions surrounding long-lasting straddle states. The memo also summarizes research examining the impact of Amendment 10 (implemented on July 18, 2016) on the occurrence of these long-lasting straddle states. In conjunction with this memo, we have provided a slide deck with tables and charts.

This research was performed by the staff of Cornerstone Research under my direction, with additional guidance and oversight from subject matter expert Dr. Timothy McCormick.

The analysis described below and in the accompanying slide deck is based on 609 trading days from August 1, 2014 to December 31, 2016. Most of the analysis described below excludes August 24, 2015, a date that experienced an extraordinary number of LULD events. Some analysis is provided for August 24, 2015. The data for this project were provided to Cornerstone Research by the staff of the Division of Economic and Risk Analysis (DERA). This includes data on straddle states, limit states, and LULD trading halts (as identified by the self-regulatory organizations ("SROs"), data from the Center for Research in Security Prices (CRSP), and consolidated intraday data from the Trade and Quote (TAQ) database.

[1] Under the LULD rules, a straddle state occurs when the National Best Bid (Offer) is below (above) the lower (upper) price band and the NMS Stock is not in a limit state. During a straddle state, there are some prices within the quoted spread at which trades can be executed, but there are prices within the quoted spread at which trades cannot be executed because they fall outside of the price bands.

The results of this research can be summarized as follows. The structure of this outline refers to corresponding sections of the accompanying slide deck.

Section I: Univariate Distributions of Long-Lasting Straddle States

August 24, 2015 was an outlier with almost 10 times more straddle events than usual. There were 1,384 straddle events lasting five minutes or more on August 24, 2015, occurring on 768 different symbols.

Based on analysis of the remainder of the sample, excluding August 24, 2015:

- 98.6% of all straddle states lasted less than five minutes.[2]
- On average, there were 141 straddle events per day lasting at least five minutes, and 66 straddle events lasting at least 30 minutes (slide 6).
- The majority of long-lasting straddle states begin at the start of trading or at 9:45 AM, the moment when the LULD bounds become narrower (slides 7–8).
- Graphs are provided summarizing the average number of long-lasting straddle events over the course of the trading day (slides 9–10).

Section II: Comparing Five- and 30-Minute Long-Lasting Straddle States

This section contains graphs showing cumulative time in straddle state conditional on the length of the longest straddle of the day. Separate graphs are provided for symbol-days on which the longest straddle state was less than five minutes, between five and 30 minutes, and greater than 30 minutes (slides 13–15).

Instances in which a security persistently flickered in and out of a straddle state—wherein the security never experienced a straddle state lasting longer than five minutes, but was in a straddle state for a total of more than 30 minutes of the day—are analyzed further. There are 156 such symbol-days in the sample, which corresponds to this event occurring roughly once every four days (slides 12–13).

- This occurred on 51 unique symbols, with one symbol flickering in and out of straddle states on 16 different dates.
- Of these flickering symbol-days, 33 symbol-days were in a straddle state for at least five hours of the trading day.

[2] There were 6,215,889 straddle states in the sample and 6,130,081 lasted less than five minutes.

Section III: Factors That Influence the Occurrence of Straddle States

The following factors were evaluated with respect to their likelihood of influencing the occurrence of straddle states:

- Market index returns: The incidence of long-lasting straddle events appears to be slightly higher on days when the S&P 500 or the Russell 2000 experiences a relatively large movement up or down (slides 18–24) or when the VIX volatility index is high (slides 25–26).

- Breakdown by primary exchange listing and type of security: NASDAQ-listed securities were more likely to experience a long-lasting straddle state than securities listed on other exchanges (slides 27–29).

- Whether the security was in Tier 1 or Tier 2 (slide 30).

- Price level of prior day's close, by price band regime (slide 31).

- Existence of an opening trade (slide 32).

- Trading volume: Long-lasting straddle states are more prevalent for lower-volume securities (slides 33–37).

- Market capitalization (for common stock only): Long-lasting straddle states are more prevalent for smaller issuers (slides 38–42).

The following logistic panel regression was used to estimate the significance of various factors contributing to the likelihood of a long-lasting straddle event:

$$Straddle\ State\ Indicator_{i,t} = \beta_0 + \beta_1 X_{i,t} + \beta_2 TE_t + \epsilon_{i,t}$$

The dependent variable $Straddle\ State\ Indicator_{i,t}$, has a value of one if there was a long-lasting straddle state on a given symbol-day and zero otherwise. The independent variables, $X_{i,t}$, include the following:

- Trading volume on that day (measured in logarithm).
- Indicator variable with a value of one if the stock is in Tier 1.
- Indicator variable with a value of one if the prior day close was $3 or below.
- Indicator variable with a value of one if the prior day close was below $0.75.
- Indicator variable with a value of one if there was no opening trade.
- Abnormal volume measured as the quintile rank of the current day's volume among the prior 30 days.

- Stock volatility measured by the standard deviation of returns over the prior 30 days.

The results indicate that stocks with higher return volatility, higher abnormal trading volume, and stocks that lack an opening trade were associated with a higher likelihood of experiencing a long-lasting straddle state. Tier 1 stocks, stocks with a prior day's closing price below $3 and below $0.75, respectively, and stocks with higher trading volume were associated with a lower likelihood of experiencing a long-lasting straddle state. These results hold for estimations with and without time fixed effects (slide 44).

Section IV: Activity During and After Long-Lasting Straddle States

Appearing first in this section is analysis on the propensity of straddle states to recur across days. Thirty symbols experienced at least one long-lasting straddle state on more than 200 days in the sample of 609 trading days. On average, 84 symbols per day experienced a long-lasting straddle event, although this number varies considerably across the sample period. Of the symbols experience a long-straddle event, typically 10–25 symbols per day had a long-lasting straddle state in each of the five previous trading days and 10–25 had a long-lasting straddle state in none of the five previous trading days (slides 47–49).

The majority of symbols that experience a long-lasting straddle state on a given day experience only one long-lasting straddle event on that day. In addition, 22% of long-lasting straddle states were resolved by immediately entering into another straddle state, while 10.8% were resolved by immediately entering into a limit state (slides 51–53).

Next, the quoting and trading activity during the long-lasting straddle state is analyzed. For several analyses in this section, a control period is constructed by taking the time window corresponding to the straddle event on the five trading days prior to the straddle event.[3] The results show the following:

- Quoting activity during the straddle event: Quoted relative spreads during the straddle state were wider relative to the control period for 95% of straddle events. For straddle events that occurred while the bands were single wide, the time-weighted relative quoted spread was between 8% and 16% more than half of the time (slides 55–59).

[3] Straddle events were included in the sample for these analyses if there were five trading days to use as a control period prior to the day of the straddle event and if there were no long-lasting straddle states during the control period.

- Trading volume during the straddle event: There were no shares traded during 75.3% of long-lasting straddle states. Overall, volume during the long-lasting straddle state was typically lower than the volume during the same time interval on the five previous trading days (slides 60–61).

- Breakdown of straddle state by straddle type: 41% of straddle states were "limit up straddle states," 32% were "limit down straddle states," 24% were instances in which the bid was below and the ask was above the price bands, and 3% fell into more than one of these categories over the course of the straddle state (slide 62).

Section V: Impact of Amendment 10 on Long-Lasting Straddle States

Amendment 10 was implemented on July 18, 2016 and was targeted at reducing the number of trading halts on stocks that did not have an opening trade. The amendment stated that stocks without any trading volume in the opening auction would use the prior day's closing price as the first reference price instead of the midpoint of the opening quote.

The impact of Amendment 10 is analyzed by extending the regression methodology outlined in Section III above. In particular, the specification adds indicator variables for whether or not the stock had an opening trade and whether the date was before or after Amendment 10 was implemented, as well as the interaction of the two. The impact of Amendment 10 on the likelihood of experiencing a trading halt is tested first.

$$Halt\ State\ Indicator_{i,t} = \beta_0 + \beta_1 Post\ Amendment_t + \beta_2 No\ Opening\ Trade_{i,t} + \beta_3 Post\ Amendment_t * No\ Opening\ Trade_{i,t} + \beta_4 X_{i,t} + \epsilon_{i,t}$$

The independent variables include the following:

- $Post\ Amendment_t$ denotes an indicator variable with a value of one after implementation.
- $No\ Opening\ Trade_{i,t}$ denotes an indicator variable with a value of one if there was no opening trade.
- $Post\ Amendment_t * No\ Opening\ Trade_{i,t}$ denotes the interaction of the two indicator variables described above.
- $X_{i,t}$ is the set of control variables described in Section III.

This analysis shows that the odds ratio of a stock experiencing a trading halt conditional on that stock having no opening trade is approximately five to seven times lower after the implementation of Amendment 10 (slide 65).

Next, the same model is used to test the impact of Amendment 10 on the likelihood of experiencing a long-lasting straddle.

$$Straddle\ State\ Indicator_{i,t} = \beta_0 + \beta_1 Post\ Amendment_t + \beta_2 No\ Opening\ Trade_{i,t} + \beta_3 Post\ Amendment_t * No\ Opening\ Trade_{i,t} + \beta_4 X_{i,t} + \epsilon_{i,t}$$

This analysis shows that the odds ratio of a stock experiencing a long-lasting straddle state conditional on that stock having no opening trade is approximately 1.2 times higher after the implementation of Amendment 10 (slide 67).

In summary, the results indicate that the implementation of Amendment 10 appears to have significantly reduced the likelihood of a trading halt, but increased the likelihood of long-lasting straddle events.

Analysis of Long-Lasting Straddle States

July 21, 2017

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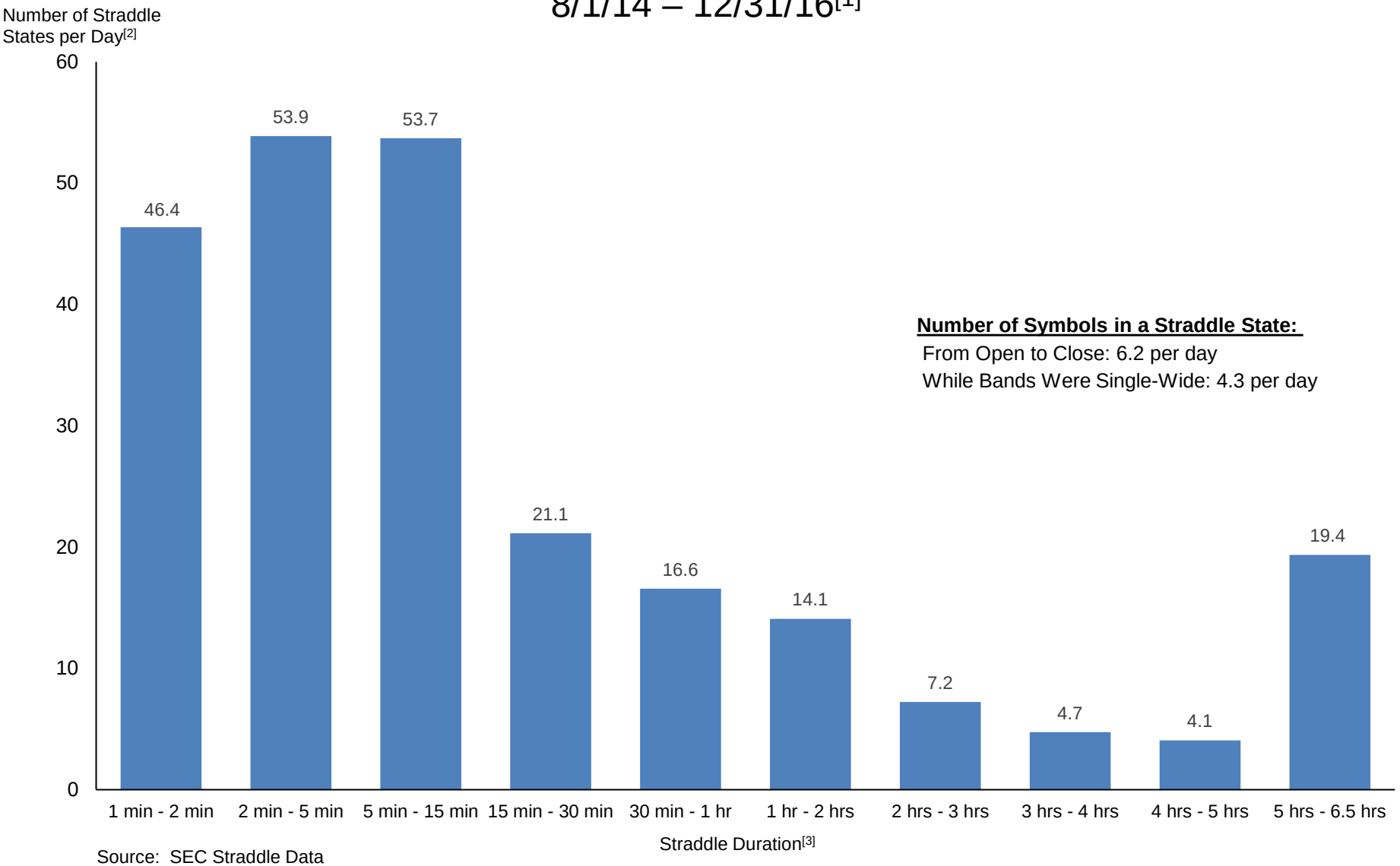
Section I: Univariate Distributions of Long-Lasting Straddle States

Univariate Distributions of Long-Lasting Straddle States

- Sample Period: August 2014 – December 2016
- 98.6% of straddle states lasted less than five minutes.
- Statistics using five–minute threshold for long-lasting straddle states:
  - Average number of straddle events: 141 per day
  - Average number of symbols that experienced at least one straddle event: 84 per day
- Statistics using 30–minute threshold for long-lasting straddle states:
  - Average number of straddle events: 66 per day
  - Average number of symbols that experienced at least one straddle event: 53 per day
- Majority of long-lasting straddle states begin at the start of trading or 9:45 AM.
- Majority of analyses will be done using five–minute threshold.
- August 24, 2015
  - There were 1,384 straddle events lasting five minutes or more, or almost 10 times more than usual. The 1,384 straddle events occurred on 768 symbols.
  - Due to the unusual nature of this day, it was excluded from most of the analysis.

Distribution of Straddle State Duration

8/1/14 – 12/31/16[1]

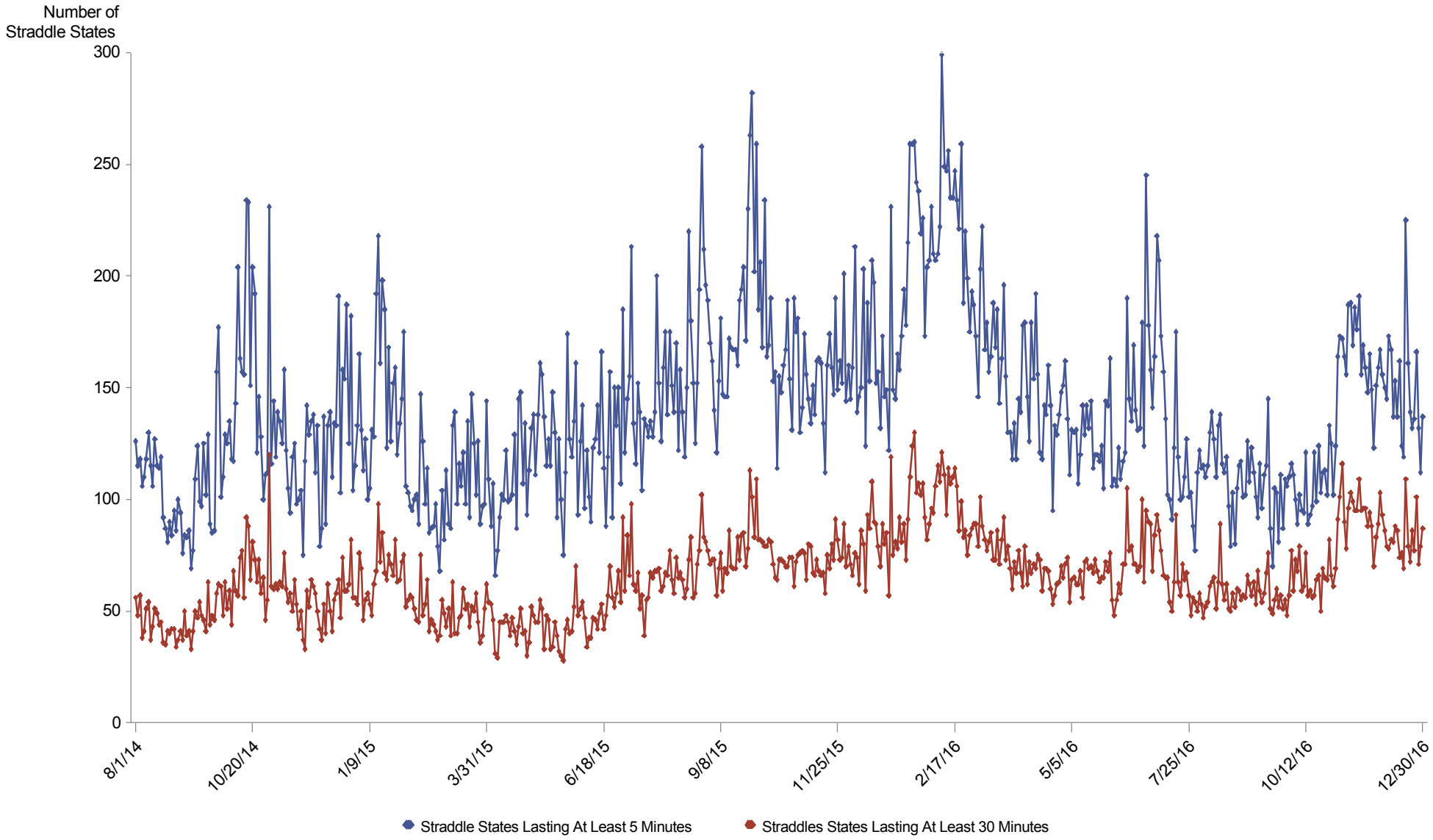


Source: SEC Straddle Data

Note:
[1] There are 609 trading days in the sample, excluding August 24, 2015.
[2] This figure depicts the distribution of straddle state durations for straddle states lasting longer than one minute. The full sample also includes 6,069,029 straddle states that lasted less than one minute, or approximately 10,000 per day.
[3] Straddle duration represents the total amount of time a straddle state lasted.

Daily Counts of Long-Lasting Straddle States

August 2014 – December 2016



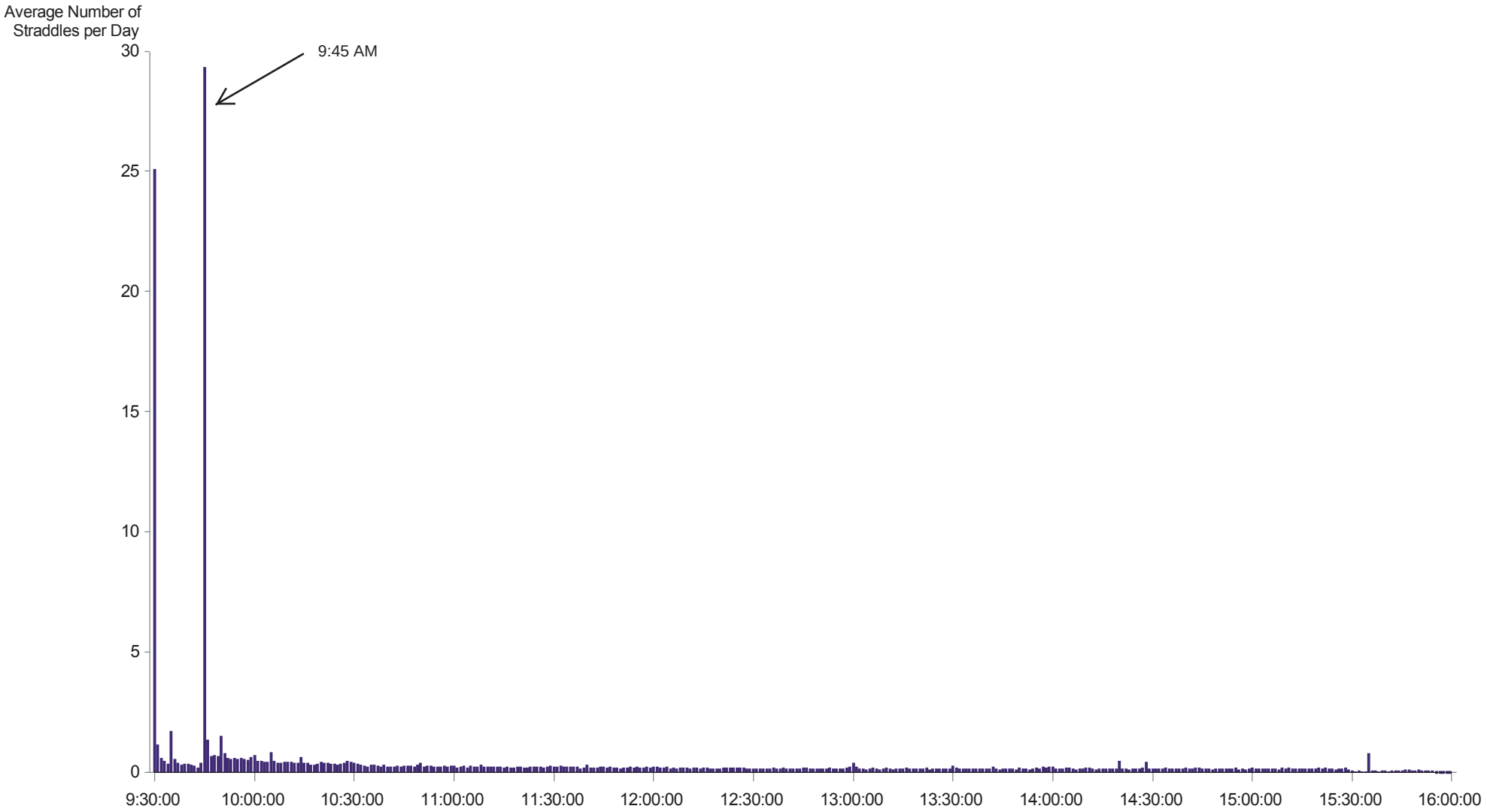
Source: SEC Straddle Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Long-Lasting Straddle States Partitioned by Start Time

Straddle States Lasting At Least Five Minutes

August 2014 – December 2016



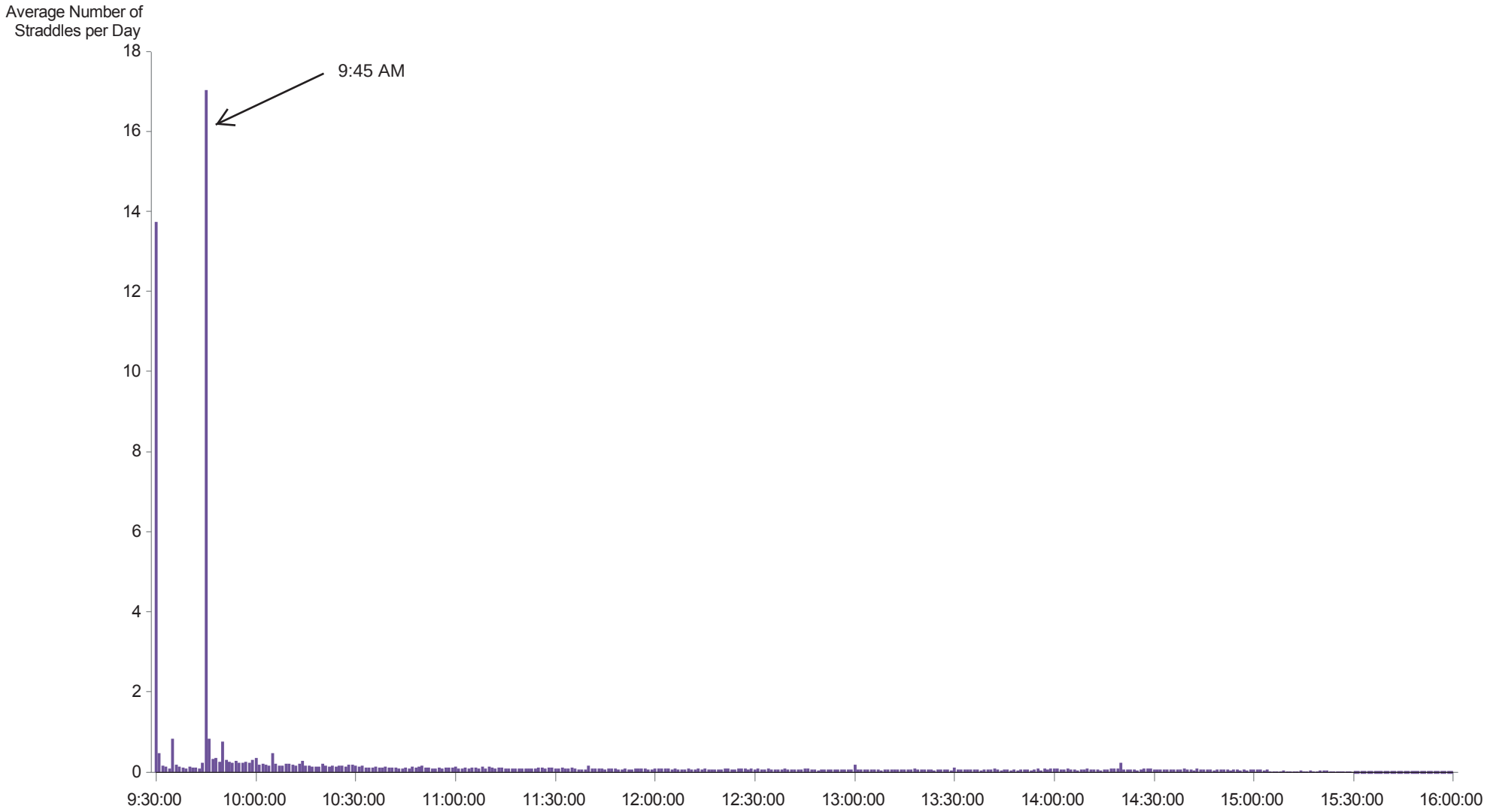
Source: SEC Straddle Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Long-Lasting Straddle States Partitioned by Start Time

Straddle States Lasting At Least 30 Minutes

August 2014 – December 2016



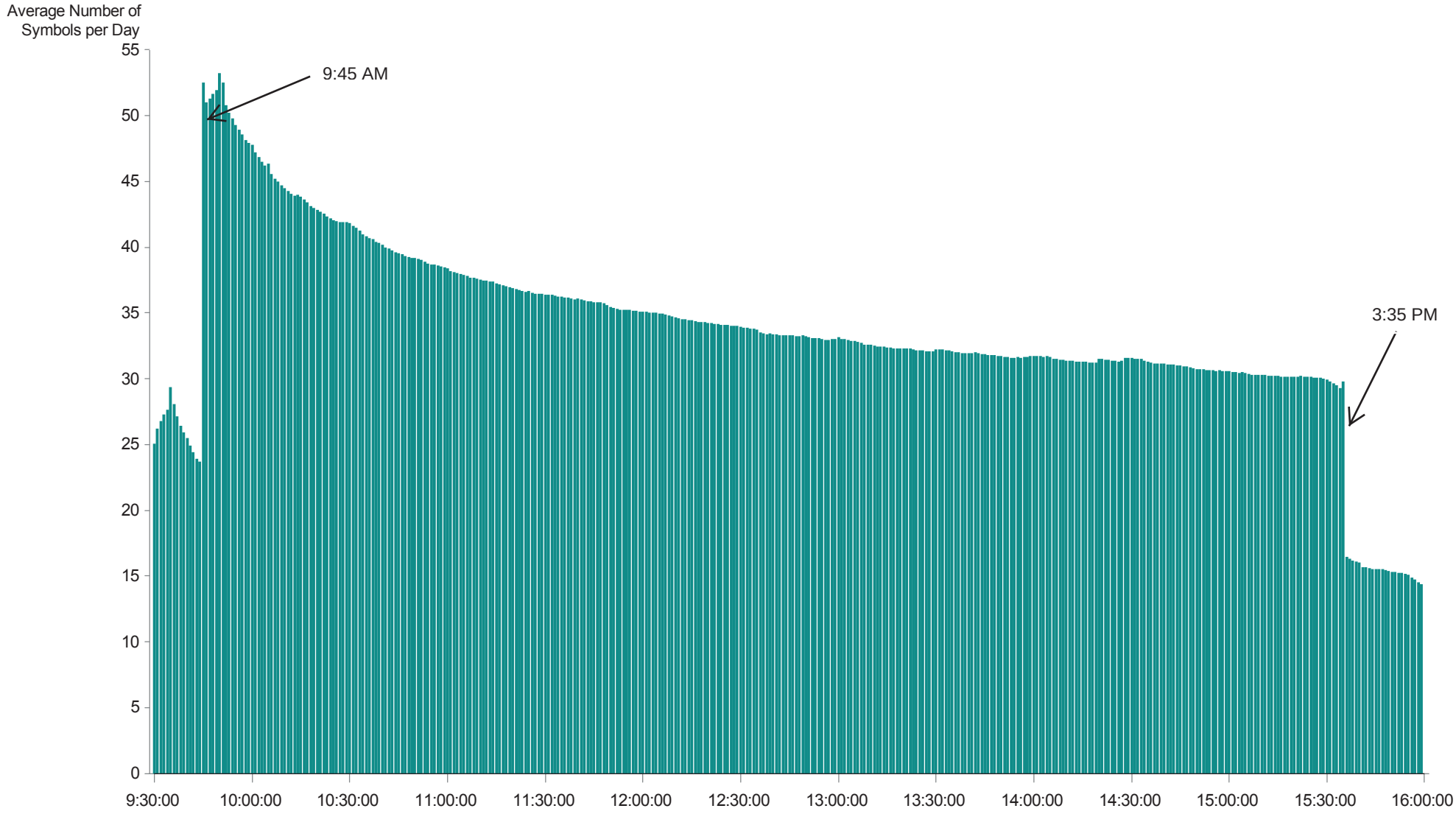
Source: SEC Straddle Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

Average Number of Symbols in a Long-Lasting Straddle State at One-Minute Intervals Throughout the Day

Straddle States Lasting At Least Five Minutes

August 2014 – December 2016



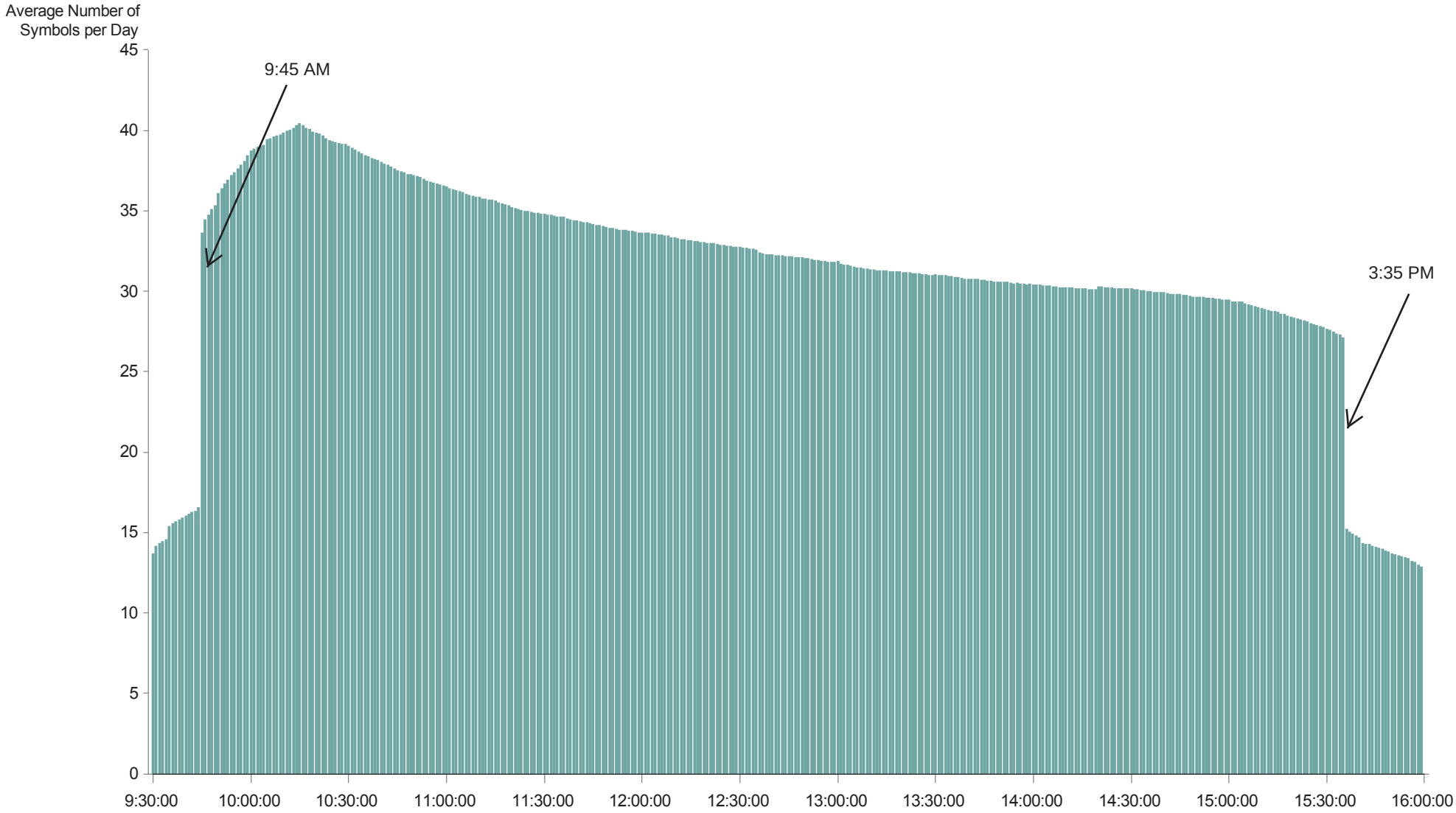
Source: SEC Straddle Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

Average Number of Symbols in a Long-Lasting Straddle State at One-Minute Intervals Throughout the Day

Straddle States Lasting At Least 30 Minutes

August 2014 – December 2016



Source: SEC Straddle Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

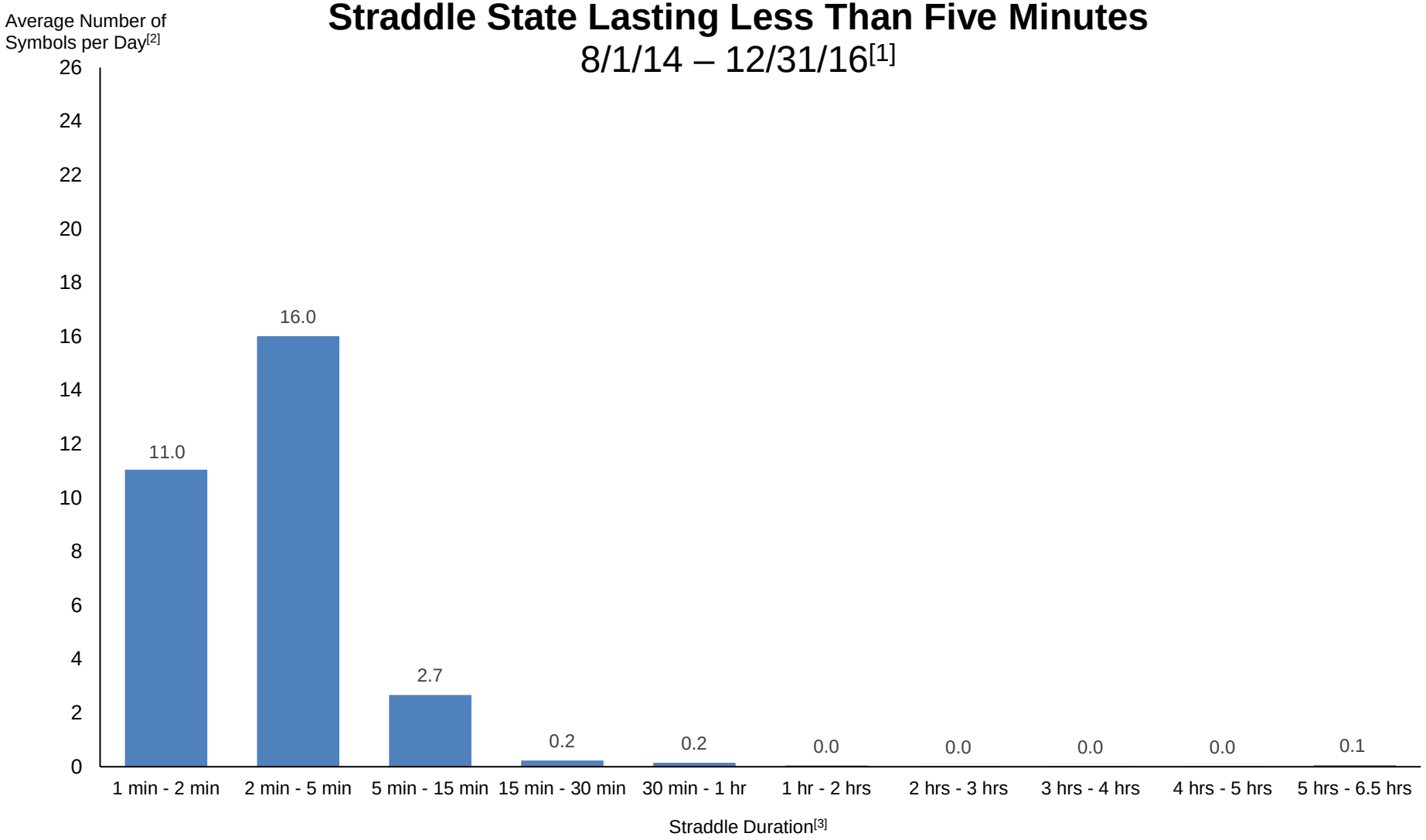
Section II: Comparing Five– and Thirty– Minute Long-Lasting Straddle States

Defining a Long-Lasting Straddle State

- 156 symbol-days (or one symbol every four days) persistently “flickered” in and out of a straddle state, wherein they experienced no straddle states lasting longer than five minutes, but were in a straddle state for more than 30 minutes of the day.
  - These flickering symbol-days were spread across 51 unique symbols, with one symbol experiencing flickering on 16 different dates.
  - Flickering occurred on 85 unique dates, with two dates having a maximum of eight different symbols experiencing flickering.
- Of these “flickering” symbol-days, 33 symbol-days (or one symbol every four weeks) were in a straddle state for at least five hours of the day.
  - These flickering symbol-days were spread across 11 unique symbols, with one symbol experiencing flickering on 13 different dates.
  - Flickering occurred on 30 unique dates, with three dates having a maximum of two different symbols experiencing flickering.

Cumulative Time in Straddle State Conditional on the Longest Straddle State Lasting Less Than Five Minutes

8/1/14 – 12/31/16[1]

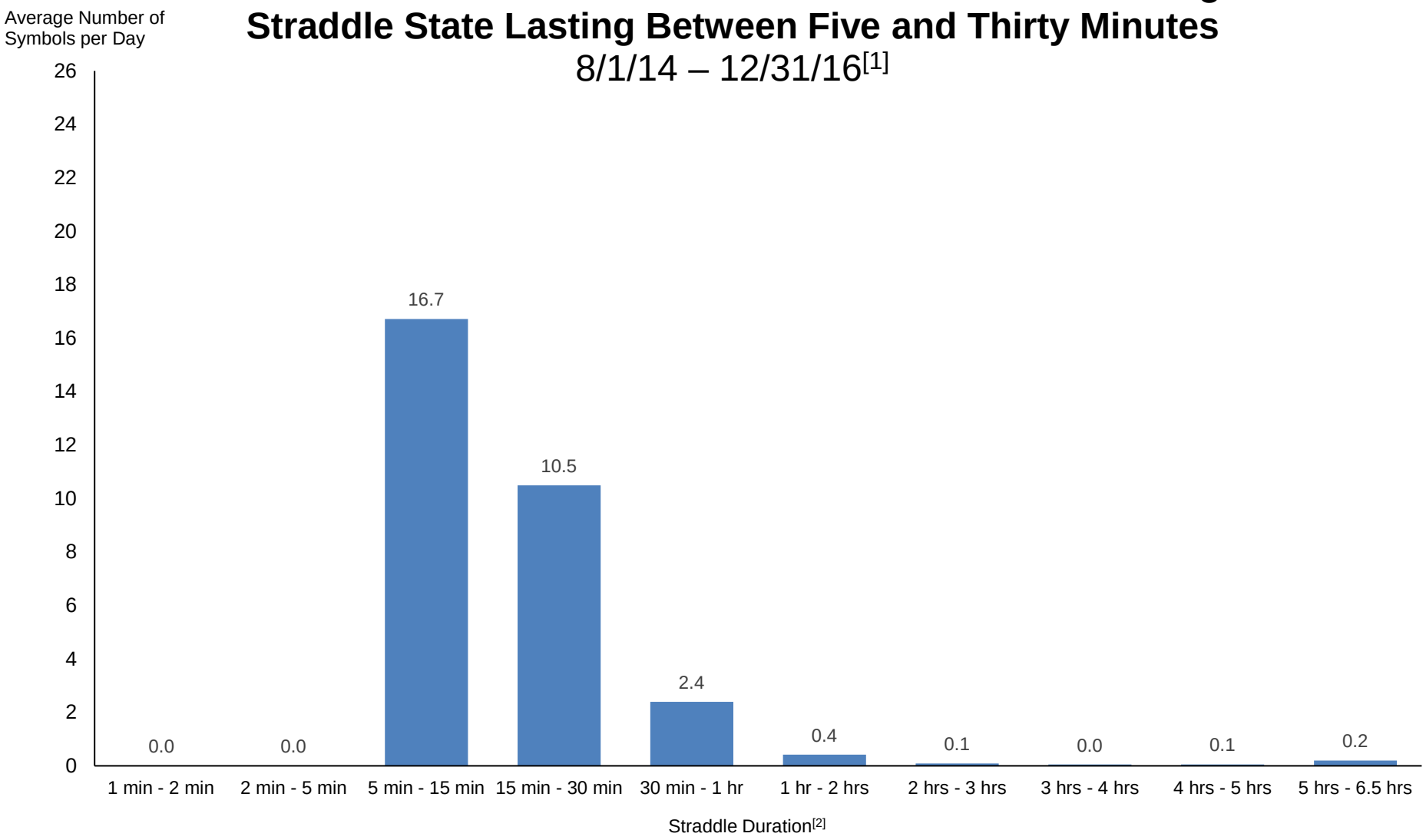


Source: SEC Straddle Data

Note:
[1] There are 609 trading days in the sample, excluding August 24, 2015.
[2] This figure does not include the 50,562 symbol-days (approximately 83 symbols per day) for which the cumulative time in straddle state was less than one minute.
[3] Straddle duration represents the total amount of time a symbol spent in a straddle state on a given day. Symbol-days on which the longest straddle states lasted less than five minutes are included.

Cumulative Time in Straddle State Conditional on the Longest Straddle State Lasting Between Five and Thirty Minutes

8/1/14 – 12/31/16[1]

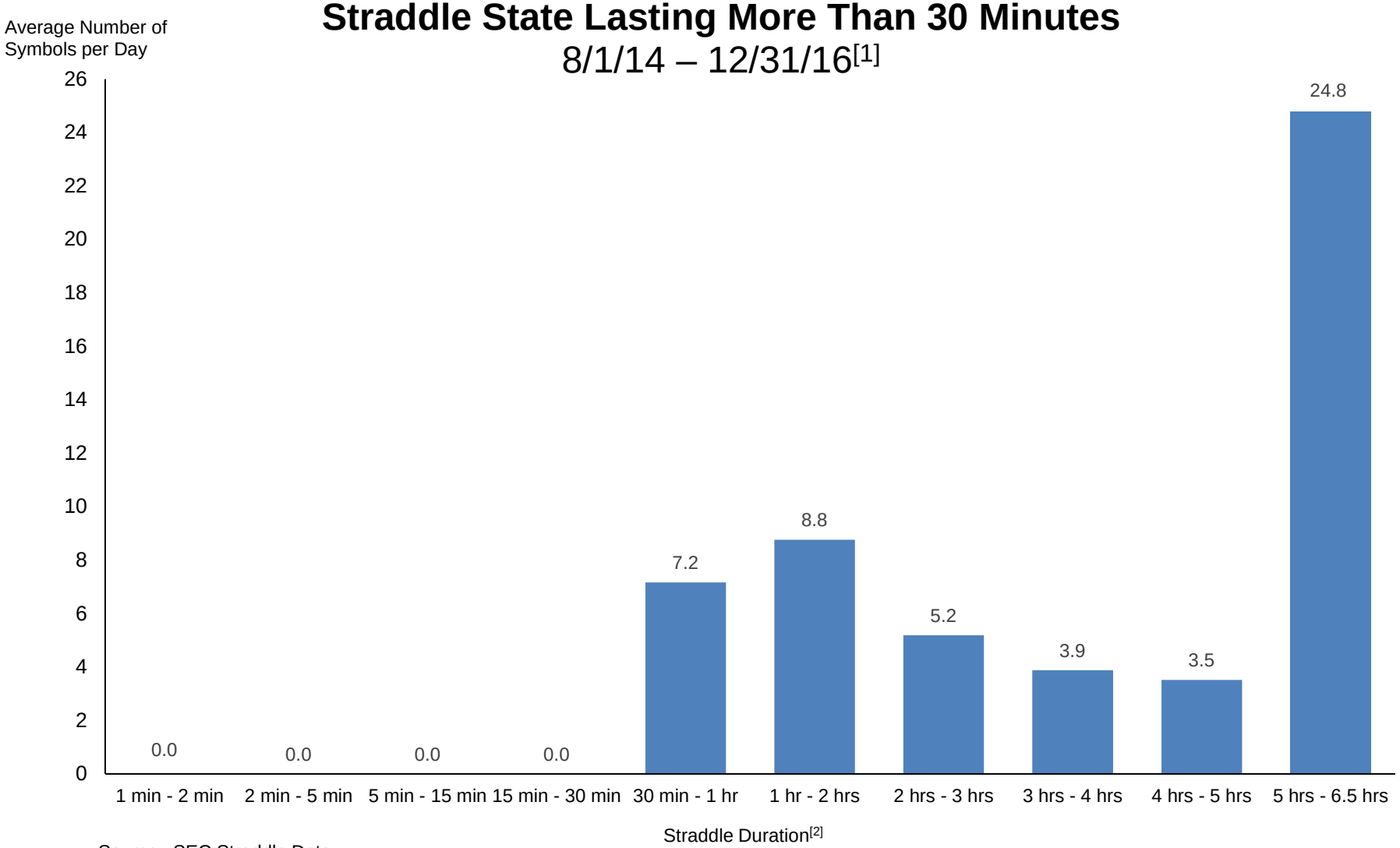


Source: SEC Straddle Data

Note:
[1] There are 609 trading days in the sample, excluding August 24, 2015.
[2] Straddle duration represents the total amount of time a symbol spent in a straddle state on a given day. Symbol-days on which the longest straddle states lasted greater than or equal to five minutes but less than 30 minutes are included.

Cumulative Time in Straddle State Conditional on the Longest Straddle State Lasting More Than 30 Minutes

8/1/14 – 12/31/16[1]



Source: SEC Straddle Data

Note:
[1] There are 609 trading days in the sample, excluding August 24, 2015.
[2] Straddle duration represents the total amount of time a symbol spent in a straddle state on a given day. Symbol-days on which the longest straddle state lasted at least 30 minutes are included.

Section III: Factors That Influence the Occurrence of Straddle States

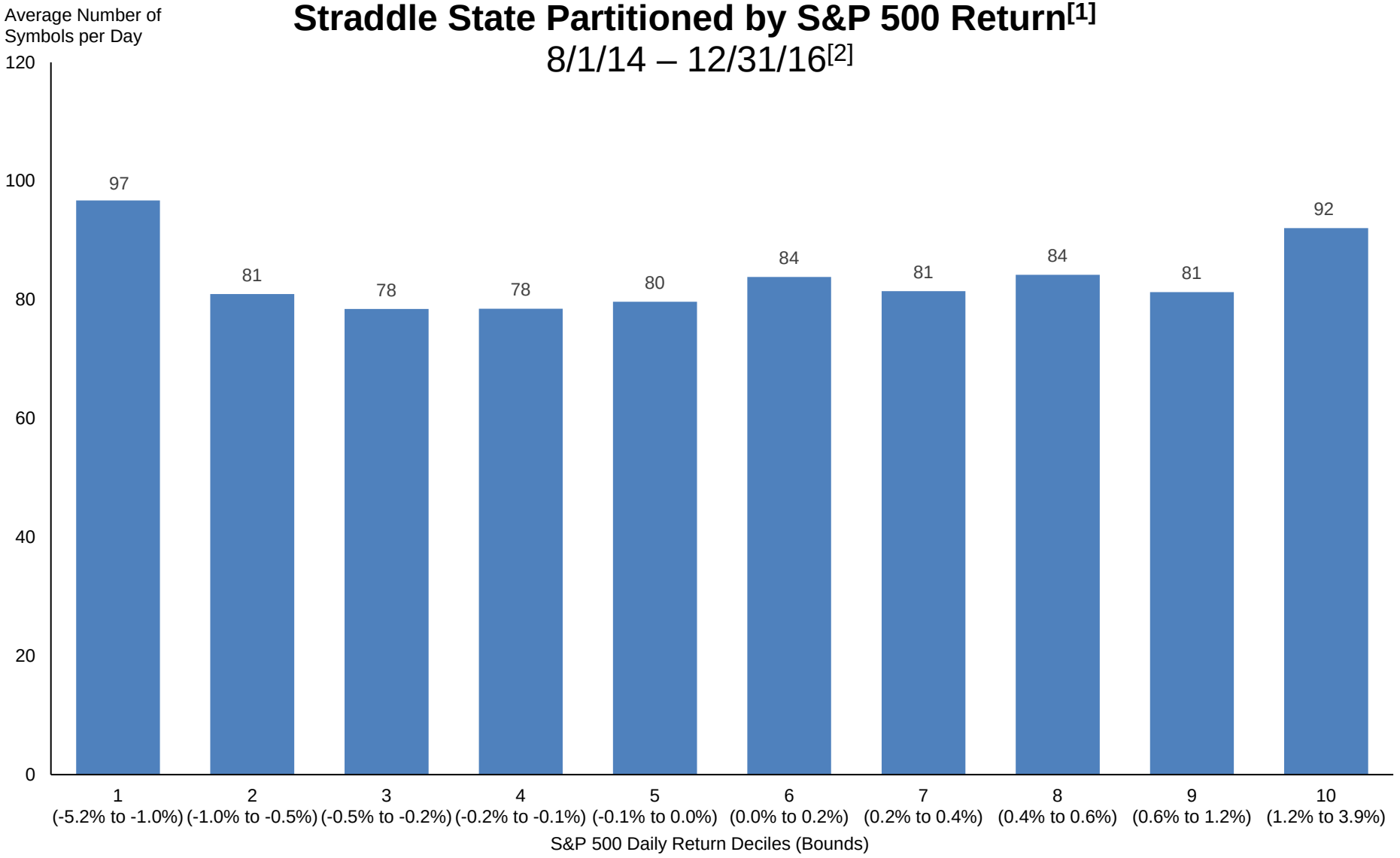
Factors That Influence the Occurrence of Straddle States

- Frequency of long-lasting straddle states shown by the following day characteristics:
  - S&P 500 Return
  - Russel 2000 Return
  - VIX Level
- Frequency of long-lasting straddle states shown by the following stock characteristics[1]:
  - Exchange
  - Type of security
  - Tier 1 or Tier 2 stock
  - Price level of prior day's close
  - Whether or not there was an opening trade
  - Volume
  - Market capitalization (includes only common stock)

[1] Most of these analyses only include stocks that are included in the CRSP database. CRSP does not have data on BATS listed securities, ETNs, preferred stock, and units.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by S&P 500 Return[1]

8/1/14 – 12/31/16[2]

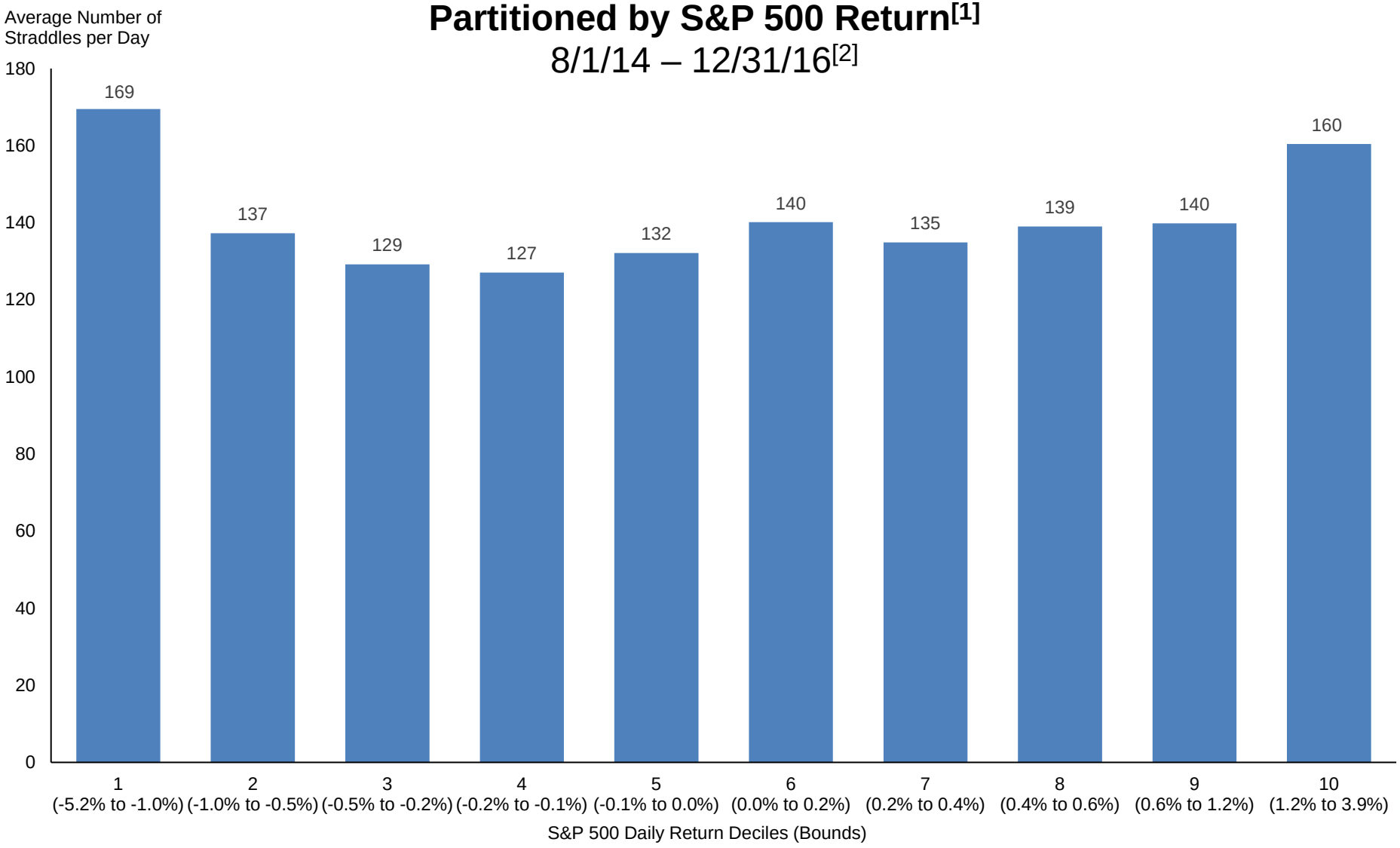


Source: SEC Straddle Data; Bloomberg S&P 500 Total Return Index Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the S&P 500 Index.
[2] There are 609 trading days in the sample, excluding August 24, 2015.

Average Number of Long-Lasting Straddle States Partitioned by S&P 500 Return[1]

8/1/14 – 12/31/16[2]



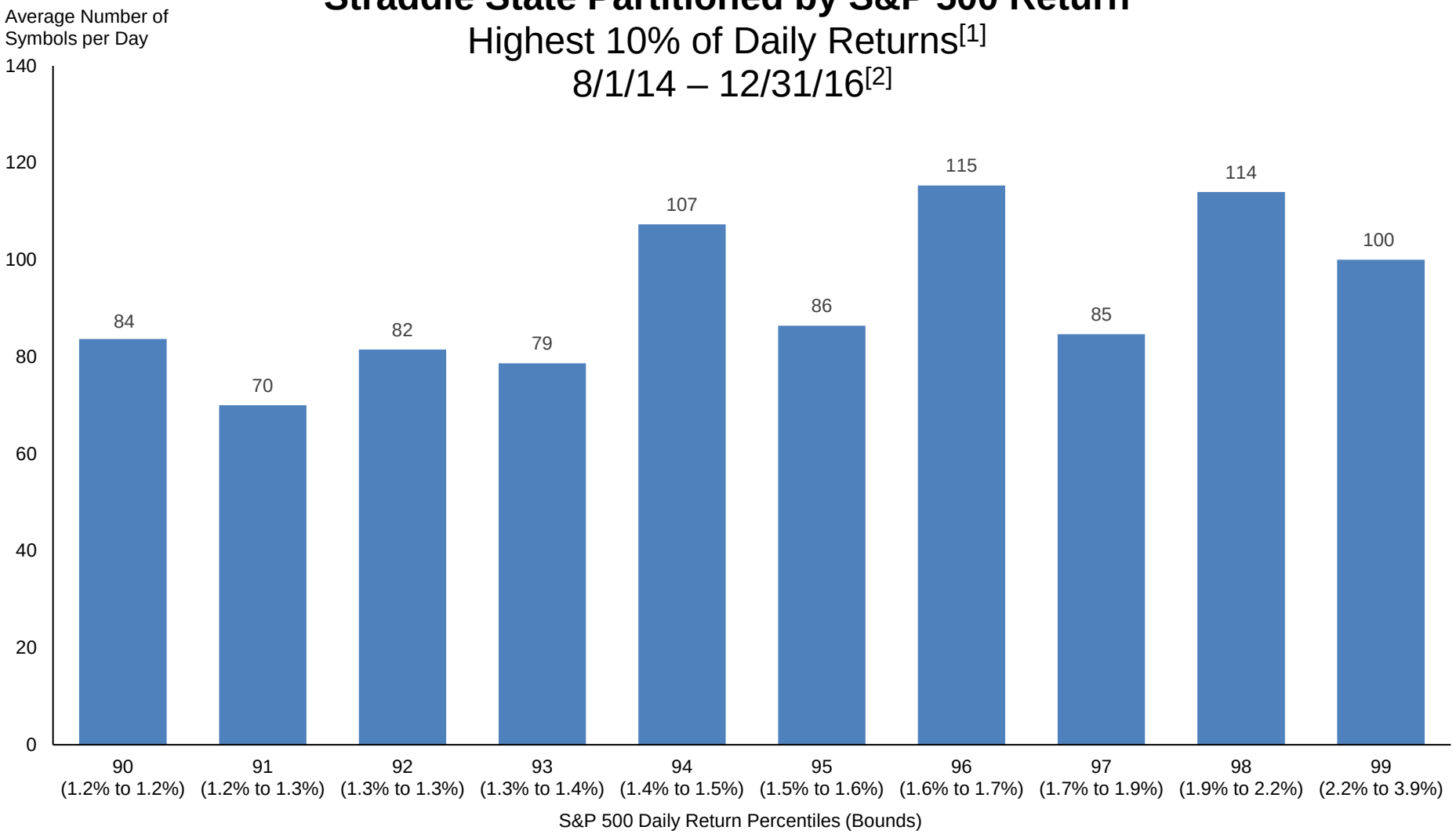
Source: SEC Straddle Data; Bloomberg S&P 500 Total Return Index Data

Note:
[1] This graph shows the average frequency of long-lasting straddle states (straddle states lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the S&P 500 Index.
[2] There are 609 trading days in the sample, excluding August 24, 2015.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by S&P 500 Return

Highest 10% of Daily Returns[1]

8/1/14 – 12/31/16[2]



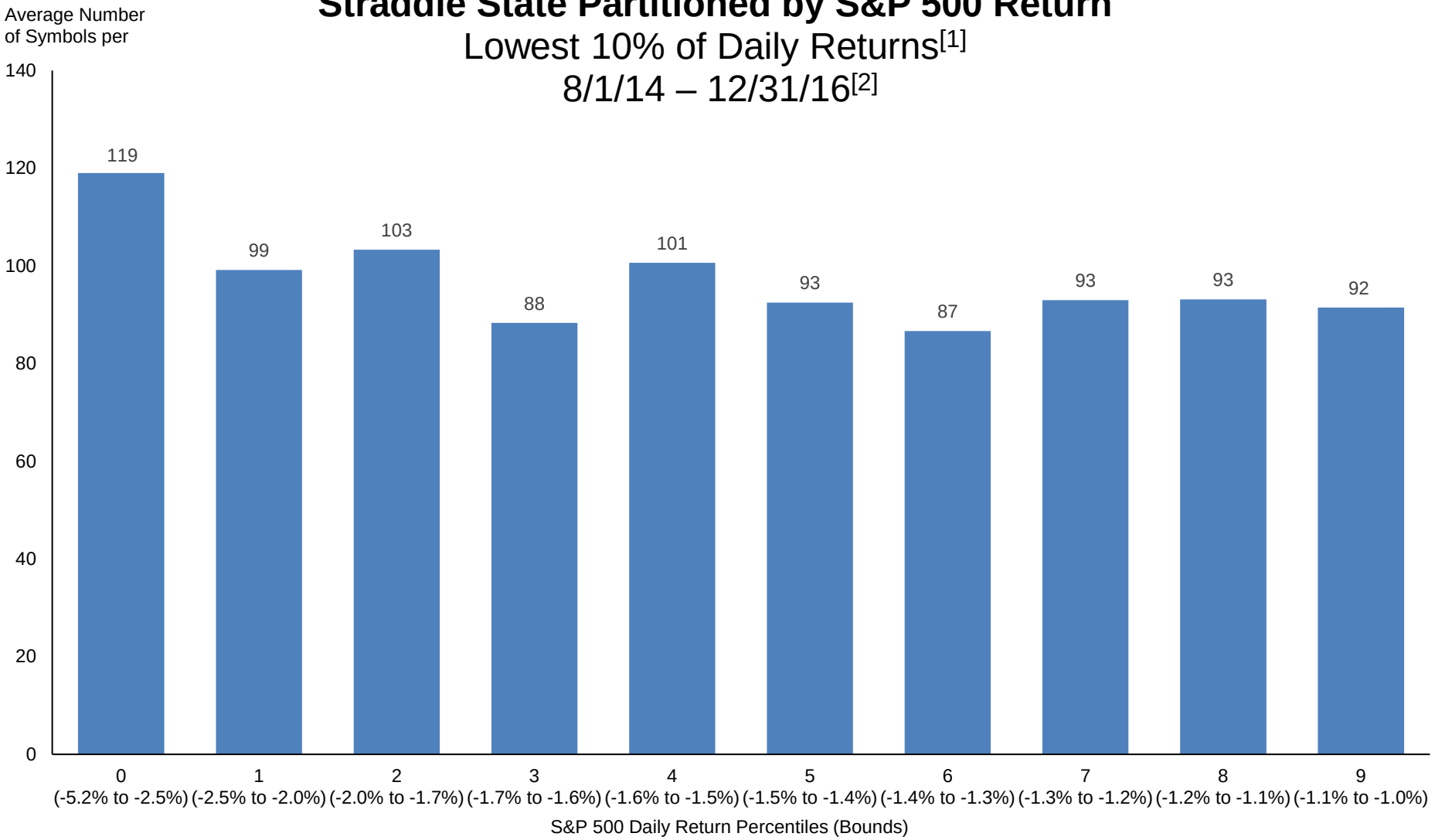
Source: SEC Straddle Data; Bloomberg S&P 500 Total Return Index Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the S&P 500 Index.
[2] There are 609 trading days in the full sample, excluding August 24, 2015. The 61 trading days included here are those with daily index returns in the highest 10% of the full sample.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by S&P 500 Return

Lowest 10% of Daily Returns[1]

8/1/14 – 12/31/16[2]

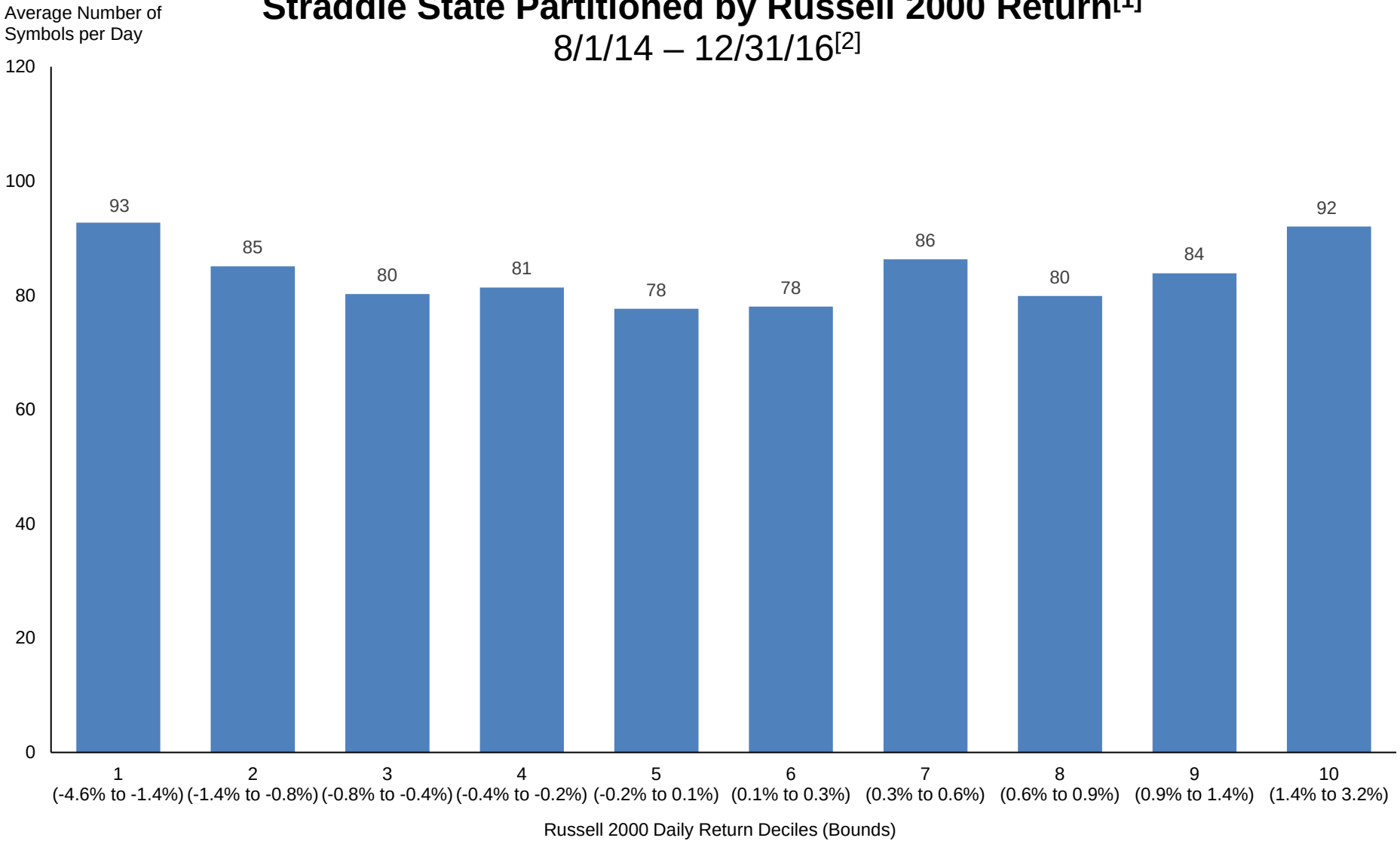


Source: SEC Straddle Data; Bloomberg S&P 500 Total Return Index Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the S&P 500 Index.
[2] There are 609 trading days in the full sample, excluding August 24, 2015. The 60 trading days included here are those with daily index returns in the lowest 10% of the full sample.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Russell 2000 Return[1]

8/1/14 – 12/31/16[2]



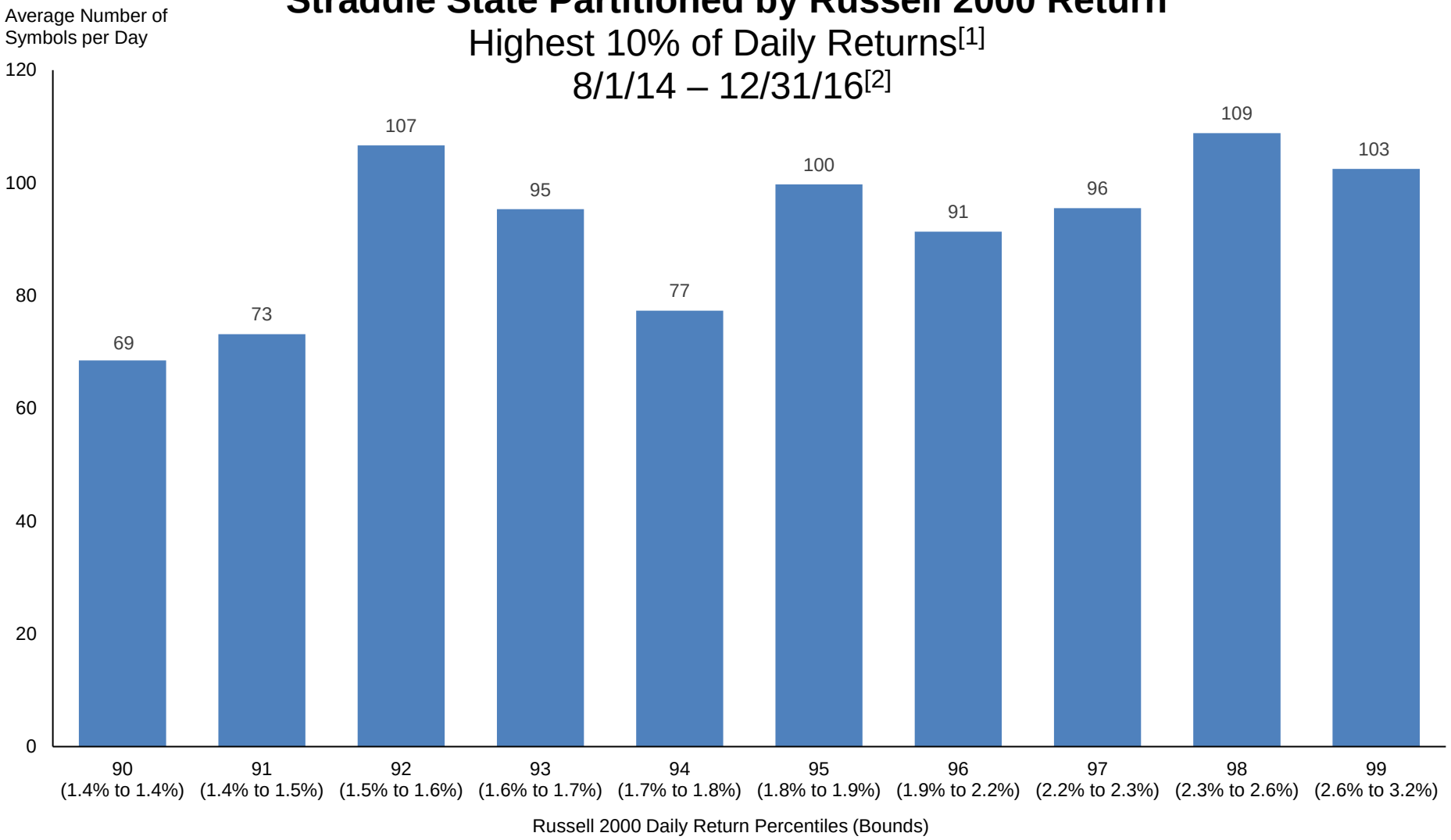
Source: SEC Straddle Data; Bloomberg Russell 2000 Total Return Index Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the Russell 2000 Index.
[2] There are 609 trading days in the sample, excluding August 24, 2015.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Russell 2000 Return

Highest 10% of Daily Returns[1]

8/1/14 – 12/31/16[2]



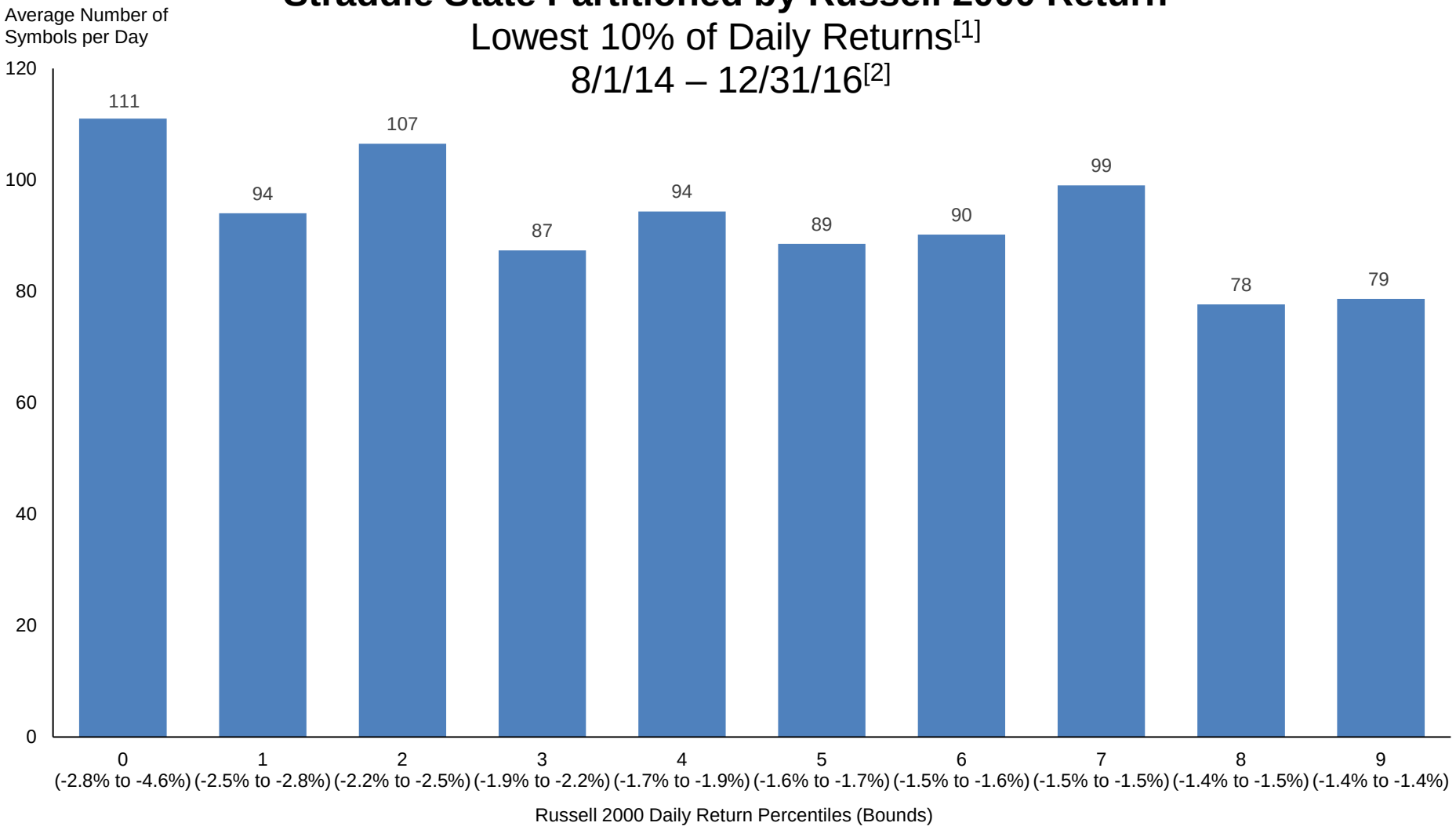
Source: SEC Straddle Data; Bloomberg Russell 2000 Total Return Index Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the Russell 2000 Index.
[2] There are 609 trading days in the full sample, excluding August 24, 2015. The 61 trading days included here are those with daily index returns in the highest 10% of the full sample.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Russell 2000 Return

Lowest 10% of Daily Returns[1]

8/1/14 – 12/31/16[2]

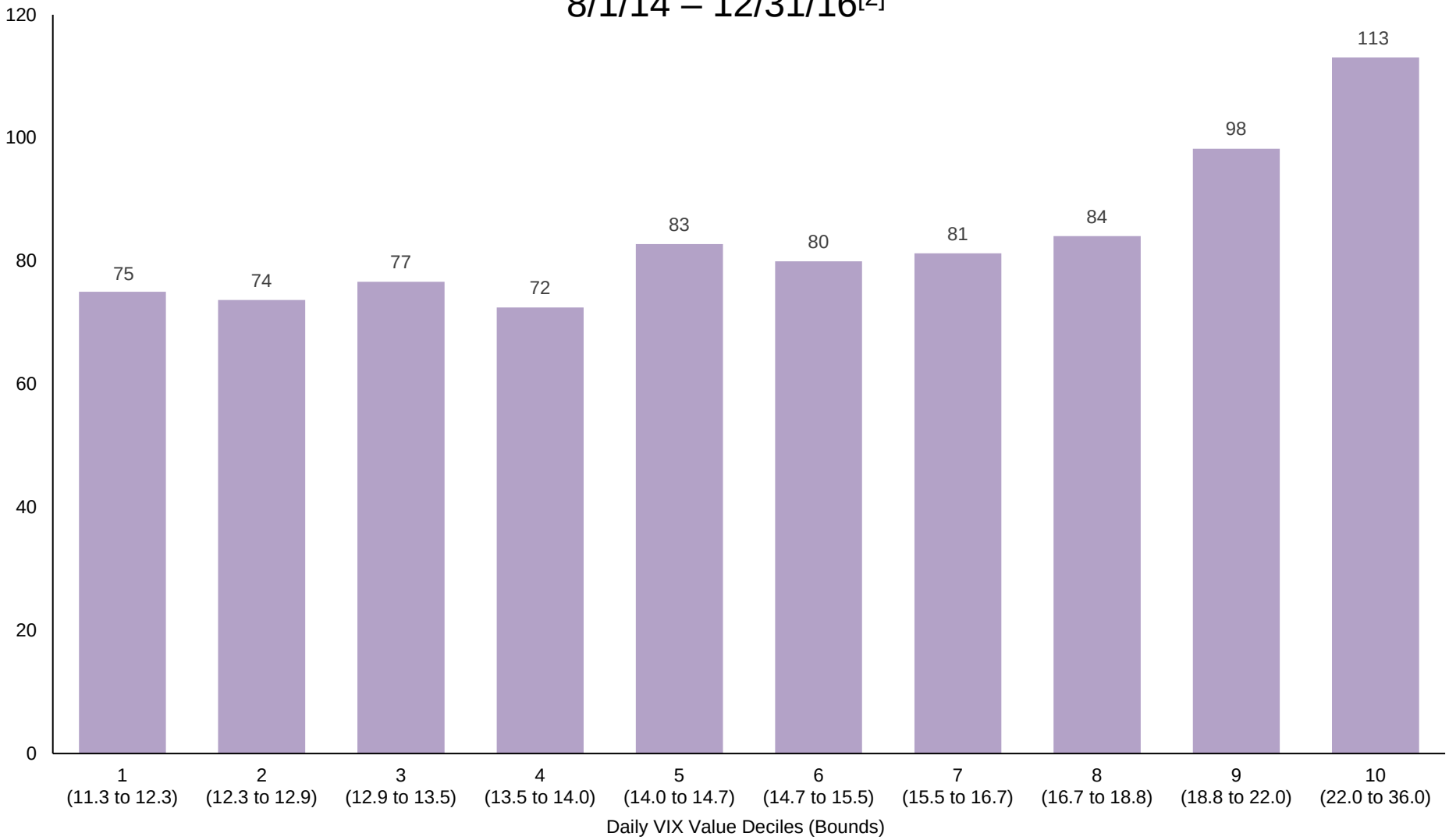


Source: SEC Straddle Data; Bloomberg Russell 2000 Total Return Index Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the daily dividend-adjusted return of the Russell 2000 Index.
[2] There are 609 trading days in the full sample, excluding August 24, 2015. The 60 trading days included here are those with daily index returns in the lowest 10% of the full sample.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by VIX Value[1]

8/1/14 – 12/31/16[2]



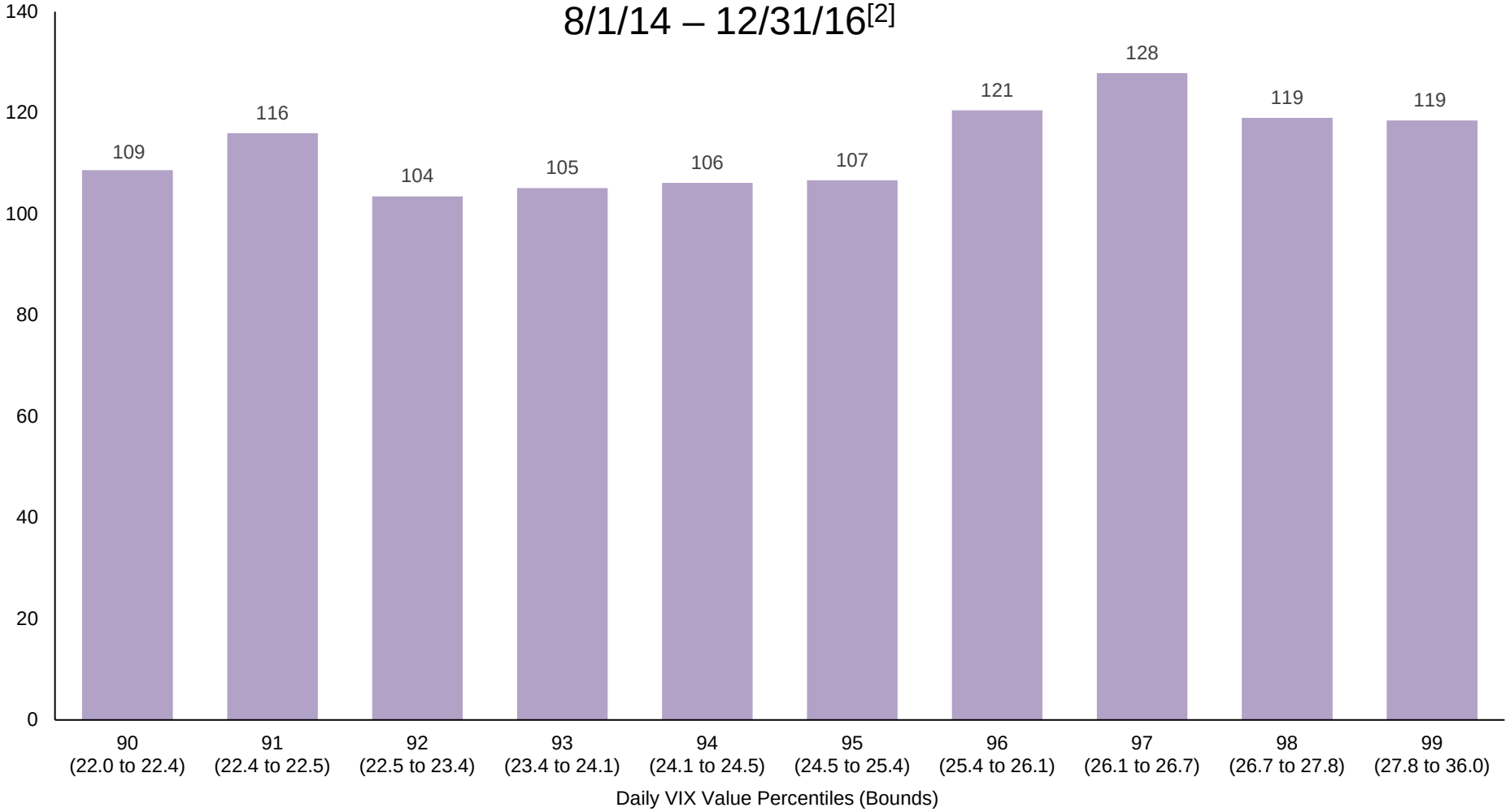
Source: SEC Straddle Data; Bloomberg VIX Data

Note:
[1] This graph shows the average number of unique symbols with a long-lasting straddle (a straddle state lasting at least five minutes) occurring on days partitioned by the VIX Value.
[2] There are 609 trading days in the sample, excluding August 24, 2015.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by VIX Value

Highest 10% of Daily Values[1]

8/1/14 – 12/31/16[2]



Source: SEC Straddle Data; Bloomberg VIX Data

Note:
[1] This graph shows the average frequency of long-lasting straddle states (straddle states lasting at least five minutes) occurring on days partitioned by the daily VIX Value.
[2] There are 609 trading days in the sample, excluding August 24, 2015. The 61 trading days included here are those with daily VIX Values in the highest 10% of the full sample.

Long-Lasting Straddle State Count Aggregated by CRSP Share Code and Primary Listing Exchange[1]

8/1/14 – 12/31/16[2]

	Long-Lasting Straddle State Counts						Percentage of Symbol-Days That Experienced a Long-Lasting Straddle State[3]					
CRSP Share Code Definitions	**NASDAQ**	**ARCA**	**NYSE**	**MKT**	**BATS**	**Across All Exchanges**	**NASDAQ**	**ARCA**	**NYSE**	**MKT**	**BATS**	**Across All Exchanges**
Domestic Common Stock[4]	36,267	–	141	155	0	**36,563**	1.54%	0.00%	0.01%	0.11%	0.00%	**0.91%**
International Common Stock[5]	7,747	–	10	6	–	**7,763**	3.11%	0.00%	0.01%	0.02%	0.00%	**1.46%**
American Depositary Receipts[6]	4,009	–	104	2	–	**4,115**	3.88%	0.00%	0.06%	0.04%	0.00%	**1.26%**
Exchange Traded Funds[7]	1,114	2,353	–	–	73	**3,540**	0.65%	0.24%	0.00%	0.00%	0.21%	**0.29%**
Other[8]	376	463	23	28	–	**890**	0.52%	1.59%	0.00%	0.04%	0.00%	**0.10%**
Total Across All CRSP Share Codes	**49,513**	**2,816**	**278**	**191**	**73**	**52,871**	**1.66%**	**0.28%**	**0.01%**	**0.08%**	**0.21%**	**0.72%**

Source: SEC Straddle Data; CRSP Data; CRSP Data Guide; TAQ Data

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. The sample is limited to the universe of stocks included in CRSP and the universe of stocks traded on BATS.
[2] There are 609 trading days in the sample, excluding August 24, 2015.
[3] Each cell in this panel of the table shows the percent of days on which symbols trading on the given exchange with the given share code experienced at least one long-lasting straddle state. For example, the cell that corresponds to share code 11 and NASDAQ represents the number of days on which symbols with share code 11 trading on NASDAQ experienced a straddle state, divided by the total number of symbol-days in CRSP with share code 11 that trade on NASDAQ.
[4] Corresponds to CRSP share code 11.
[5] Corresponds to CRSP share code 12.
[6] Corresponds to CRSP share code 31.
[7] Corresponds to CRSP share code 73.
[8] Corresponds to all other CRSP share codes and includes securities such as closed-end funds and REITs.

Long-Lasting Straddle State Count Aggregated by CRSP Share Code and Primary Listing Exchange[1]

8/24/15

CRSP Share Code Definitions	Long-Lasting Straddle State Counts						Percentage of Symbol-Days That Experienced a Long-Lasting Straddle State[2]					
	NASDAQ	ARCA	NYSE	MKT	BATS	Across All Exchanges	NASDAQ	ARCA	NYSE	MKT	BATS	Across All Exchanges
Domestic Common Stock[3]	227	–	32	1	–	**260**	4.63%	0.00%	2.27%	0.49%	0.00%	**3.57%**
International Common Stock[4]	46	–	5	0	–	**51**	10.68%	0.00%	1.81%	0.00%	0.00%	**5.73%**
American Depositary Receipts[5]	14	–	6	0	–	**20**	7.34%	0.00%	2.20%	0.00%	0.00%	**3.82%**
Exchange Traded Funds[6]	86	760	–	–	6	**852**	26.59%	30.77%	0.00%	0.00%	17.14%	**29.99%**
Other[7]	7	5	20	0	–	**32**	8.33%	9.38%	2.33%	0.00%	0.00%	**2.82%**
Total Across All CRSP Share Codes	**380**	**765**	**63**	**1**	**6**	**1,215**	**6.68%**	**30.27%**	**2.25%**	**0.28%**	**17.14%**	**9.28%**

Source: SEC Straddle Data; CRSP Data; CRSP Data Guide; TAQ Data

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. The sample is limited to the universe of stocks included in CRSP and the universe of stocks traded on BATS.
[2] Each cell in this panel of the table shows the percent of days on which symbols trading on the given exchange with the given share code experienced at least one long-lasting straddle state. For example, the cell that corresponds to share code 11 and NASDAQ represents the number of days on which symbols with share code 11 trading on NASDAQ experienced a straddle state, divided by the total number of symbol-days in CRSP with share code 11 that trade on NASDAQ.
[3] Corresponds to CRSP share code 11.
[4] Corresponds to CRSP share code 12.
[5] Corresponds to CRSP share code 31.
[6] Corresponds to CRSP share code 73.
[7] Corresponds to all other CRSP share codes and includes securities such as closed-end funds and REITs.

Long-Lasting Straddle State Count Aggregated by CRSP Share Code and Primary Listing Exchange[1]

8/1/14 – 12/31/16[2]

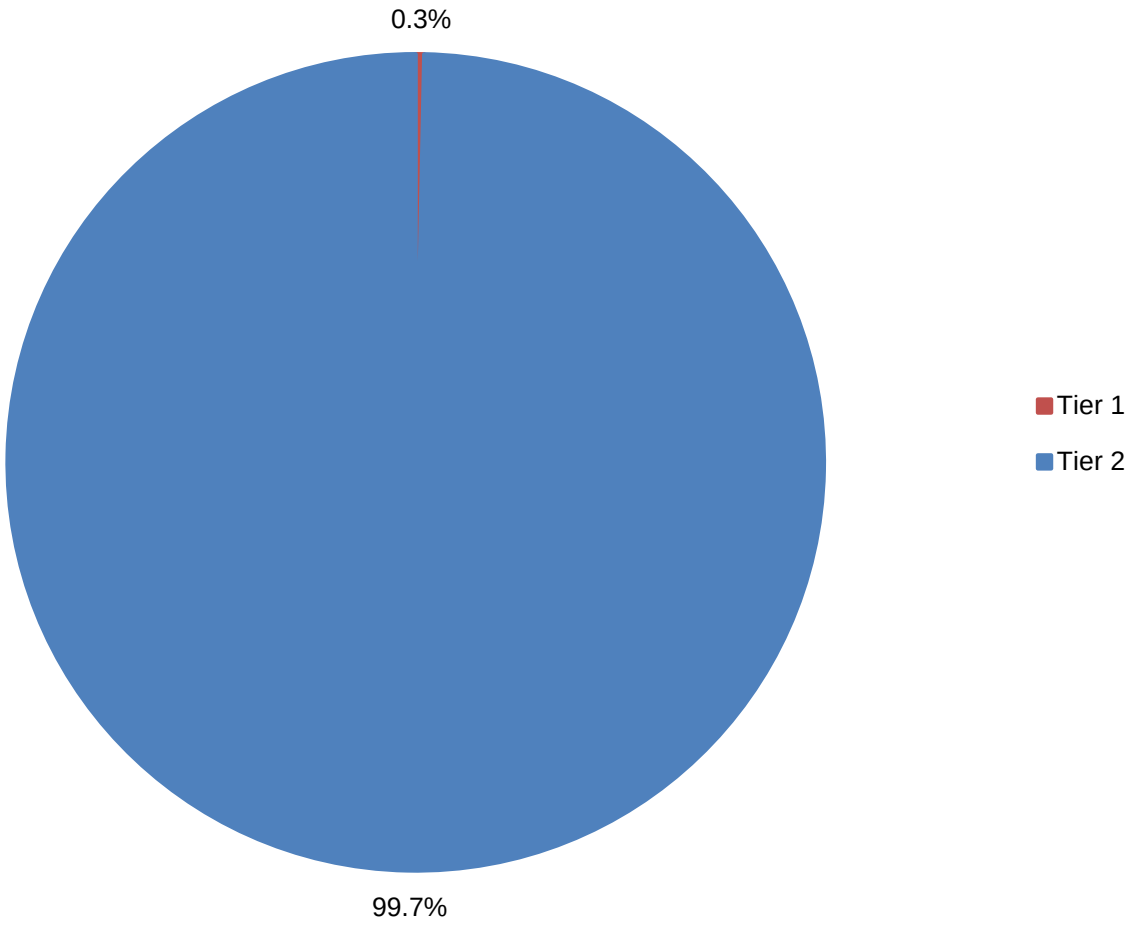
CRSP Share Code Definitions	Long-Lasting Straddle State Counts for Symbols That Experienced a Long-Lasting Straddle on More Than 100 Days						Long-Lasting Straddle State Counts for Symbols That Experienced a Long-Lasting Straddle on More Than 200 Days					
	NASDAQ	ARCA	NYSE	MKT	BATS	Across All Exchanges	NASDAQ	ARCA	NYSE	MKT	BATS	Across All Exchanges
Domestic Common Stock[3]	15,351	–	–	–	–	**15,351**	7,392	–	–	–	–	**7,392**
International Common Stock[4]	3,997	–	–	–	–	**3,997**	1,951	–	–	–	–	**1,951**
American Depositary Receipts[5]	2,170	–	–	–	–	**2,170**	1,213	–	–	–	–	**1,213**
Exchange Traded Funds[6]	–	–	–	–	–	**–**	–	–	–	–	–	**–**
Other[7]	–	–	–	–	–	**–**	–	–	–	–	–	**–**
Total Across All CRSP Share Codes	**21,518**	**–**	**–**	**–**	**–**	**21,518**	**10,556**	**–**	**–**	**–**	**–**	**10,556**

Source: SEC Straddle Data; CRSP Data; CRSP Data Guide; TAQ Data

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. The sample is limited to the universe of stocks included in CRSP and the universe of stocks traded on BATS.
[2] There are 609 trading days in the sample, excluding August 24, 2015.
[3] Corresponds to CRSP share code 11.
[4] Corresponds to CRSP share code 12.
[5] Corresponds to CRSP share code 31.
[6] Corresponds to CRSP share code 73.
[7] Corresponds to all other CRSP share codes and includes securities such as closed-end funds and REITs.

Breakdown of Symbol-Days with at Least One Long-Lasting Straddle State by Tier[1]

8/1/14 – 12/31/16[2]

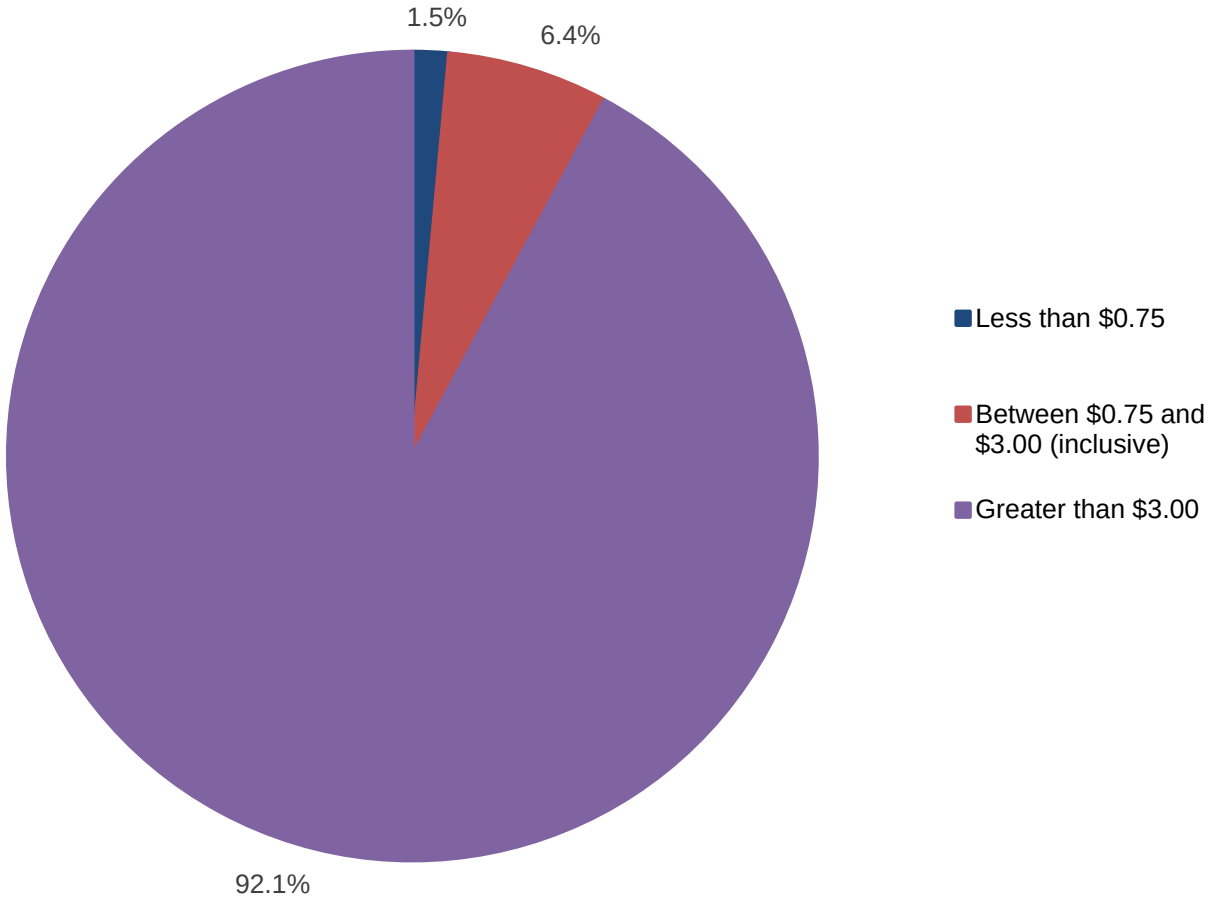


Source: CRSP; SEC Price Bands Data

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. The sample is limited to the universe of symbols in CRSP.
[2] The straddle states that occurred on August 24, 2015 have been excluded.

Breakdown of Symbol-Days with at Least One Long-Lasting Straddle State by Closing Price on the Prior Day[1]

8/1/14 – 12/31/16[2]

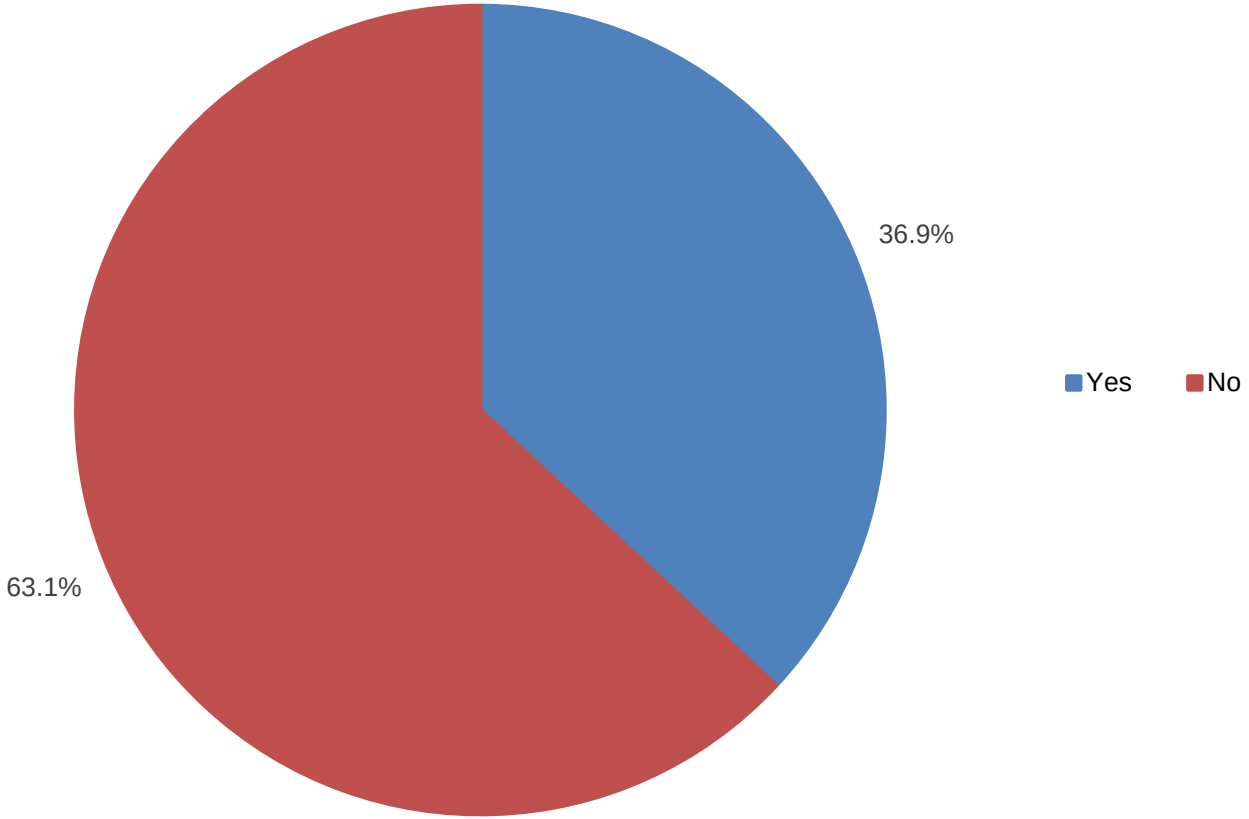


Source: CRSP

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. The sample is limited to the universe of symbols in CRSP.
[2] The straddle states that occurred on August 24, 2015 have been excluded.

Breakdown of Symbol-Days with at Least One Long-Lasting Straddle State by Whether or Not There Was an Opening Trade[1][2]

8/1/14 – 12/31/16[3]

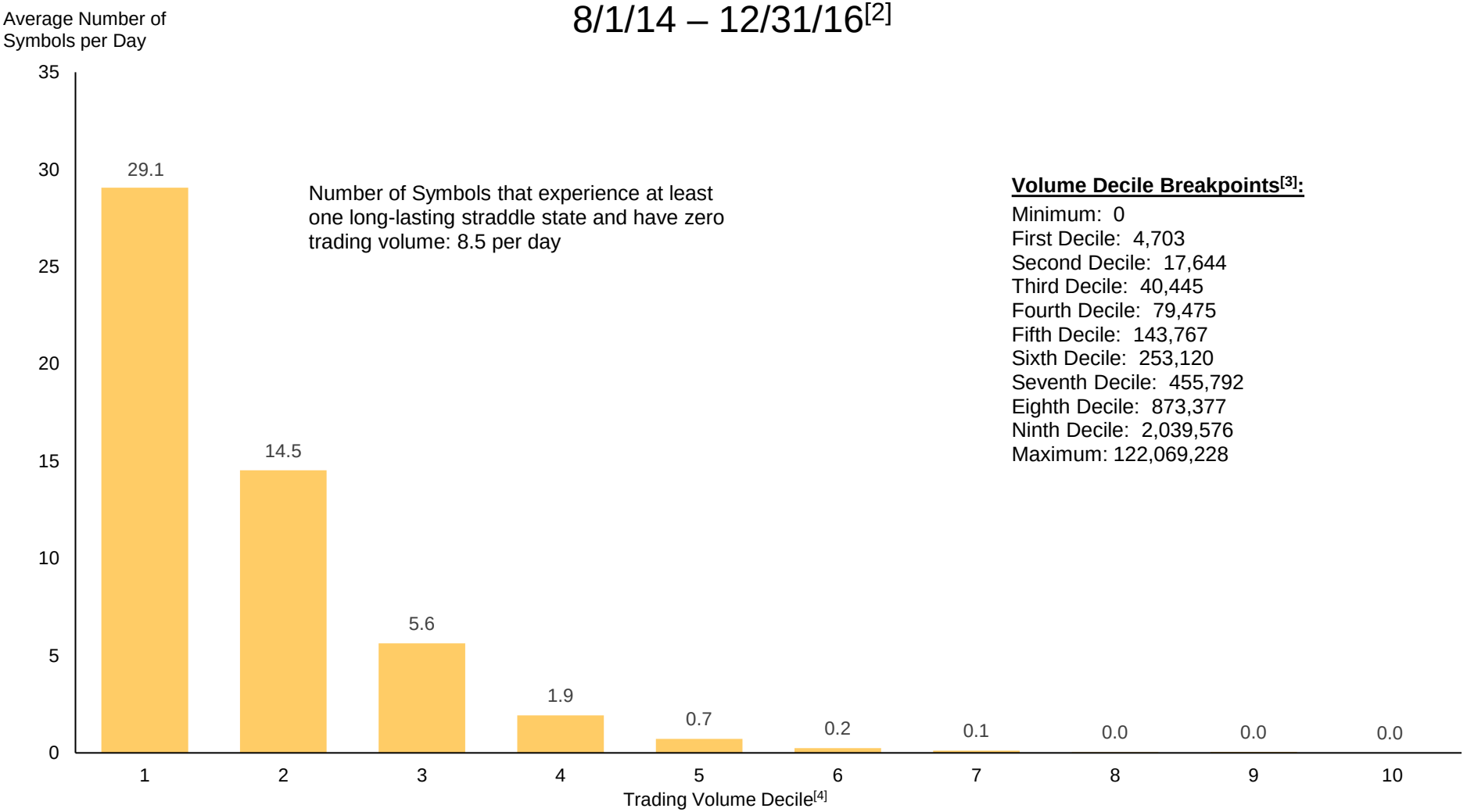


Source: CRSP; SEC Price Bands Data; TAQ Data

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. The sample is limited to the universe of symbols in CRSP.
[2] For straddle states that began at 9:30 AM, 32% of the symbols had an opening trade. For straddle states that began at 9:45 AM, 43% of the symbols had an opening trade.
[3] The straddle states that occurred on August 24, 2015 have been excluded.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Monthly Trading Volume[1]

8/1/14 – 12/31/16[2]



Number of Symbols that experience at least one long-lasting straddle state and have zero trading volume: 8.5 per day

Volume Decile Breakpoints[3]:

Minimum: 0
First Decile: 4,703
Second Decile: 17,644
Third Decile: 40,445
Fourth Decile: 79,475
Fifth Decile: 143,767
Sixth Decile: 253,120
Seventh Decile: 455,792
Eighth Decile: 873,377
Ninth Decile: 2,039,576
Maximum: 122,069,228

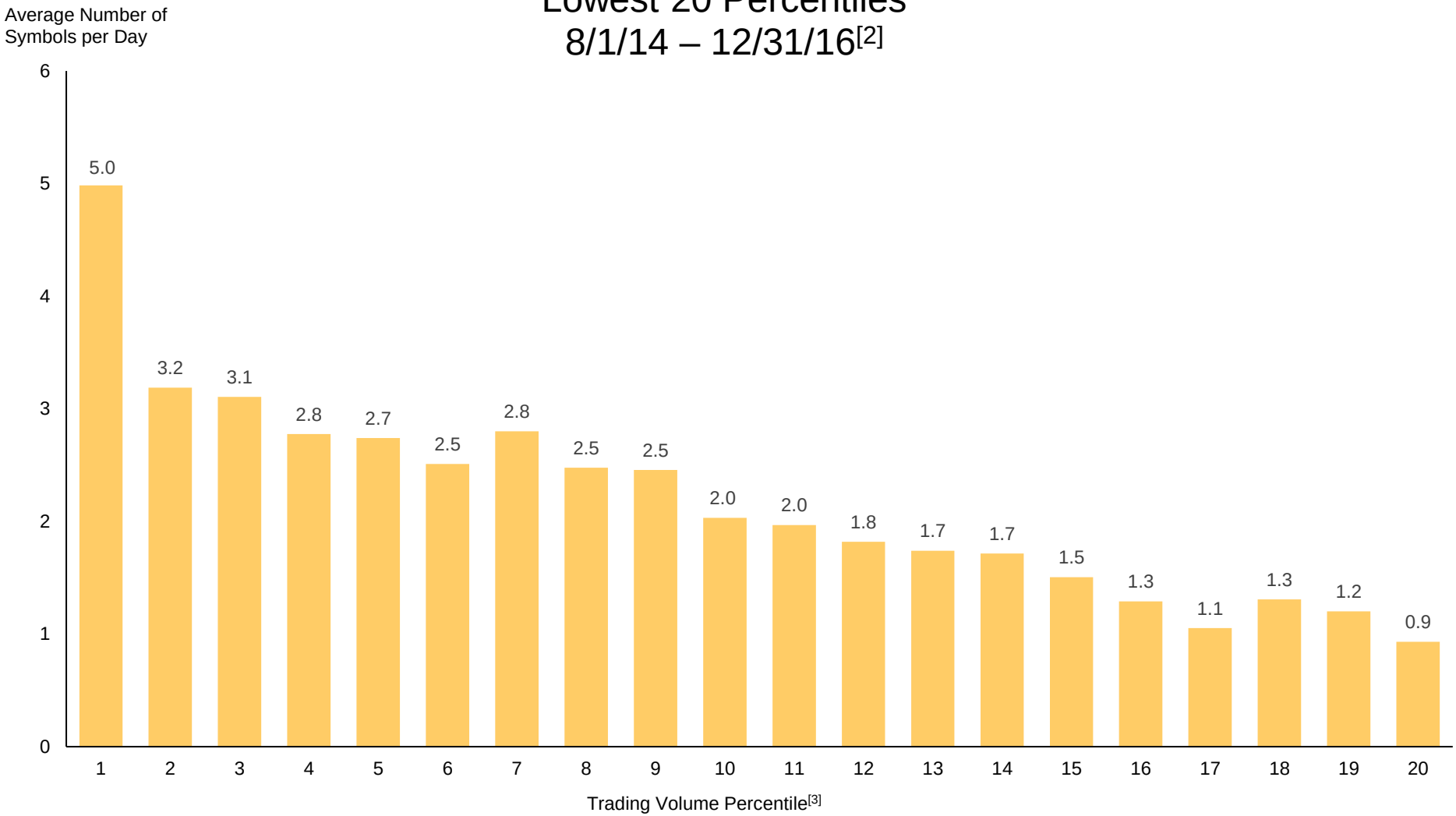
Source: SEC Straddle Data; CRSP Data

Note:
[1] Monthly trading volume is calculated by summing the daily trading volume of a given symbol within the month.
[2] There are 609 trading days in the sample, excluding August 24, 2015.
[3] Symbol-days were assigned to trading volume deciles based on each individual month of trading. Therefore, a given symbol's percentile can vary from month to month.
[4] The volume decile breakpoints are reported in shares per day and are averaged across the months of the sample period.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Monthly Trading Volume[1]

Lowest 20 Percentiles

8/1/14 – 12/31/16[2]

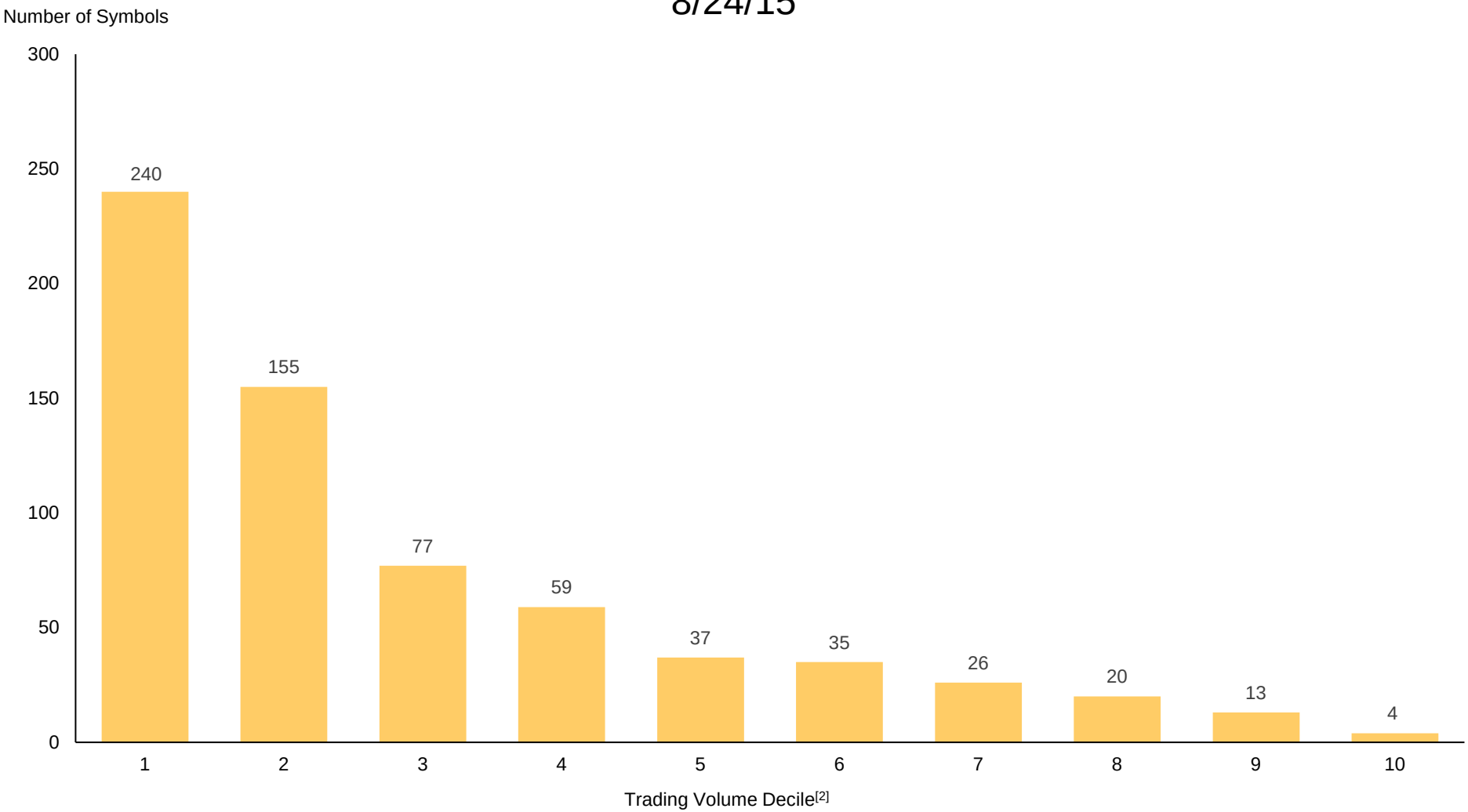


Source: SEC Straddle Data; CRSP Data

Note:
[1] Monthly trading volume is calculated by summing the daily trading volume of a given symbol within the month.
[2] There are 609 trading days in the sample, excluding August 24, 2015.
[3] Symbol-days were assigned to trading volume deciles based on each individual month of trading. Therefore, a given symbol's percentile can vary from month to month.

Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Monthly Trading Volume[1]

8/24/15

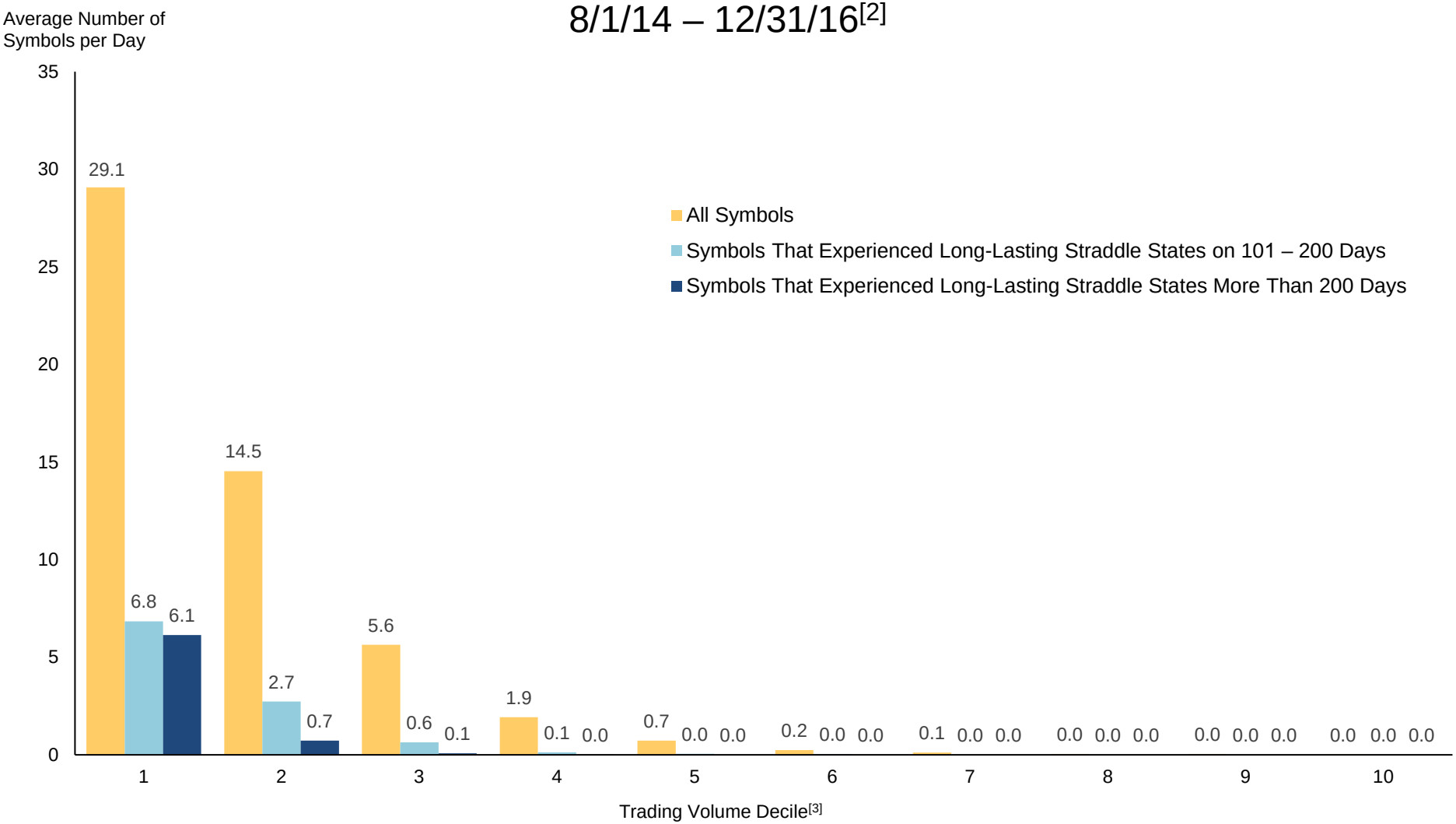


Source: SEC Straddle Data; CRSP Data

Note:
[1] Monthly trading volume is calculated by summing the daily trading volume of a given symbol within the month.
[2] Symbol-days were assigned to market capitalization deciles based on trading in August 2015.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Monthly Trading Volume[1]

8/1/14 – 12/31/16[2]

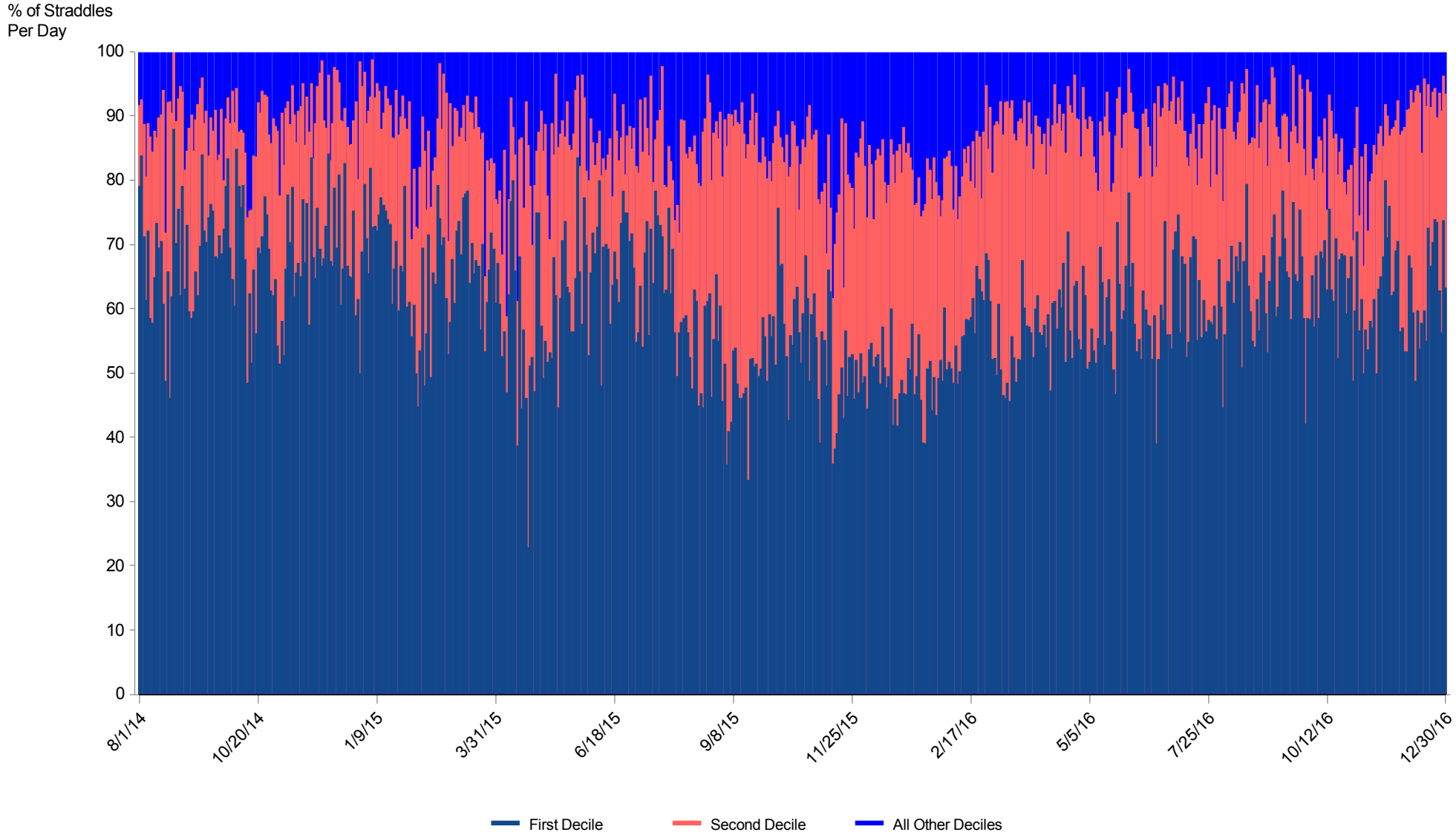


Source: SEC Straddle Data; CRSP Data

Note:
[1] Monthly trading volume is calculated by summing the daily trading volume of a given symbol within the month.
[2] There are 609 trading days in the sample, excluding August 24, 2015.
[3] Symbol-days were assigned to trading volume deciles based on each individual month of trading. Therefore, a given symbol's percentile can vary from month to month.

Percent of Long-Lasting Straddle States per Trading Day by CRSP Volume Deciles

August 2014 – December 2016



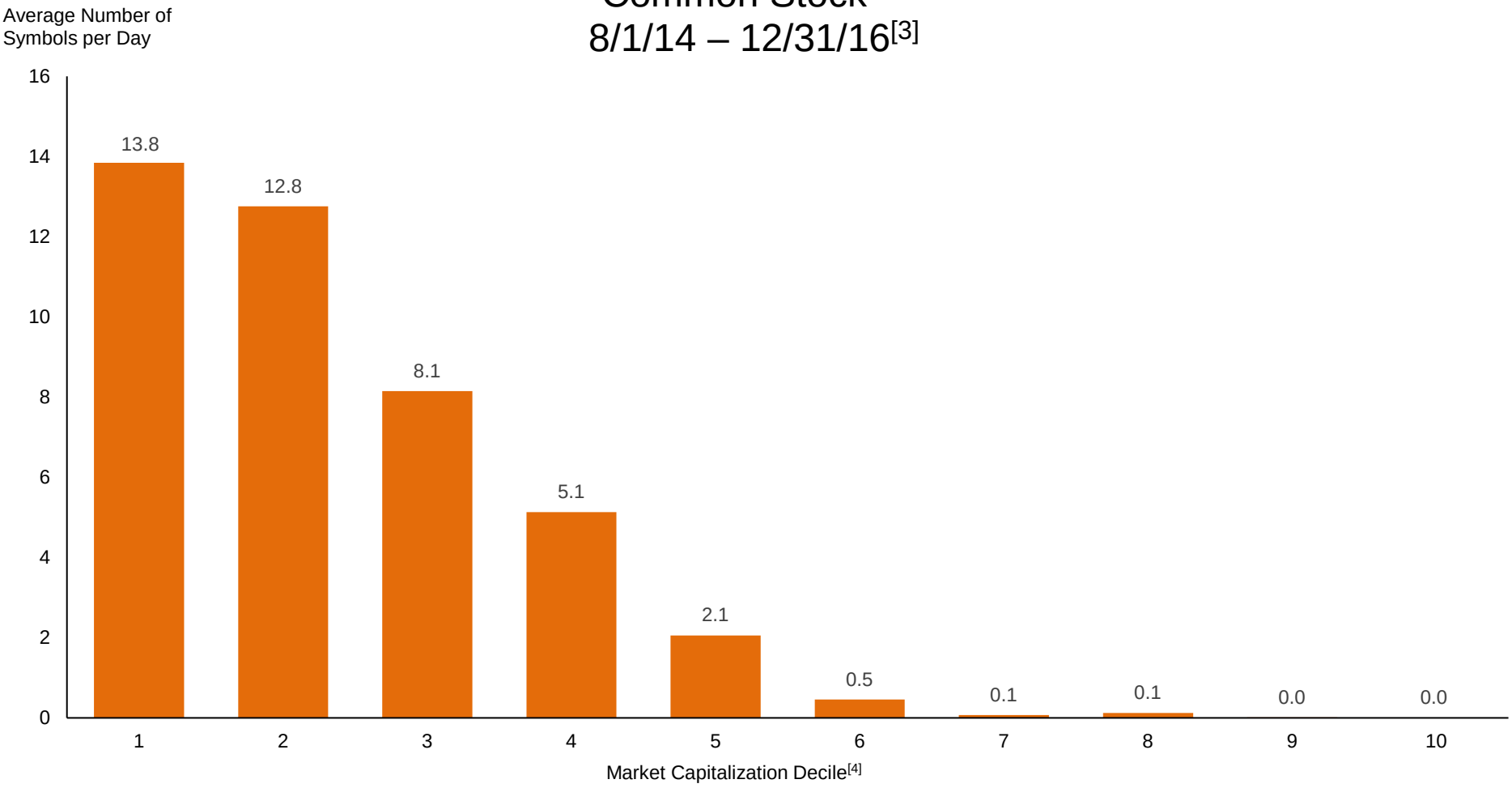
Source: SEC Straddle Data; CRSP Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Average Daily Market Capitalization[1]

Common Stock[2]

8/1/14 – 12/31/16[3]



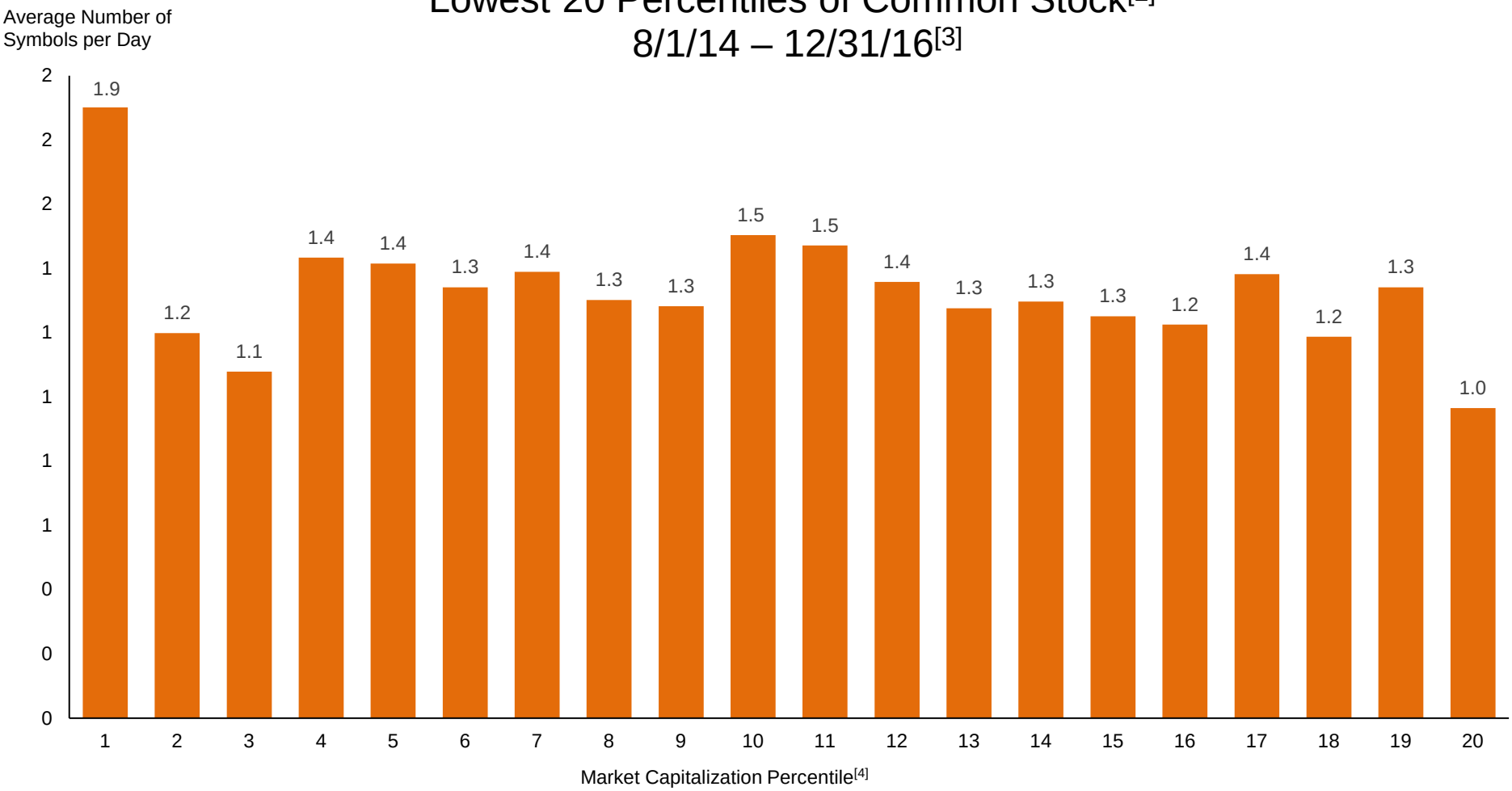
Source: SEC Straddle Data; CRSP Data

Note:
[1] Average daily market capitalization is calculated on a monthly basis by multiplying the daily closing price by the daily number of shares outstanding, summing this value across the month, and then dividing this sum by the number of trading days in the month.
[2] Common stocks are symbols with CRSP share code 11 or 12. Symbols with other share codes are excluded.
[3] There are 609 trading days in the sample, excluding August 24, 2015.
[4] Symbol-days were assigned to market capitalization deciles based on each individual month of trading. Therefore, a given symbol's percentile can vary from month to month.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Average Daily Market Capitalization[1]

Lowest 20 Percentiles of Common Stock[2]

8/1/14 – 12/31/16[3]



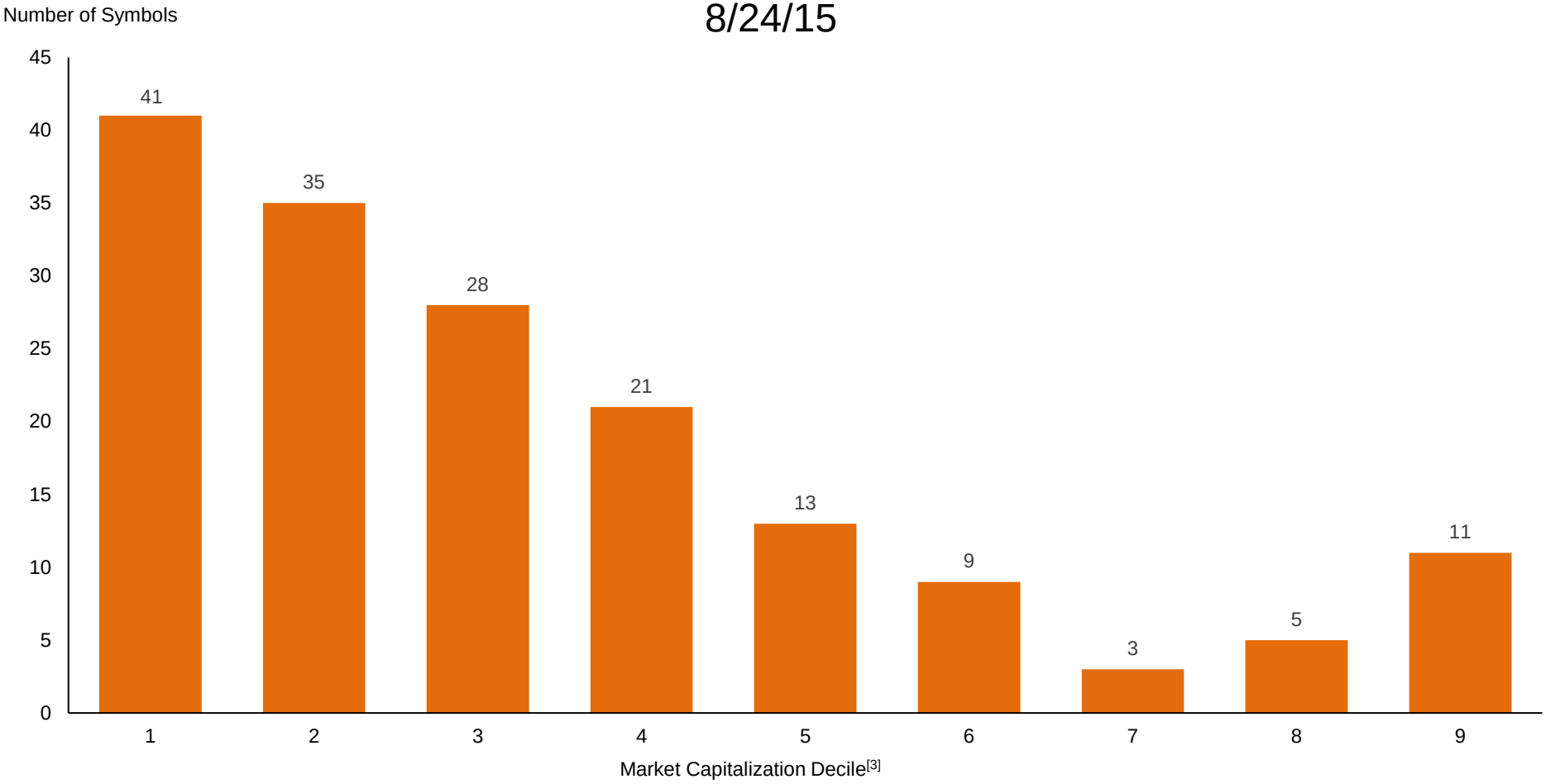
Source: SEC Straddle Data; CRSP Data

Note:
[1] Average daily market capitalization is calculated on a monthly basis by multiplying the daily closing price by the daily number of shares outstanding, summing this value across the month, and then dividing this sum by the number of trading days in the month.
[2] Common stocks are symbols with CRSP share code 11 or 12. Symbols with other share codes are excluded.
[3] There are 609 trading days in the sample, excluding August 24, 2015.
[4] Symbol-days were assigned to market capitalization deciles based on each individual month of trading. Therefore, a given symbol's percentile can vary from month to month.

Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Average Daily Market Capitalization[1]

Common Stock[2]

8/24/15



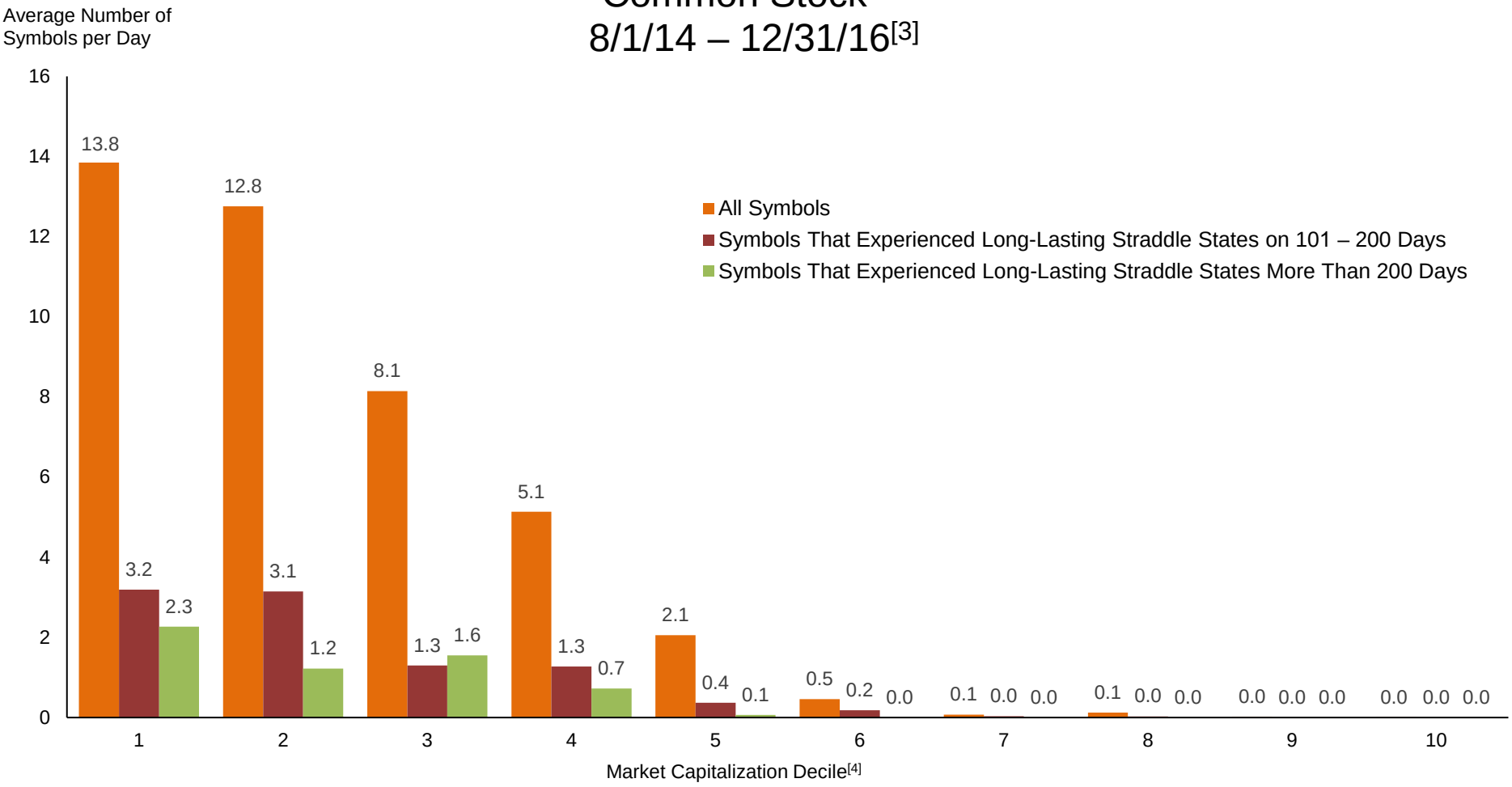
Source: SEC Straddle Data; CRSP Data

Note:
[1] Average daily market capitalization is calculated on a monthly basis by multiplying the daily closing price by the daily number of shares outstanding, summing this value across the month, and then dividing this sum by the number of trading days in the month.
[2] Common stocks are symbols with CRSP share code 11 or 12. Symbols with other share codes are excluded.
[3] Symbol-days were assigned to market capitalization deciles based on trading in August 2015.

Average Number of Symbols Experiencing at Least One Long-Lasting Straddle State Partitioned by Average Daily Market Capitalization[1]

Common Stock[2]

8/1/14 – 12/31/16[3]



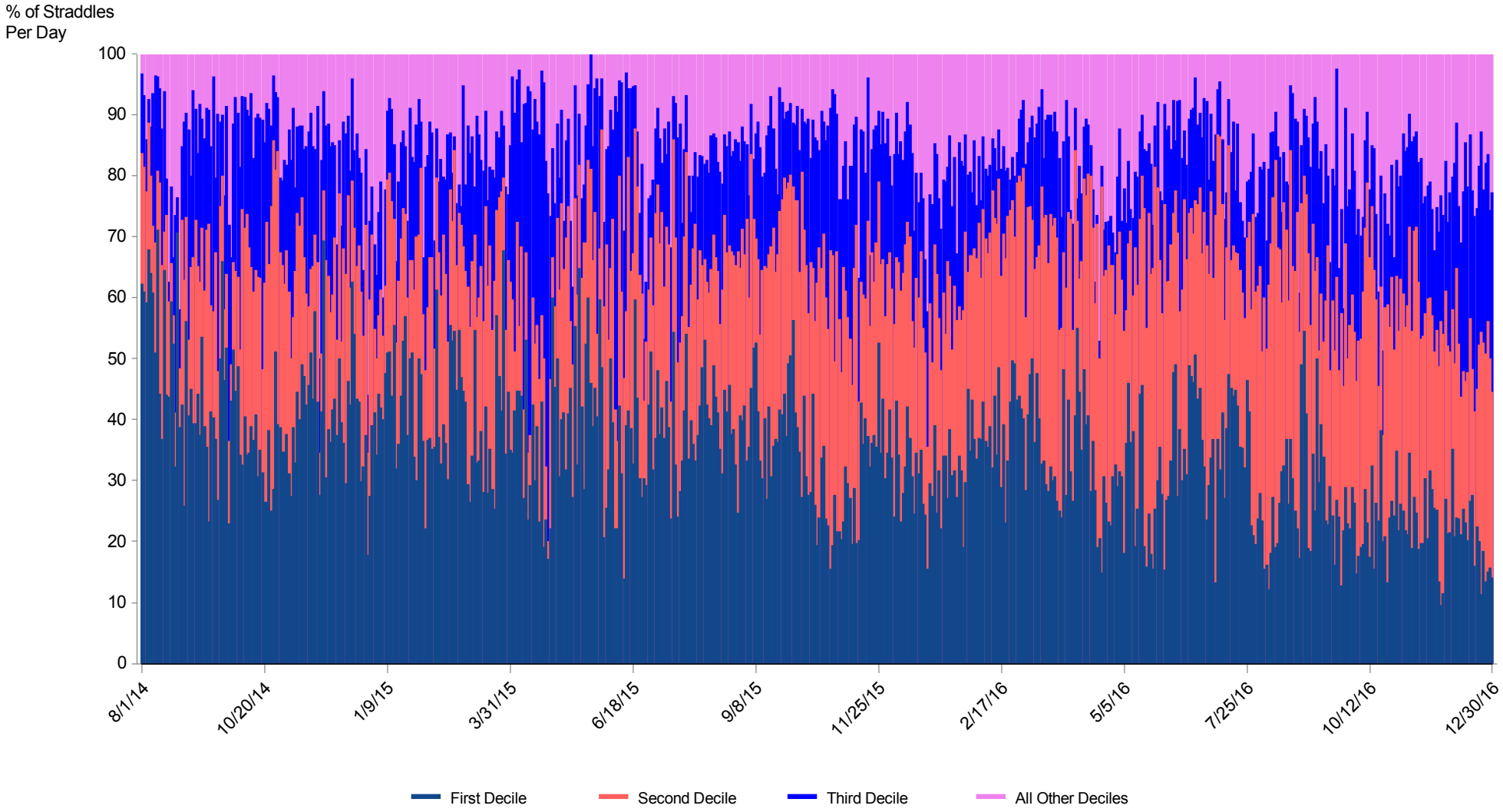
Source: SEC Straddle Data; CRSP Data

Note:
[1] Average daily market capitalization is calculated on a monthly basis by multiplying the daily closing price by the daily number of shares outstanding, summing this value across the month, and then dividing this sum by the number of trading days in the month.
[2] Common stocks are symbols with CRSP share code 11 or 12. Symbols with other share codes are excluded.
[3] There are 609 trading days in the sample, excluding August 24, 2015.
[4] Symbol-days were assigned to market capitalization deciles based on each individual month of trading. Therefore, a given symbol's percentile can vary from month to month.

Percent of Long-Lasting Straddle States per Trading Day by CRSP Market Cap Deciles

Common Stocks Only

August 2014 – December 2016



Source: SEC Straddle Data; CRSP Data

Note: The straddle states that occurred on August 24, 2015 have been excluded.

Factors That Influence the Occurrence of Straddle States

$$Straddle\ State\ Indicator_{i,t} = \beta_0 + \beta_1 X_{i,t} + \beta_2 TE_t + \epsilon_{i,t}$$

- Implement a Logistic Regression Model to test which factors significantly increase the likelihood of experiencing a long-lasting straddle state.

- Run at the symbol-day level.
  - Dependent Variable: Indicator variable with a value of one if the stock experienced at least one long-lasting straddle state on that particular day.
  - Independent Variables:
    - Log of trading volume on that day.
    - Indicator variable with a value of one if the stock is in Tier 1.
    - Indicator variable with a value of one if the prior day close was $3 or below.
    - Indicator variable with a value of one if the prior day close was below $0.75.
    - Indicator variable with a value of one if there was no opening trade.
    - Abnormal volume measured as quintile rank of the current day's volume among the prior 30 days.
    - Stock volatility measured by the standard deviation of returns over the prior 30 days.
  - Sample is limited to the universe of stocks in CRSP.[1]

[1] CRSP does not have data on BATS listed securities, ETNs, preferred stock, and units. In addition, symbols-days for which the standard deviation of the daily returns of the prior 30 days exceeded 20% and instances in which the existence of an opening trade could not be identified are excluded. One share is added to the volume on all symbol-days in order to preserve symbol-days with zero volume.

Logistic Regression Results[1]

Likelihood of Experiencing a Long-Lasting Straddle[2]

8/1/14 – 12/31/16[3]

				Including Time Fixed Effects[4]		
Parameter	**All Symbols**	**Common Stock**	**ETFs**	**All Symbols**	**Common Stock**	**ETFs**
	(1)	(2)	(3)	(4)	(5)	(6)
Log Volume	-0.277**	-0.362**	-0.232**	-0.275**	-0.361**	-0.243**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tier 1	-2.714**	-3.605**	-0.825**	-2.724**	-3.632**	-0.721**
	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
Prior Day's Close Below $3	-1.385**	-1.464**	-1.406*	-1.390**	-1.485**	-1.488**
	(0.000)	(0.000)	(0.047)	(0.000)	(0.000)	(0.002)
Prior Day's Close Below $0.75[5]	-1.420**	-1.136**	–	-1.460**	-1.197**	–
	(0.000)	(0.000)		(0.000)	(0.000)	
Abnormal Volume	0.363**	0.449**	0.472**	0.354**	0.443**	0.471**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
No Opening Trade	0.698**	0.570**	1.090**	0.727**	0.607**	1.179**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility	37.373**	31.067**	36.465**	37.361**	30.805**	41.804**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of Symbol/Days	4,261,730	2,247,031	915,771	4,261,730	2,247,031	839,834

Sources: CRSP; SEC Straddle Data; SEC Price Bands Data; TAQ Data

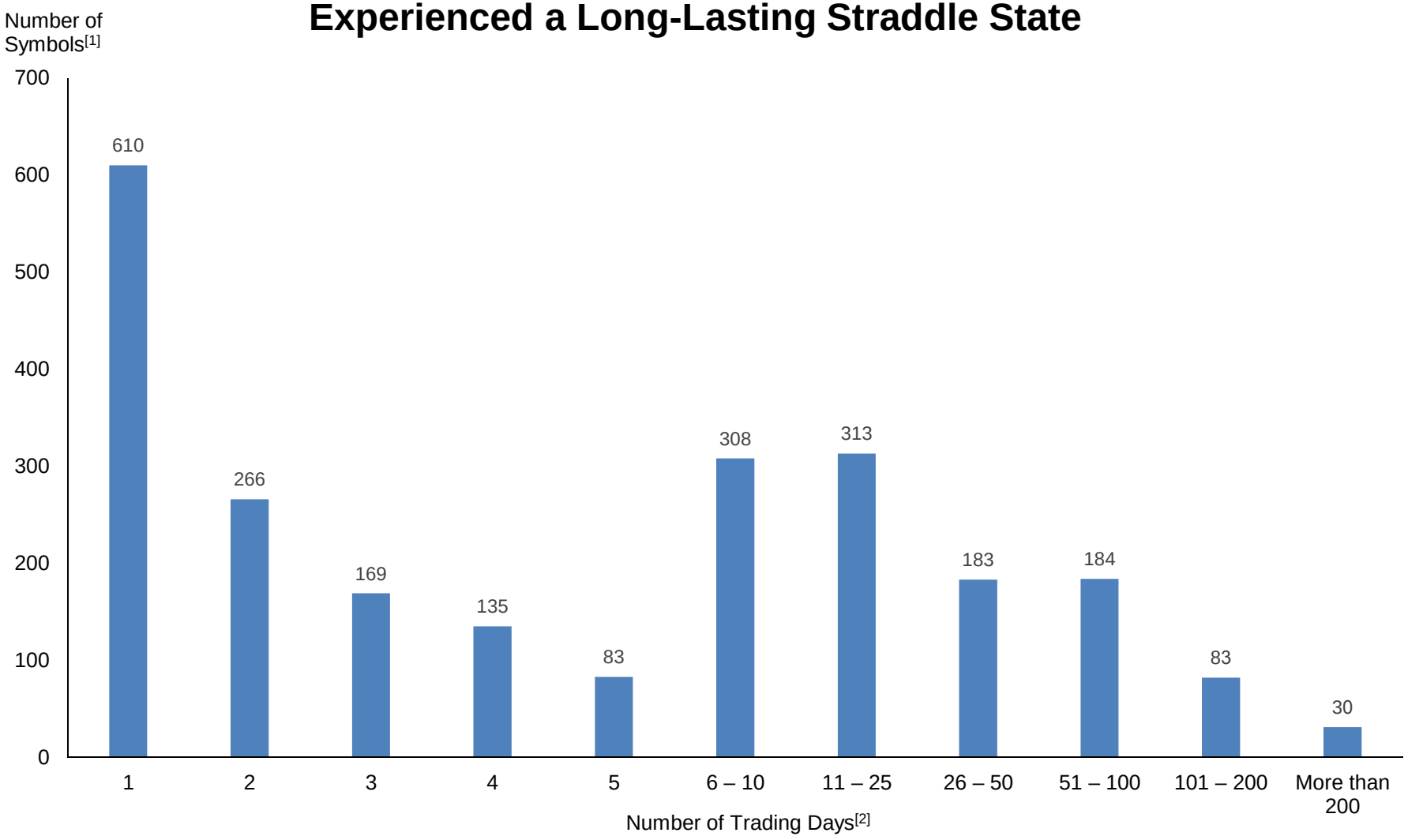
[1] This table reports results from a logit regression estimating the effects of various factors on the likelihood of experiencing a long-lasting straddle state. The sample includes data for all stocks included in the CRSP database. The dependent variable is an indicator variable that equals one if a stock experienced a long-lasting straddle on that particular day. Standard errors are estimated by clustering on stocks for the specifications run without fixed effects. The "Permno" in CRSP is used to identify stocks over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] Long-lasting straddle states are defined as a straddle state lasting at least five minutes.
[3] The straddle states that occurred on August 24, 2015 have been excluded.
[4] Time fixed effects were implemented at the day level.
[5] There were only 11 observations where the prior day's closing price was below $0.75 for ETFs. This variable is excluded for the specifications that only include ETFs.

Section IV: Activity During and After Long-Lasting Straddle States

Propensity of Straddle States to Recur Across Days

- Of the 2,364 symbols that experienced a long-lasting straddle state, 26% experienced long-lasting straddle states on just one day.
- 30 symbols experienced at least one long-lasting straddle state on more than 200 days out of a sample of 609 days.
  - These 30 symbols are not concentrated within a particular volume decile, market capitalization decile, or price level.
- Typically 10 to 25 symbols per day had a long-lasting straddle state in each of the five previous trading days.
- Similarly, 10 to 25 symbols per day had no long-lasting straddle states in the previous five trading days, although there was more day-to-day variation in this metric.

Distribution of Number of Trading Days on Which a Stock Experienced a Long-Lasting Straddle State



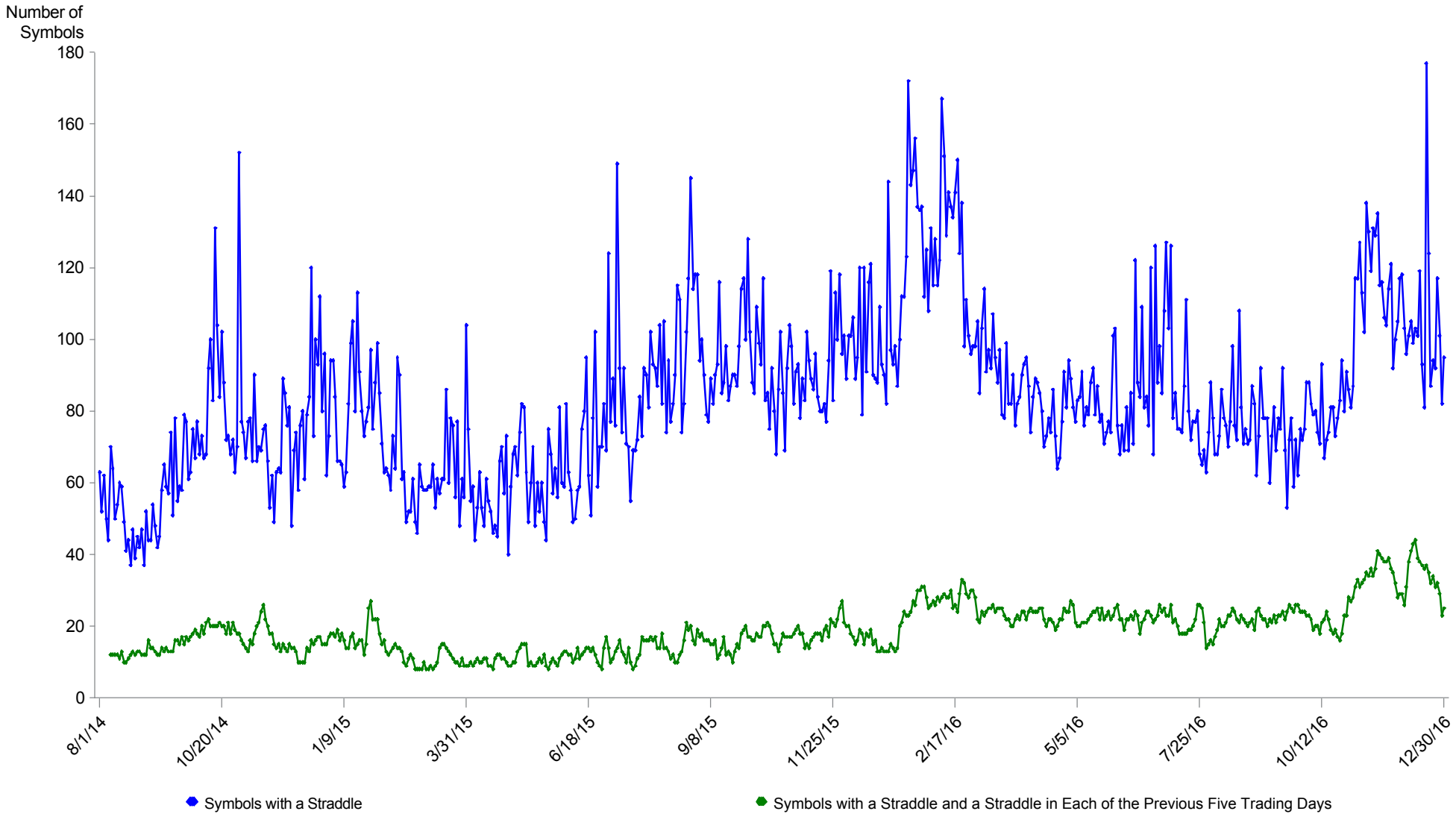
Source: SEC Straddle Data

Note:
[1] There are 2,364 unique symbols in the full sample.
[2] There are 609 trading days in the full sample. August 24, 2015 has been excluded from the sample.

Daily Counts of Symbols Experiencing at Least One Long-Lasting Straddle State

Compared to Symbols with a Long-Lasting Straddle State in Each of the Previous Five Trading Days

August 2014 – December 2016



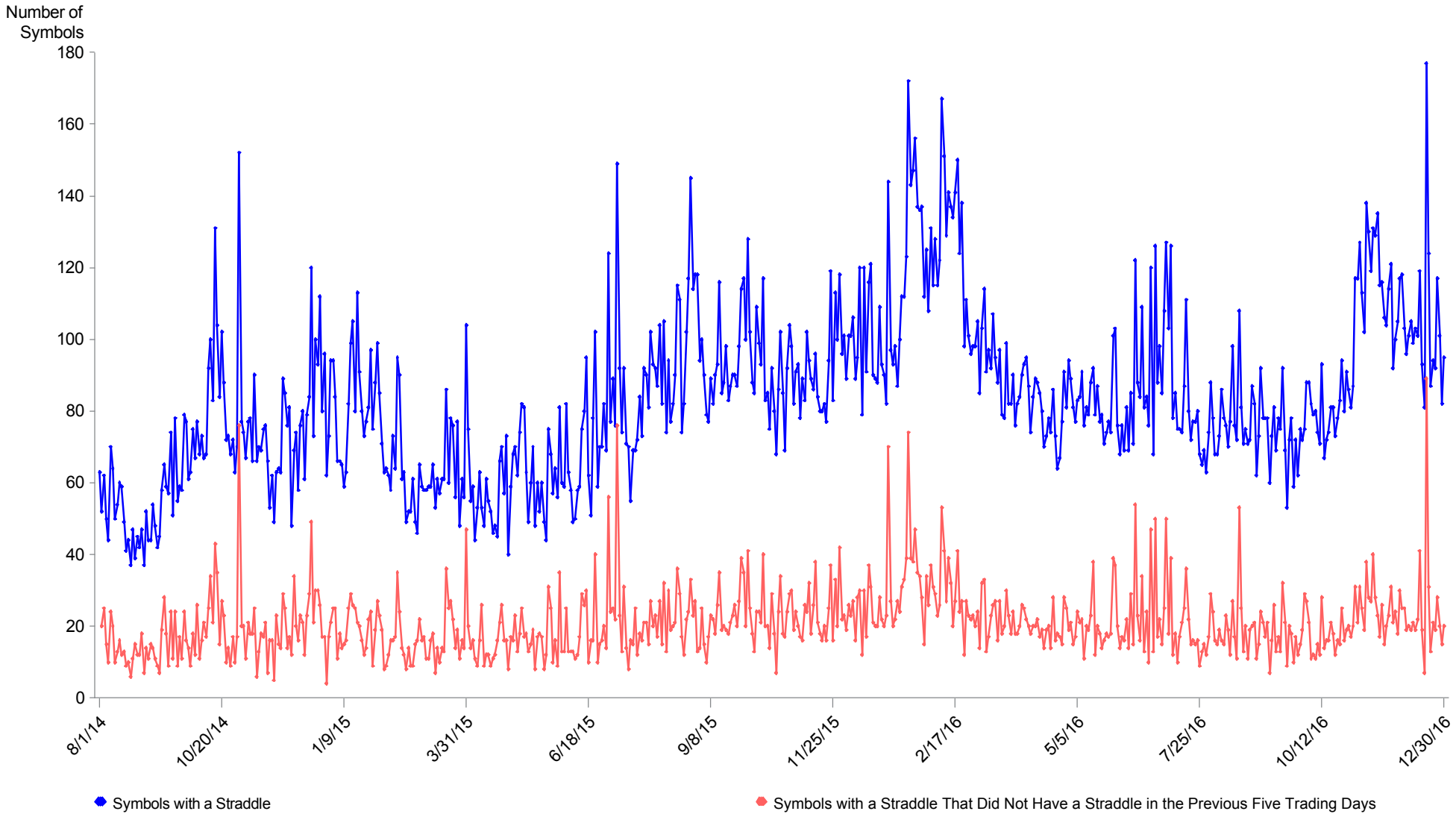
Source: SEC Straddle Data

Note: The symbols that experienced straddle states on August 24, 2015 have been excluded.

Daily Counts of Symbols Experiencing at Least One Long-Lasting Straddle State

Compared to Symbols without a Long-Lasting Straddle in the Last Five Trading Days

August 2014 – December 2016



Source: SEC Straddle Data

Note: The symbols that experienced straddle states on August 24, 2015 have been excluded.

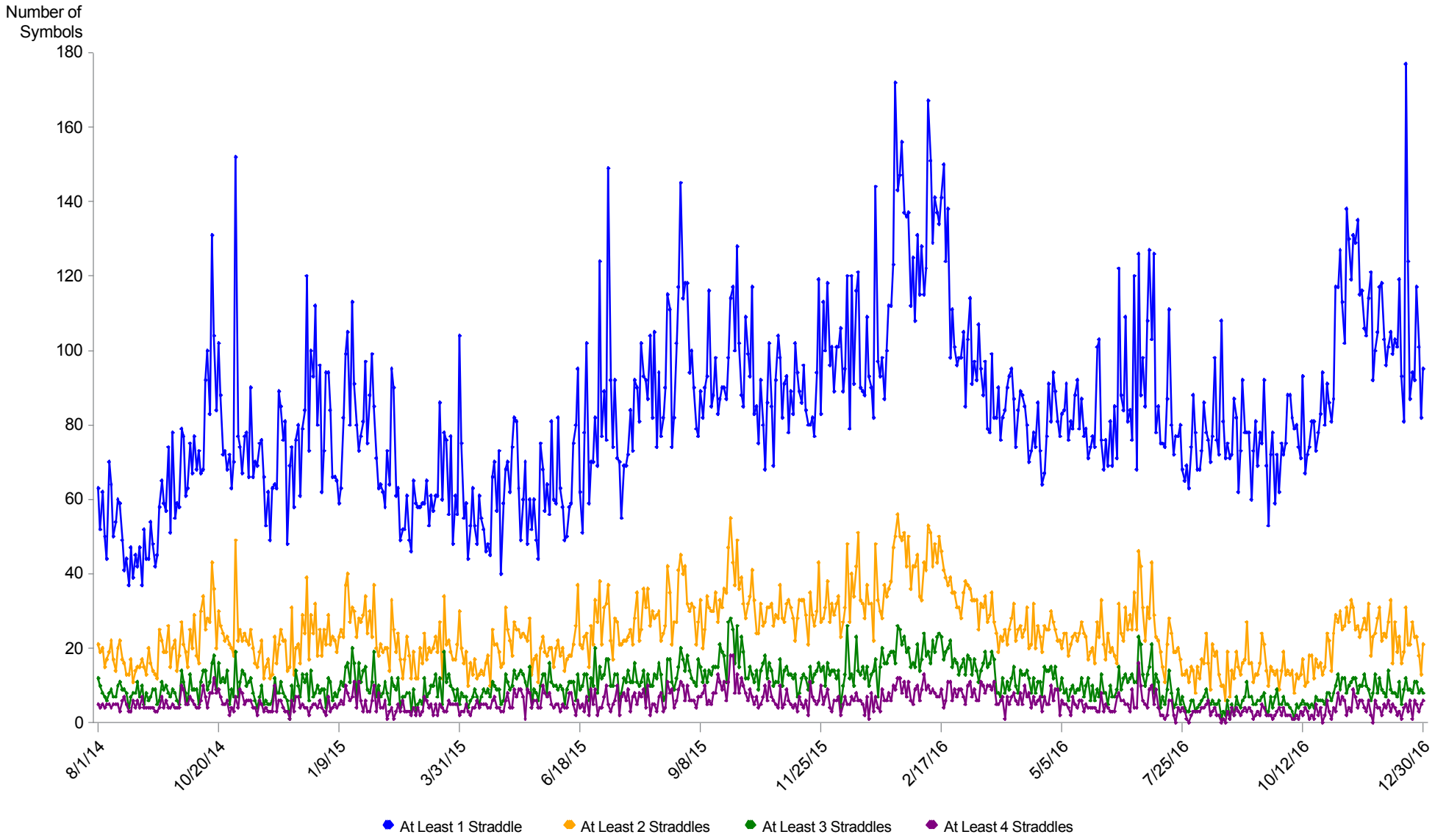
Propensity of Straddle States to Recur Within Days

- The majority of symbols that experience a long-lasting straddle state on a given day experience only one long-lasting straddle state on that day.
  - Of the symbols that experience a long-lasting straddle state on a given day, 29.5% experience at least two long-lasting straddles, and 12.8% experience at least three long-lasting straddles.
- 54.4% of long-lasting straddle states are eventually followed by another straddle state, short or long, on the same day.
  - 67.6% of the next straddle states are short and 32.4% are long.
  - 22% of long-lasting straddle states are immediately followed by another straddle state, and another 13.5% are followed by another straddle state within one minute.[1]
- The majority of long-lasting straddle states did not end by immediately entering into a limit or straddle state.
  - 10.8% of long-lasting straddle states resulted in a limit state.
  - 7.0% of long-lasting straddle states ultimately resulted in a trading halt.
- Symbols in the first decile of trading volume were more likely to immediately enter into another straddle state and about equally likely to enter into a limit state when compared to symbols with higher trading volume.

[1] "Immediately" means that the symbol entered into another straddle state within the same millisecond.

Daily Counts of Symbols Experiencing at Least One Long-Lasting Straddle State

August 2014 – December 2016



Source: SEC Straddle Data

Note: The symbols that experienced straddle states on August 24, 2015 have been excluded.

Long-Lasting Straddle States Partitioned by Time to Recurrence and Whether the Ensuing Straddles State Was Short or Long[1]

8/1/14 – 12/31/16[2]

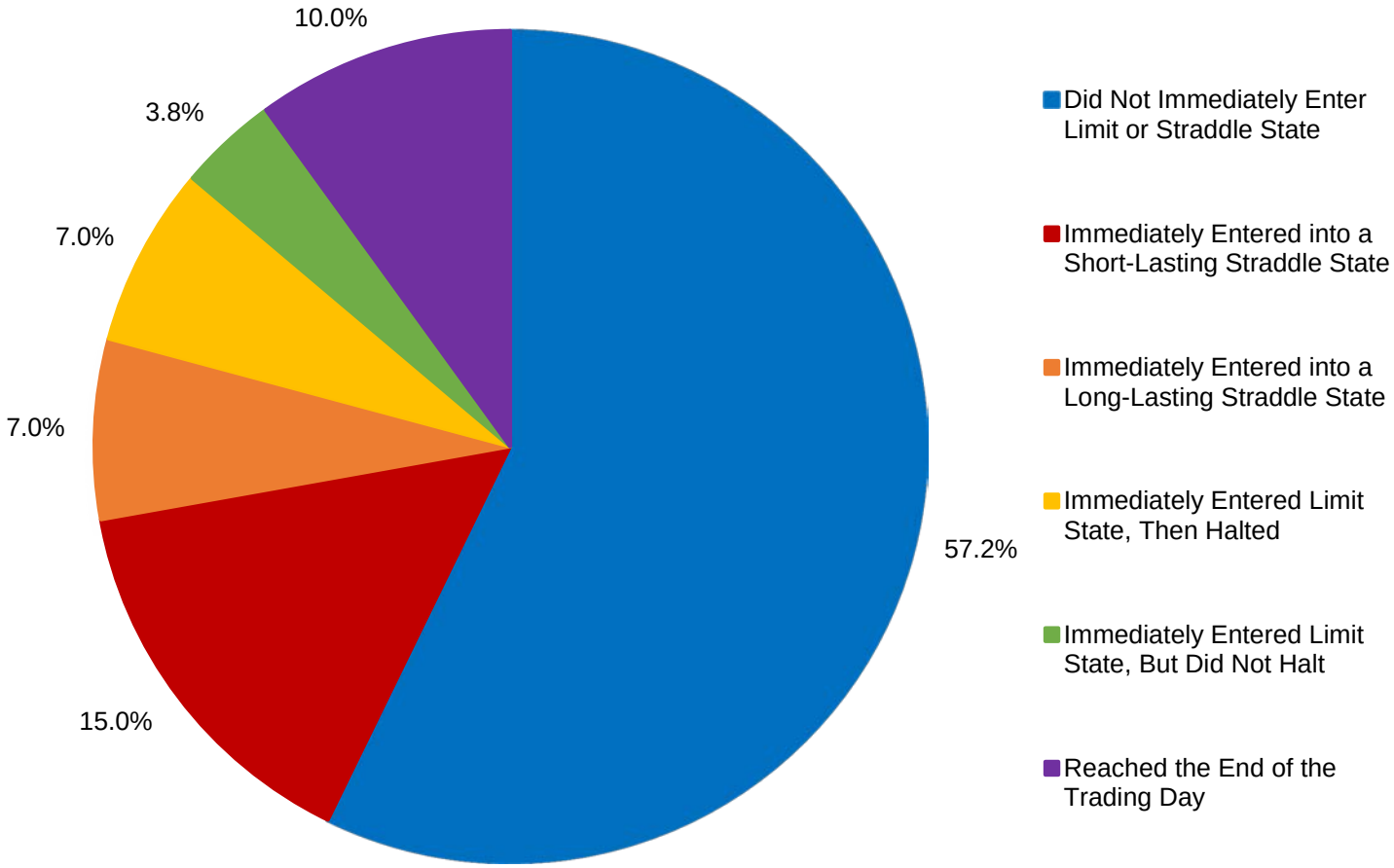
	Number of Straddles States			As a Percentage of All Long-Lasting Straddle States[3]		
Time to Next Straddle State	Entered into a Short Straddle State	Entered into a Long Straddle State	Total	Entered into a Short Straddle State	Entered into a Long Straddle State	Total
Immediately Re-entered[4]	12,837	5,998	18,835	15.0%	7.0%	22.0%
> 0 seconds – 1 minute	8,465	3,156	11,621	9.9%	3.7%	13.5%
1 minute – 10 minutes	5,253	3,243	8,496	6.1%	3.8%	9.9%
10 minutes – 1 hour	2,878	1,572	4,450	3.4%	1.8%	5.2%
1 hour – 6.5 hours	2,141	1,145	3,286	2.5%	1.3%	3.8%
Total	31,574	15,114	46,688	36.8%	17.6%	54.4%

Source: SEC Straddle Data

Note:
[1] Long-lasting straddle states are defined as lasting five minutes or more and short-lasting straddle states include all other straddle states.
[2] The straddle states that occurred on August 24, 2015 have been excluded.
[3] Of the 85,808 long-lasting straddle states in the sample, 39,120 (45.6% of the full sample) of the long-lasting straddle states were the last straddle state of the day, short or long. Of those 39,120 straddle states, 8,569 (10% of the full sample) lasted until the end of the trading day.
[4] “Immediately” means that the symbol entered into another straddle state within the same millisecond.

Long-Lasting Straddle Count by Manner in which the Straddle State Was Resolved[1]

8/1/14 – 12/31/16[2]



Source: SEC Straddle Data; SEC Halts Data; SEC Limit Data

Note:
[1] Long-lasting straddle states are defined as a straddle state lasting at least five minutes. "Immediately" means that the symbol entered into another straddle state within the same millisecond.
[2] The straddle states that occurred on August 24, 2015 have been excluded.

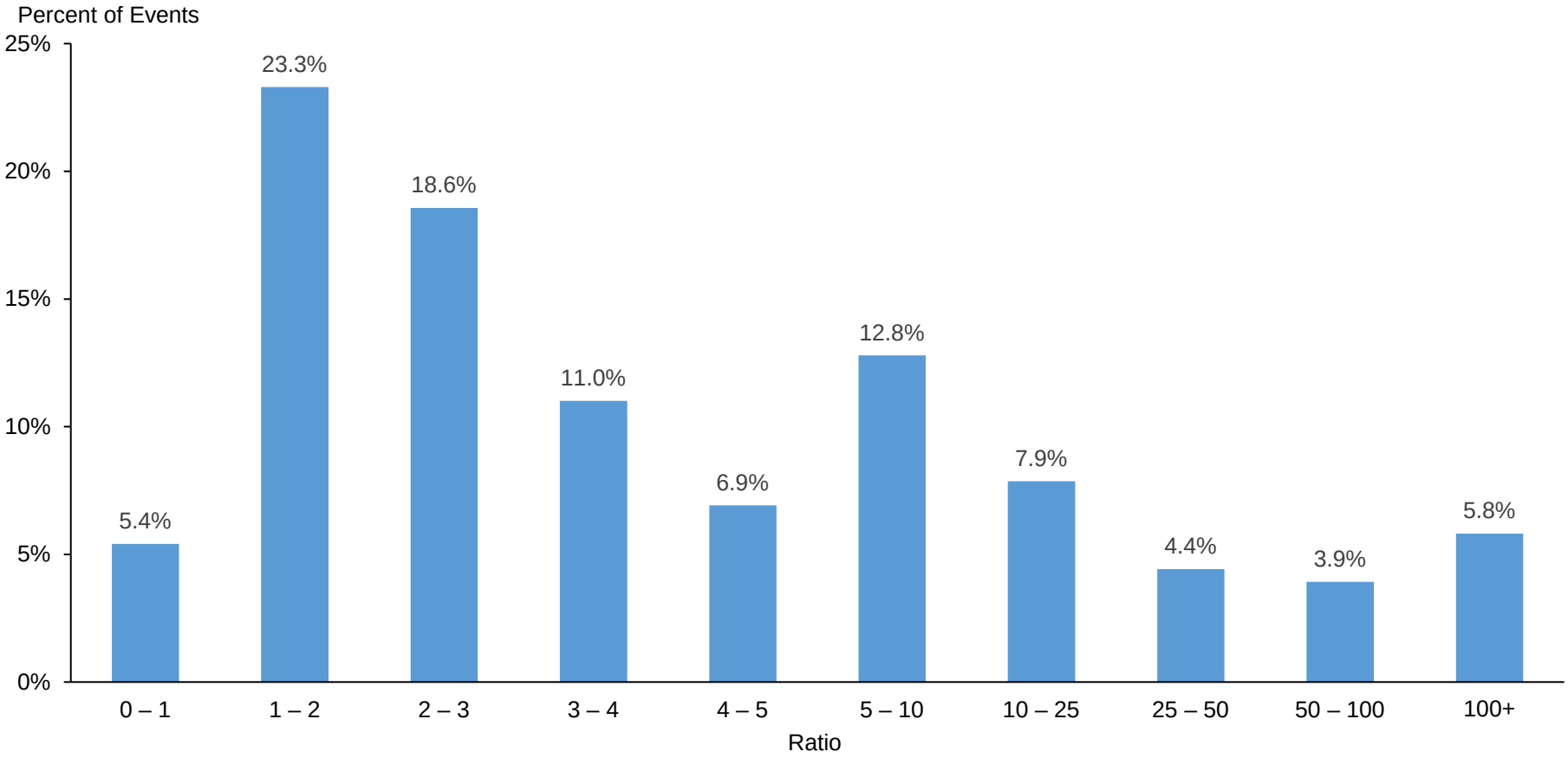
Trading and Quoting Activity During Long-Lasting Straddle States

- For a sample of straddle states with a clean control period[1][2], spreads during the straddle state were wider relative to the spread during the same time interval on the five previous trading days for 95% of straddle events.
  - For straddle events that occurred while the bands were single wide, relative quoted spreads were typically between 8% and 16%, though with more variation for symbols in the lowest quintile of volume.[3]
- In 14% of long-lasting straddle events the relative quoted spread was locked, crossed, or exceeded 100% for at least 80% of the duration of the straddle state.[4]
- There were no shares traded during 75.3% of long-lasting straddle states.[5]
  - For a sample of straddle states with a clean control period[1], volume during the long-lasting straddle state was typically lower than the volume during the same time interval on the five previous trading days.
- Limit up long-lasting straddle states were somewhat more common than limit down long-lasting straddle states.
  - For roughly one-quarter of straddle states, both the bid and the offer were outside the price bands.

[1] The control period for these analyses is the time window corresponding to the straddle event on the five trading days prior to the straddle event. A control period is “clean” if there were five trading days to use as a control period prior to the day of the straddle event and there were no long-lasting straddle states during the control period.
[2] Intervals during which the quoted relative spread was greater than 100% (or greater than 150% if the bid-ask midpoint was below $0.75) and intervals during which the quoted spread was locked or crossed have been excluded. If the total amount of time excluded from the time-weighted spread calculation exceeded 50% of the straddle duration, the straddle state was excluded from the analysis.
[3] This sample includes symbols trading between $5 and $100 and symbols that appear in the CRSP data. Approximately 10% of straddle events are included in this sample.
[4] If the bid-ask midpoint was below $0.75, a threshold of 150% was used instead of 100%.
[5] Traded volume includes regular trades, intermarket sweep orders, and odd lots.

Quoted Spreads during Straddle Events Relative to Typical Quoted Spreads[1][2]

8/1/14 – 12/31/16[3]



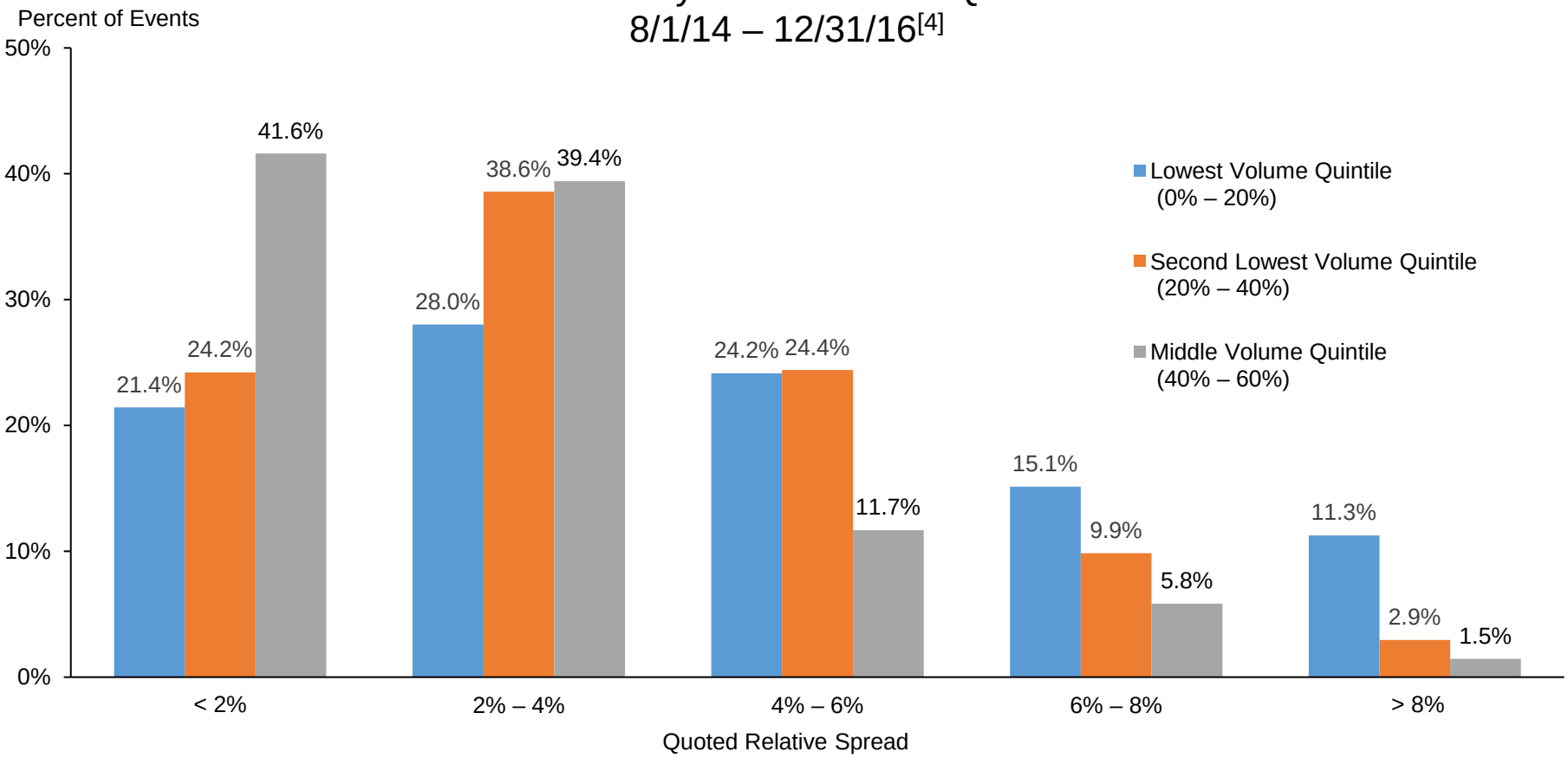
Source: SEC Straddle Data; SEC Halts Data; TAQ Data

Note:
[1] Calculated as the ratio of the time-weighted relative quoted spread during the straddle event to the time-weighted relative quoted spread during the control period. The control period spread is the average quoted spread during the same window of time as the straddle event on the five preceding trading days. If a symbol was in a long-lasting straddle state during any of the control windows of time, or if there were not five prior trading days (e.g., the stock listed less than five days ago), the straddle state was excluded from the analysis.
[2] Intervals during which the quoted relative spread was greater than 100% (or greater than 150% if the bid-ask midpoint was below $0.75) and intervals during which the quoted spread was locked or crossed have been excluded. If the total amount of time excluded from the time-weighted spread calculation exceeded 50% of the straddle duration, the straddle state was excluded from the analysis.
[3] The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Time-Weighted Quoted Relative Spreads during the Control Period[1][2]

Partitioned by CRSP Volume Quintile[3]

8/1/14 – 12/31/16[4]



Source: SEC Straddle Data; SEC Halts Data; TAQ Data; CRSP

Note:

[1] The sample includes straddle states that occurred during the time period that the bands were single wide and on symbols with a closing price between $5 and $100. The control period spread is the average quoted spread during the same window of time as the straddle event on the five preceding trading days. If a symbol was in a long-lasting straddle state during any of the control windows of time, or if there were not five prior trading days (e.g., the stock listed less than five days ago), the straddle state was excluded from the analysis.

[2] Intervals during which the quoted relative spread was greater than 100% (or greater than 150% if the bid-ask midpoint was below $0.75) and intervals during which the quoted spread was locked or crossed have been excluded. If the total amount of time excluded from the time-weighted spread calculation exceeded 50% of the straddle duration, the straddle state was excluded from the analysis.

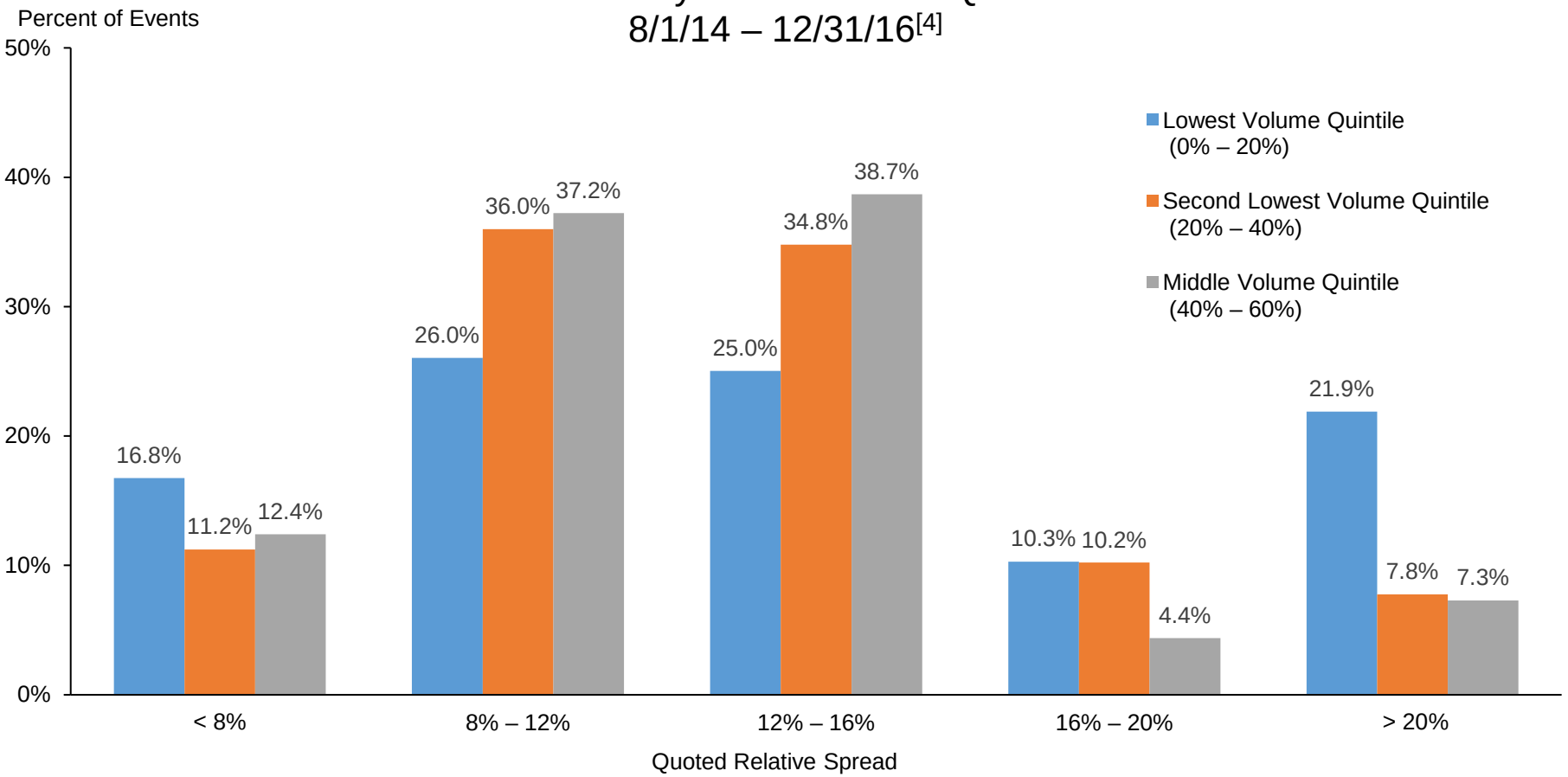
[3] Symbols are partitioned into quintiles on a monthly basis using trading volume in CRSP.

[4] The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Time-Weighted Quoted Relative Spreads during the Straddle Event[1][2]

Partitioned by CRSP Volume Quintile[3]

8/1/14 – 12/31/16[4]



Source: SEC Straddle Data; SEC Halts Data; TAQ Data; CRSP

Note:

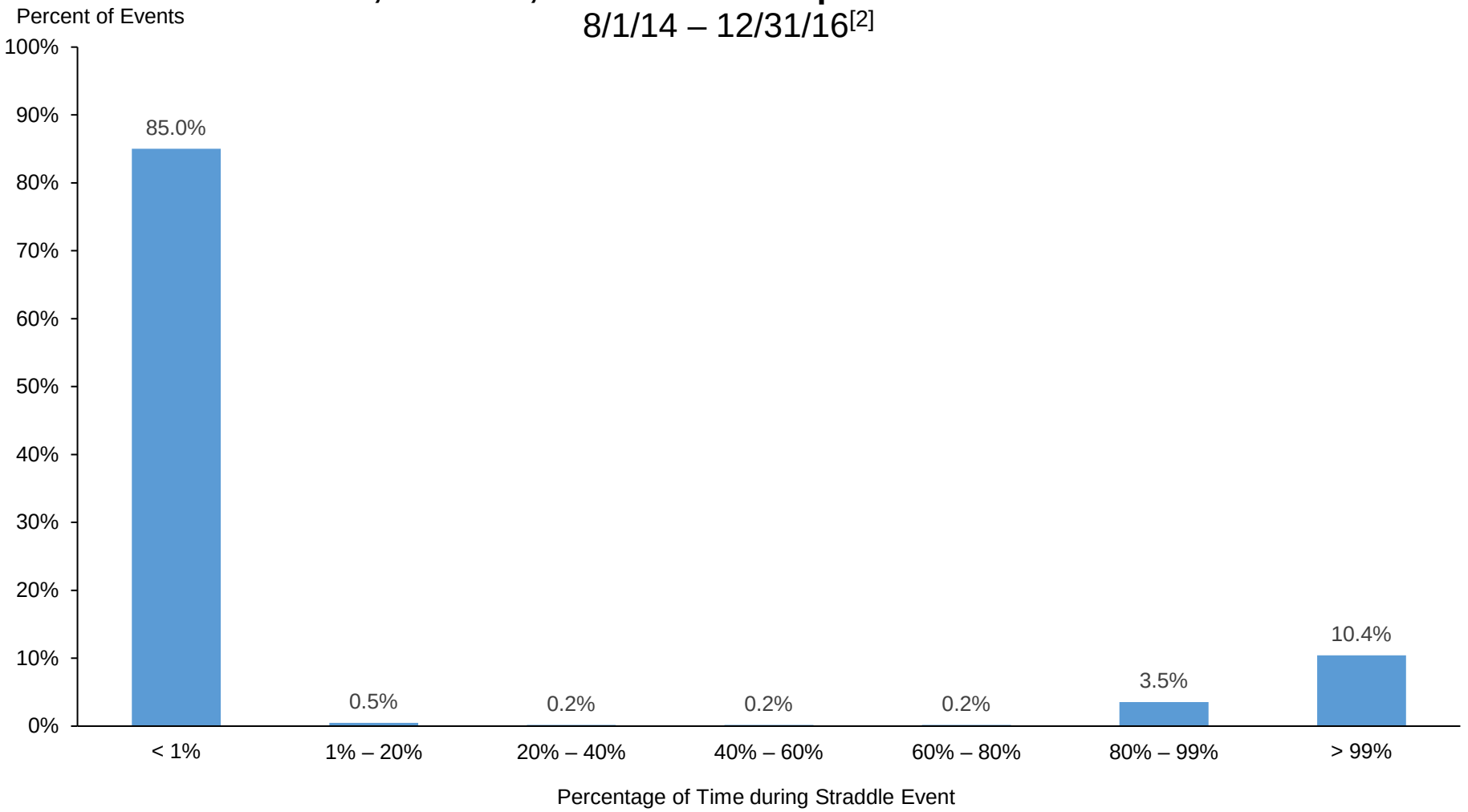
[1] The sample includes straddle states that occurred during the time period that the bands were single wide and on symbols with a closing price between $5 and $100. In order to make the sample parallel to the control period sample, if a symbol was in a long-lasting straddle state during any of the control windows of time, or if there were not five prior trading days (e.g., the stock listed less than five days ago), the straddle state was excluded from the analysis.

[2] Intervals during which the quoted relative spread was greater than 100% (or greater than 150% if the bid-ask midpoint was below $0.75) and intervals during which the quoted spread was locked or crossed have been excluded. If the total amount of time excluded from the time-weighted spread calculation exceeded 50% of the straddle duration, the straddle state was excluded from the analysis.

[3] Symbols are partitioned into quintiles on a monthly basis using trading volume in CRSP.

[4] The straddle states that occurred on August 24, 2015 have been excluded.

Percentage of Time during Straddle Event That the Quoted Spread Was Locked, Crossed, or the Relative Spread Exceeded 100%[1]
8/1/14 – 12/31/16[2]

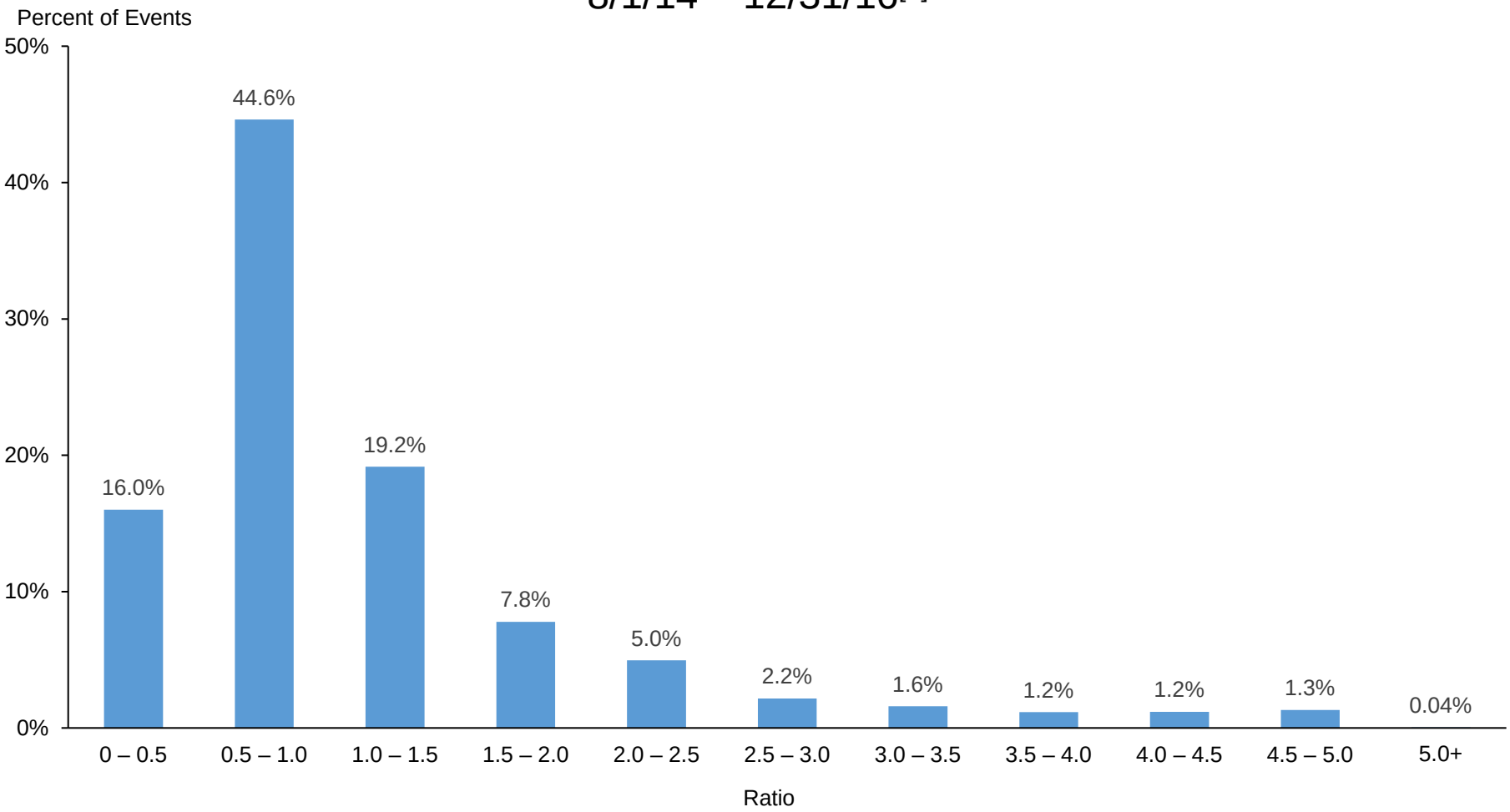


Source: SEC Straddle Data; SEC Halts Data; TAQ Data

Note:
[1] Calculated as the percentage of time during the straddle event that the quoted relative spread was locked, crossed, or greater than 100% (or greater than 150% if the bid-ask midpoint was below $0.75).
[2] The straddle states that occurred on August 24, 2015 have been excluded.

Quoted Spreads during Straddle Events Relative to the Price Bands[1][2]

8/1/14 – 12/31/16[3]

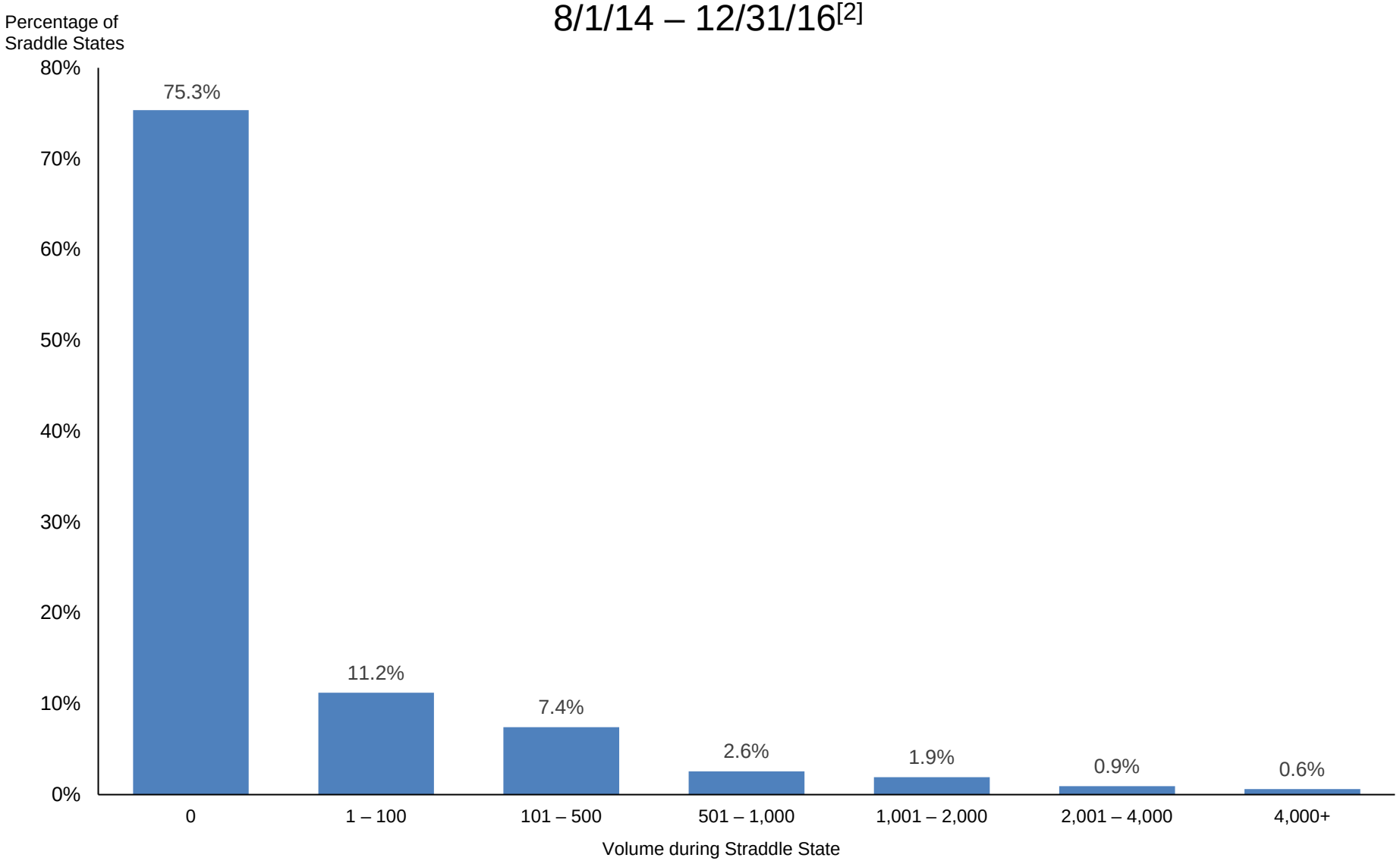


Source: SEC Straddle Data; SEC Halts Data; SEC Price Bands Data; TAQ Data

Note:
[1] Calculated as the ratio of the time-weighted relative quoted spread during the straddle event to the width of the price bands.
[2] Intervals during which the quoted relative spread was greater than 100% (or greater than 150% if the bid-ask midpoint was below $0.75) and intervals during which the quoted spread was locked or crossed have been excluded. If the total amount of time excluded from the time-weighted spread calculation exceeded 50% of the straddle duration, the straddle state was excluded from the analysis.
[3] The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Traded Volume during Long-Lasting Straddle States[1]

8/1/14 – 12/31/16[2]



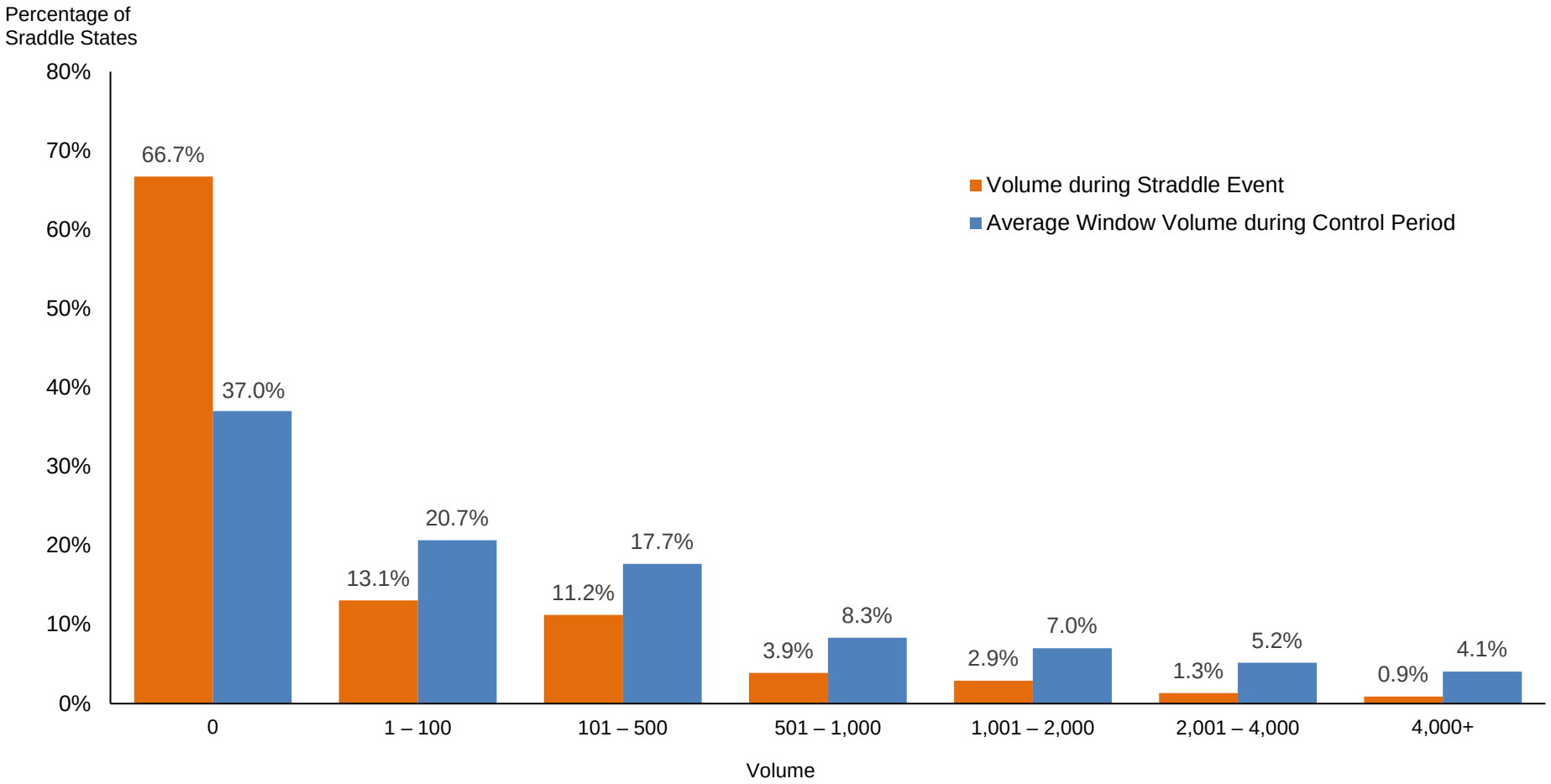
Source: SEC Straddle Data; TAQ Data

Note:
[1] Traded volume includes regular trades, intermarket sweep orders, and odd lots.
[2] The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Traded Volume during Long-Lasting Straddle States and the Control Period[1]

Sample of Symbols with No Long-Lasting Straddle States in the Control Period[2]

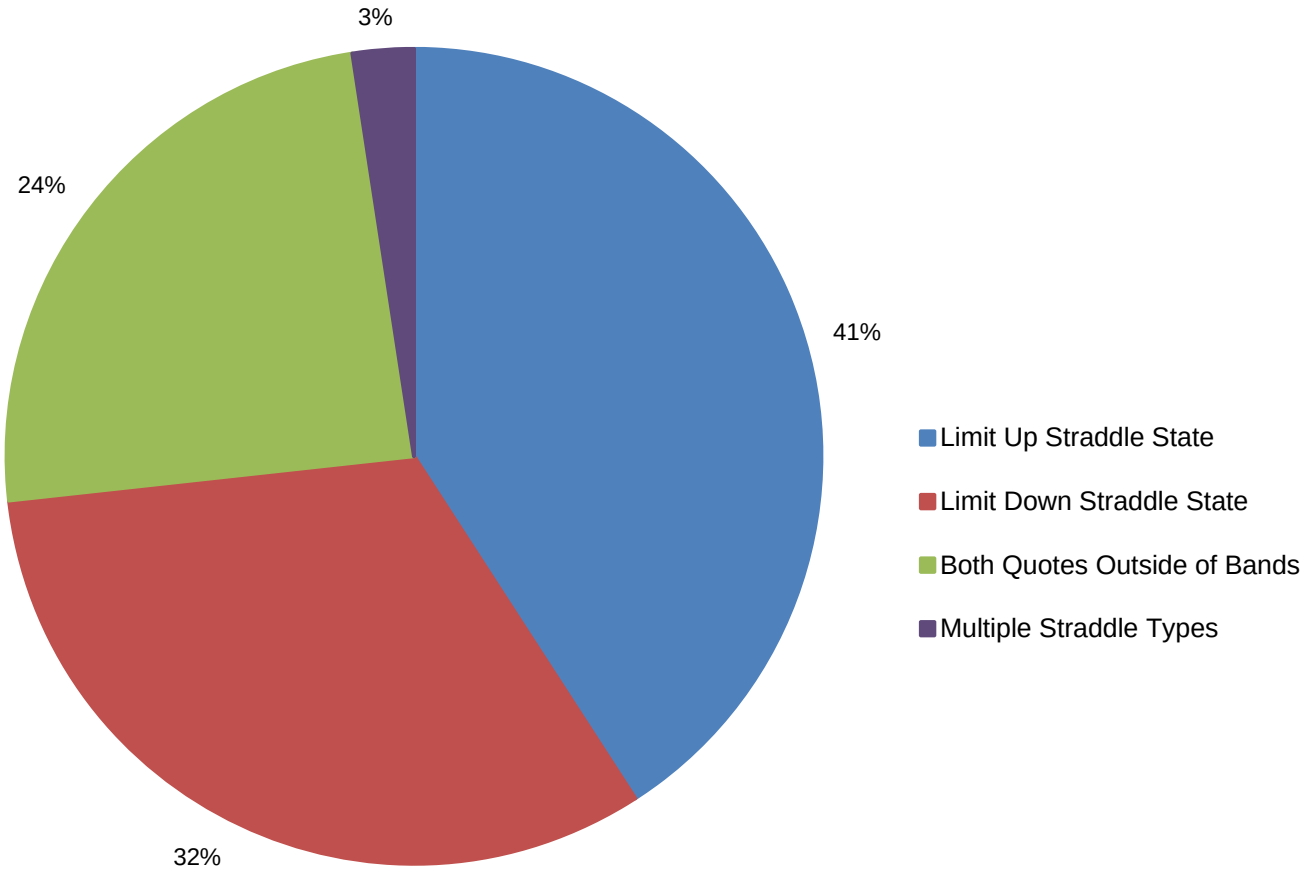
8/1/14 – 12/31/16[3]



Source: SEC Straddle Data; SEC Halts Data; TAQ Data

Note:
[1] Traded volume includes regular trades, intermarket sweep orders, and odd lots.
[2] The control period spread is the average daily volume during the same window of time as the straddle event on the five preceding trading days. If a symbol was in a long-lasting straddle state during any of the control windows of time, or if there were not five prior trading days (e.g., the stock listed less than five days ago), the straddle state was excluded from the analysis.
[3] The straddle states that occurred on August 24, 2015 have been excluded.

Distribution of Long-Lasting Straddle States by Straddle Type
8/1/14 – 12/31/16[1]



Source: SEC Straddle Data; SEC Price Bands Data; TAQ Data

Note:
[1] The straddle states that occurred on August 24, 2015 have been excluded.

Section V: Impact of Amendment 10 on Long-Lasting Straddle States

Impact of Amendment 10 on Trading Halts

- Amendment 10 stated that stocks with no volume in the opening auction would use the price of the prior day's close as the first reference price instead of the midpoint of the opening quote.
  - Implemented on July 18, 2016
- Extend methodology of logistic regression model from Section III to test the impact of rule change on trading halts (the target of the rule change).

$$Halt\ State\ Indicator_{i,t} = \beta_0 + \beta_1 Post\ Amendment_{i,t} + \beta_2 No\ Opening\ Trade_{i,t} + \beta_3 Post\ Amendment * No\ Opening\ Trade_{i,t} + \beta_4 X_{i,t} + \epsilon_{i,t}$$

  - $Post\ Amendment$ is an indicator variable with a value of one after implementation.
  - $No\ Opening\ Trade$ is an indicator variable with a value of one if there was no opening trade.
  - $Post\ Amendment * No\ Opening\ Trade$ is the interaction of the two indicators.
  - $X_{i,t}$ are the control variables from the prior regression.
- In this specification, the coefficient on the variable of interest, the interaction term, is significant and corresponds to the odds ratio of a stock experiencing a trading halt conditional on that stock having no opening trade being roughly five to seven times *lower* after the implementation of Amendment 10.

Logistic Regression Results[1]

Likelihood of Experiencing a Trading Halt[2]

8/1/14 – 12/31/16[3]

Parameter	Full Sample	Balanced Panel
	(1)	(2)
Log Volume	-0.181** (0.000)	-0.233** (0.000)
Tier 1	-0.484** (0.000)	-0.212 (0.162)
Prior Day's Close Below $3	-1.217** (0.000)	-1.236** (0.000)
Prior Day's Close Below $0.75	-0.680** (0.000)	-0.455** (0.009)
No Opening Trade	2.248** (0.000)	2.143** (0.000)
Post Amendment 10	-0.160* (0.044)	-0.022 (0.820)
No Opening Trade∗Post Amendment 10	-1.743** (0.000)	-1.909** (0.000)
Abnormal Volume	0.400** (0.000)	0.498** (0.000)
Equity Volatility	30.200** (0.000)	33.884** (0.000)
Number of Symbol/Days	4,261,730	3,242,584

Sources: CRSP; SEC Halts Data; SEC Price Bands Data; TAQ Data

[1] This table reports results from a logit regression estimating the effects of various factors on the likelihood of experiencing a trading halt. The sample includes data for all stocks included in the CRSP database. The dependent variable is an indicator variable that equals one if a stock experienced a halt on that particular day. Standard errors are estimated by clustering on stocks. The "Permno" in CRSP is used to identify stocks over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] Trading halts that were unrelated to the Limit Up-Limit Down rules were removed.
[3] The straddle states that occurred on August 24, 2015 have been excluded.

Impact of Amendment 10 on Long-Lasting Straddle States

- We use the same methodology to test whether Amendment 10 had any impact on the likelihood of a stock experiencing a long-lasting straddle state.

$$Straddle\ State\ Indicator_{i,t} = \beta_0 + \beta_1 Post\ Amendment_{i,t} + \beta_2 No\ Opening\ Trade_{i,t} + \beta_3 Post\ Amendment * No\ Opening\ Trade_{i,t} + \beta_4 X_{i,t} + \epsilon_{i,t}$$

  - $Post\ Amendment$ is an indicator variable with a value of one after implementation.
  - $No\ Opening\ Trade$ is an indicator variable with a value of one if there was no opening trade.
  - $Post\ Amendment * No\ Opening\ Trade$ is the interaction of the two indicators.
  - $X_{i,t}$ are the control variables from the prior regression.

- The coefficient on the variable of interest, the interaction term, is significant and corresponds to the odds ratio of a stock experiencing a long-lasting straddle state conditional on that stock having no opening trade being roughly 1.2 times *greater* after the implementation of Amendment 10.

Logistic Regression Results[1]

Likelihood of Experiencing a Long-Lasting Straddle[2]

8/1/14 – 12/31/16[3]

Parameter	Full Sample	Balanced Panel
	(1)	(2)
Log Volume	-0.276** (0.000)	-0.352** (0.000)
Tier 1	-2.713** (0.000)	-2.685** (0.000)
Prior Day's Close Below $3	-1.384** (0.000)	-1.437** (0.000)
Prior Day's Close Below $0.75	-1.418** (0.000)	-1.060** (0.000)
No Opening Trade	0.674** (0.000)	0.512** (0.000)
Post Amendment 10	-0.026 (0.683)	-0.036 (0.640)
No Opening Trade∗Post Amendment 10	0.153* (0.032)	0.226** (0.009)
Abnormal Volume	0.362** (0.000)	0.468** (0.000)
Equity Volatility	37.397** (0.000)	39.391** (0.000)
Number of Symbol/Days	4,261,730	3,242,584

Sources: CRSP; SEC Straddle Data; SEC Price Bands Data; TAQ Data

[1] This table reports results from a logit regression estimating the effects of various factors on the likelihood of experiencing a long-lasting straddle state. The sample includes data for all stocks included in the CRSP database. The dependent variable is an indicator variable that equals one if a stock experienced a long-lasting straddle on that particular day. Standard errors are estimated by clustering on stocks. The "Permno" in CRSP is used to identify stocks over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] Long-lasting straddle states are defined as a straddle state lasting at least five minutes.

[3] The straddle states that occurred on August 24, 2015 have been excluded.