MEMORANDUM

TO: FILE
FROM: DIVISION OF ECONOMIC AND RISK ANALYSIS[1]
SUBJECT: CORNERSTONE ANALYSIS OF TRADING AND MARKET QUALITY METRICS ON AUGUST 24, 2015
DATE: DECEMBER 2017

The Division of Economic and Risk Analysis ("DERA") contracted with Cornerstone Research ("Cornerstone"), an economic and financial consulting firm, to assist the staff in better understanding the market events on August 24, 2015, with a focus on the impact on linked option and futures contracts. The Division believes that the methodology employed by Cornerstone is appropriate for an exploratory analysis and agrees with Cornerstone's preliminary findings based on that analysis.

Cornerstone designed the data analysis to understand the market events on August 24, 2015, with a focus on how liquidity shocks and the operation of the Limit-Up/Limit Down mechanism in the equity market impacted linked option and futures markets. The analysis calculates daily market quality metrics for 2015, and intraday market quality metrics on August 24, 2015 for various traded instruments linked to broad indices, including exchange-traded funds ("ETFs"), futures, ETF options, and index options.[2] Cornerstone identified two high level objectives for the analysis: (1) "Depict data that summarize the extent to which trading volume was abnormally high on August 24, 2015 and in the next several days afterwards," and (2) "Produce graphs and summary statistics relevant to understanding how the liquidity shock during the morning of August 24, 2015 impacted linked options and futures markets." Cornerstone also identified a set of possible questions for future research.

Analysis of Daily Trading Volume and Trading Pauses:
The Cornerstone analysis compares daily share volume on August 24, 2015 to prior and later trading days in an effort to investigate and give context to the abnormally high execution volumes experienced by many instruments linked to broad indices. The analysis shows that cumulative trading volume in ETFs having listed options, as well as cumulative trading volume in linked futures, on August 24, 2015 was approximately 3.5 times the average daily total trading volume ("ADTV") between January 2, 2016 and October 16, 2016; cumulative trading volume in linked option classes was approximately 2.5 times the ADTV over the same period. The analysis further shows that each instrument type saw this same cumulative share volume metric remain abnormally high, yet decline day-over-day for the three trading days following August 24, 2015. To compare the volume executed in each symbol on August 24, 2015 to the volume during 2015, the Cornerstone analysis calculates a symbol-day metric defined as whether or not the volume for a symbol in each trading day of 2015 was less than the trading volume on August 24, 2015. The distribution of this metric was

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 The Cornerstone analysis calculated daily and intraday market quality metrics over a set of data containing 462 ETFs having listed options, 483 option classes on ETFs and indexes, and 10 futures indexes.

highly skewed at the symbol level, revealing August 24, 2015 as having higher trading volume than most prior trading days in the calendar year, in fact, 80% of the ETFs, and 40% of option classes on ETFs and indexes were in the 90th percentile of the distribution, and four of the ten futures indexes experienced August 24, 2015 as the highest volume trading day to date within the calendar year.

The Cornerstone analysis investigates the frequency of trading pauses experienced by ETFs on August 24, 2015; 90 of 462 ETFs experienced no trading pauses, 16 ETFs paused trading just once, 50 ETFs experienced more than four trading pauses, with one ETF having paused trading 11 times. The Cornerstone analysis also examines trading pauses by ADTV and market capitalization. The analysis shows that higher ATDV ETFs experienced fewer trading pauses than ETFs categorized as having lower ADTV.[3] The analysis also shows that the ratio of trading volume on August 24, 2015 to the ADTV between January 2, 2016 and October 16, 2016 was similarly high among all market capitalization categories,[4] irrespective of the number of trading pauses experienced by the market capitalization category.

Analysis of the Liquidity Shock on Linked Option and Futures Markets:
The Cornerstone analysis investigates liquidity provision across instruments linked to broad indices on the morning of August 24, 2015 by presenting a series of intraday market quality metrics including quoted spreads, and the percentage of time where option classes had an absence of displayed firm quotes on both sides of the market. The analysis shows that ETF quoted spreads on August 24, 2015 were seven times wider than the average quoted spread over the next five trading days, and that options quoted spreads on August 24, 2015 were twice as wide as average quoted spread over the following five trading days.[5] The analysis also reveals a positive relationship between quoted spreads and number of trading pauses experienced by an ETF. However, this relationship did not hold for option classes on ETFs and indexes. SPY options quoted spreads were particularly wide on the morning of August 24, 2015, they experienced a 12-fold widening relative to the average quoted spread over the following four trading days. After accounting for the duration of time in which the underlying ETF was paused, which in turn pauses associated option classes, the analysis shows that option classes associated with paused ETFs experienced longer periods of time without firm displayed bids or offers when compared to option classes associated with underlying ETFs that did not have a trading pause.

The Cornerstone analysis presents a series of index tracking performance case studies. The case studies reveal that option classes associated with the S&P 500 and S&P 400 appeared to

3 ETFs with listed options were grouped into four average daily trading volume categories. The ETF SPY was the only ETF in the "SPY" category, 47 ETFs with greater than 5 million ADTV were categorized as "High Volume", 127 ETFs with between 500,000 and 5 million ADTV were categorized as "Medium Volume", and 287 ETFs with less than 500,000 ADTV were categorized as "Low Volume".

4 ETFs with listed options were grouped into four categories the market capitalization categories, defined as the product number of shares outstanding and the closing price on August 21, 2015. The ETF SPY was the only ETF in the "SPY" category, 48 ETFs with greater than $10 billion market capitalization were categorized as "High", 154 ETFs with between $1 and $10 billion market capitalization were categorized as "Medium", and 259 ETFs with less than $1 billion market capitalization were categorized as "Low".

5 Quoted spread is defined as the time weighted average difference between the National Best Offer (NBO) and the National Best Bid (NBB) between 9:30 am and 10:00 am; durations of time where an ETF was experiencing a trading pause were excluded from the calculation.

track their respective index on par with one another, though many option series for which the underlying ETF was experiencing extreme price volatility did temporarily stop quoting. The final component of the liquidity provision investigation offered a visual representation of how close, in price terms, the top-of-book quotations of individual equity and option exchanges were to the NBBO on both the morning of August 24, 2015 and for a benchmark period defined over the following five trading days. The analysis shows that the highest bid and lowest offer of many exchanges was further away from the NBBO on the morning of August 24, 2015 then they were during the benchmark period.

MEMORANDUM

DATE: Saturday, October 15, 2016

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

FROM: Stewart Mayhew, Cornerstone Research

RE: Overview of Preliminary Findings and Possible Future Research (August 24, 2015 Project)

This memo summarizes research we have conducted pursuant to TIL Number 01-16 (under Contract SECHQ1-16-C-0024), constituting a preliminary investigation of trading and market quality metrics on August 24, 2015 of various traded instruments linked to broad indexes, including ETFs, futures, ETF options, and index options. Separately, we have provided a slide deck with tables and charts. The research summarized below was performed under my direction by the staff of Cornerstone Research, with additional guidance and oversight from subject matter experts Amber Anand and D. Timothy McCormick.

This research was exploratory and preliminary in nature, designed to identify high-level observations readily observable in the data, to create a database suitable for use in future research by DERA staff or others, and to identify questions for future research. The approach at this stage was not one of formulating and testing hypotheses, or designing methodologies to control for extraneous factors and isolate questions of interest.

Data

The data examined for this research included

- Daily and intraday equity market data for 462 ETFs with listed options (Sources: CRSP, Bloomberg, TickData)
- Daily and intraday options market data for 483 ETFs and Indexes with listed options and non-zero option trading volume (Sources: iVolatility, TickData)
- Daily and intraday futures market data for 10 index futures, including the VIX volatility index (Sources: Bloomberg, TickData)
- Data on Limit-Up/Limit Down (LULD) trading halts (Provided by SROs through DERA)

Preliminary findings based on analysis of daily data

- Trading volume was unusually high on August 24, 2015 across a broad spectrum of ETFs with listed options (on average, volume was more than three times the year-to-date average daily trading volume (ADTV)). For example, August 24 was in the top 10% of year-to-date daily volume for nearly 80% of the 462 ETFs with listed options. (Daily slide deck, page 4)
- Trading volume on ETFs remained higher than normal in the days after August 24, on average more than double year-to-date ADTV for the next three days. (Daily slide deck, pages 5–6)
- The majority of ETFs experienced no LULD trading halts on August 24, but of those that did, many experienced multiple halts. (Daily slide deck, pages 7–8)
- ETF trading volume on August 24 was significantly higher than normal for ETFs of all different sizes (market cap of assets), and regardless of whether or not LULD trading halts occurred. LULD halts were observed for ETFs of all sizes (but not for the SPDR S&P 500 ETF (SPY)). (Daily slide deck, page 9).
- LULD halts were infrequent among the ETFs with highest ADTV. For example, of the 48 ETFs with ADTV greater than five million, only one experienced a halt (approximately 2%). By comparison, for ETFs with ADTV between 500,000 and five million, the number was 23 out of 127 (18%), and for ETFs with ADTV below 500,000 it was 66 of 287 (23%). (Daily slide deck, page 10)
- Trading volume in ETF options and index options was higher than normal on August 24 and on the following three days, but perhaps not to the same extent as observed in the ETF trading. (Daily slide deck, pages 13–17, in comparison to pages 4–6)
- Trading volume on most stock index futures, including the VIX volatility index, was more than three times higher on August 24 compared to the year-to-date ADTV. (Volume on VIX futures was more than four times higher on August 24 compared to year-to-date ADTV). Futures trading volume was more than two times the ADTV for the next two days after August 24. (Daily slide deck, page 22–23)

Preliminary findings based on analysis of intraday data

- Average quoted spreads on ETFs between 9:30 AM and 10:00 AM were wider on August 24, 2015 compared to average spreads during the same time interval over the next five trading days (August 25–31). (Intraday slide deck, page 5)

    - For various sub-samples, average quoted spreads during the first half hour of trading on August 24 ranged from three times wider to more than 24 times wider than on the benchmark days.
    - The largest differences were observed for ETFs that experienced LULD trading halts.
- Average quoted spreads on ETF options between 9:30 AM and 10:00 AM were wider on August 24 compared to average spreads during the same time interval over the next five trading days (August 25–31). (Intraday slide deck, page 7)
    - For various sub-samples, average quoted spreads in options during the first half hour of trading on August 24 ranged from 1.6 times wider to more than 12.8 times wider than on the benchmark days.
    - SPY options experienced a very large widening of average spreads from 32.9 cents to 422.1 cents.
- Option classes for which the underlying ETF experienced a trading halt had, on average, longer periods during which there were no firm bids and offers in the option series, even after accounting for periods during which the EFT was halted. (Intraday slide deck, page 8)
- A comparison of intraday price charts on the morning of August 24 for three different ETFs tracking the S&P 500 suggests that the SPY and the Vanguard S&P 500 ETF (VOO) had better market quality than the iShares S&P 500 ETF (IVV).
    - SPY and VOO appear to track the E-Mini S&P 500 futures price relatively closely, but extreme price deviations were observed for IVV. (Intraday slide deck, pages 10–12)
    - SPY and VOO quoted spreads appear to be approximately six times wider than during a benchmark period. The IVV experienced two LULD halts, and between the two halts spreads spiked to more than 250 times the average. During the same time period, spreads on the E-Mini S&P 500 futures were approximately 50% wider than average. (Intraday slide deck, pages 14–15)
- The large deterioration in quoted spreads observed in the equity market for IVV compared to SPY and VOO was not as readily apparent in the option market (apart from the fact that the option market for IVV was halted when the underlying IVV ETF halted).
    - At times when the market was not halted, quoted spreads on IVV options were comparable in magnitude to spreads on VOO and SPY. (Intraday slide deck, pages 17–26)
    - During the benchmark period, option spreads on SPY were much narrower than either IVV or VOO (SPY is far more actively

traded). Relative to this benchmark, spreads on SPY options increased more than on IVV or VOO options. (Intraday slide deck, pages 18–20)

- Large differences were observed across S&P 500-linked options in terms of the degree to which exchanges disseminated firm quotes on the morning of August 24, with VOO having the most firm quotes and SPY having the second-most firm quotes. Results are also presented for the SPX cash-settled options. (Intraday slide deck, pages 27–28)

- Results presented in the slide deck provide a similar comparison between two different option classes on the S&P Mid-Cap 400 (MDY and IJH). (Intraday slide deck, pages 29–43)
- Results presented in the slide deck show the performance of the Nasdaq 100 ETF (QQQ) compared to the E-Mini Nasdaq futures contract. (Intraday slide deck, pages 44–50)
- Results presented in the slide deck show a graphical summary of which exchanges were quoting near the NBBO in both equity and option markets. (Intraday slide deck, pages 51–63)

<u>Possible questions for future research</u>

1. We now have data on intraday quoted spreads for all series on each of the 462 ETF option classes in our sample, as well as intraday spread data for the underlying ETFs, and a record of all LULD trading halts on these ETFs, for August 24, 2015 and the subsequent five trading days. These data (perhaps supplemented to include a control sample further away in time from August 24) could serve as a basis for a study of the determinants of spreads on ETF options. Such a study could provide evidence on the impact of LULD rules on option market quality.
    a. In particular, such a study would model how spreads, quoted depth, and effective spreads on ETF options can be explained by factors such as liquidity characteristics of the underlying ETF (e.g., volume, size, spreads, number of authorized participants, volatility); characteristics of the option (e.g., price level, moneyness, time to expiration, series volume, class volume); the existence of other actively traded ETFs that are close substitutes for the ETF (e.g., other ETFs that track the same index); and the existence of other hedging vehicles such as a futures contract tracking the same index. The model could then be used to explore the extent to which LULD trading halts and other LULD events in the ETF impact market quality in option markets, outside of the time when the halt is in effect.

b. Evidence from such a study would be useful if the Commission decides to reconsider whether ETFs should be exempted from LULD rules when all or most of the component stocks are not in a LULD state.

c. Such a study would also be useful if the Commission wishes to consider whether option exchanges should implement alternative rules regarding when option trading should halt. For example, should options be allowed to continue trading during a halt in the underlying ETF if there are other liquid ETFs tracking the same index that are not halted?

2. Further analysis of option market quality on August 24 immediately prior to LULD halts in the underlying ETF, as well as for ETFs that did not halt, could provide additional evidence useful to the Commission in evaluating the LULD rules. In particular, if market quality in the options was poor immediately prior to the halts, this would confirm that halting trading may have been appropriate from the perspective of investor protection. Conversely, if option market quality was high immediately prior to a halt, this suggests that the benefits to halting trading may be more limited. It would also be instructive to identify any instances where the options were halted (or had no valid quotes) and the underlying ETF was not halted. If there are events like this in the data, they can potentially be used to identify the effect of a non-functional option market on the underlying market.

3. The existing analysis can be extended to examine the extent to which abnormally high volume may have impacted market quality. For example, one approach would be to categorize ETFs into quintiles based on the increase in option trading volume relative to a benchmark period. We could then compare liquidity measures for the first and fifth quintiles for both the options and the underlying, allowing us to analyze market resilience to abrupt changes in volume. We could also do pairwise comparisons of each quintile to the lowest abnormal volume quintile to examine whether there is a point until which the market is resilient toward volume increases. Another useful analysis to measure the effect of option trading on the underlying market would be to focus on the sample of options with the highest abnormal trading volume and examine whether option order imbalances lead or lag price changes in the underlying.

4. Existing academic literature does not fully establish whether the option market is more resilient (or fragile) relative to the underlying equity markets. On one hand, a derivative market may rely on the underlying market for pricing as well as hedging, and a disruption in the underlying market may be further magnified in the derivative market. On the other hand, for some markets such as for index and ETF options, price discovery may occur through alternative channels such as the futures market, other ETFs tracking the same index, or the cash index as calculated from the underlying component securities.

Hedging may also occur through these other markets. When the market for a particular index or ETF is disrupted by a liquidity shock, options market makers may realize that the underlying market disruption affected a particular set of securities more severely, and may use the prices of less affected securities to help price the options. In this scenario, options markets may be more resilient and, in fact, may help to stabilize the underlying market. Thus, the question of whether (and when) option markets are more resilient than the underlying market is an empirical question. The data from ETFs, futures, and options on August 24 would seem to be well designed for addressing these questions. Further work would be necessary to explore what methodological design would be best for addressing this question.

Analysis of Market Events on August 24, 2015

End-of-Day Data

Overall Objective and Sample Selection

Objective: Depict data that summarize the extent to which trading volume was abnormally high on August 24, 2015 and in the next several days afterwards.

End-of-Day Data Sample:

- Options Sample:
  - List of ETFs and Indexes with listed options were acquired from iVolatility
  - 68 option classes with no trading volume between 8/24/15 and 8/31/15 were removed
  - Sample consists of the remaining 483 ETFs and Indexes with listed options
- ETF Sample:
  - Sample includes all ETFs with listed options in the options sample for which CRSP has data
  - Sample contains 462 ETFs
- Futures Sample:
  - Sample includes 10 futures for which intraday data are available from TickData

ETF Data

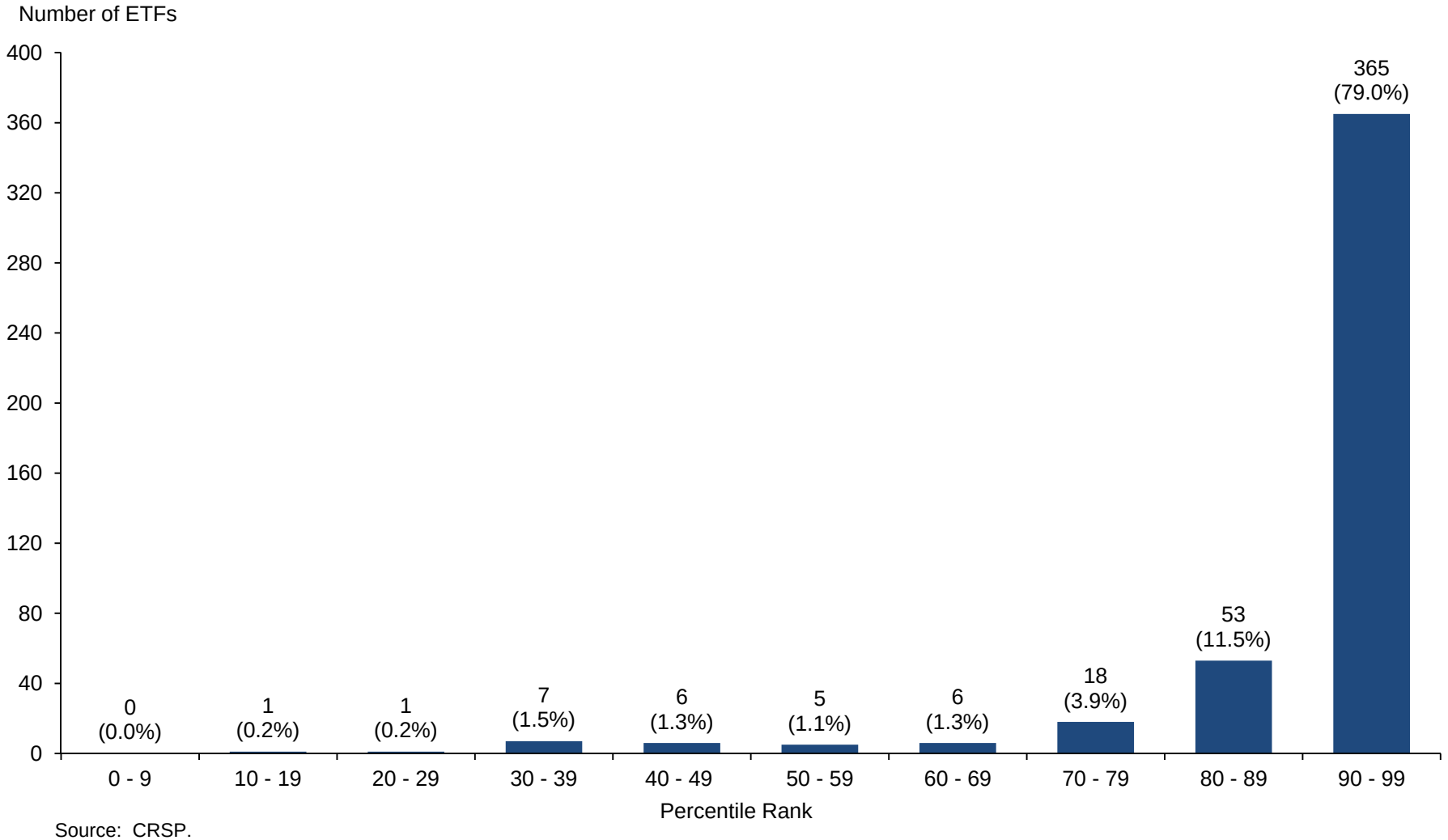
Source: CRSP

Number of Symbols in Sample: 462

Time Range: 1/2/15 – 12/31/15

Percentile Rank of Volume on 8/24/15 Relative to YTD Daily Volume

ETF Data



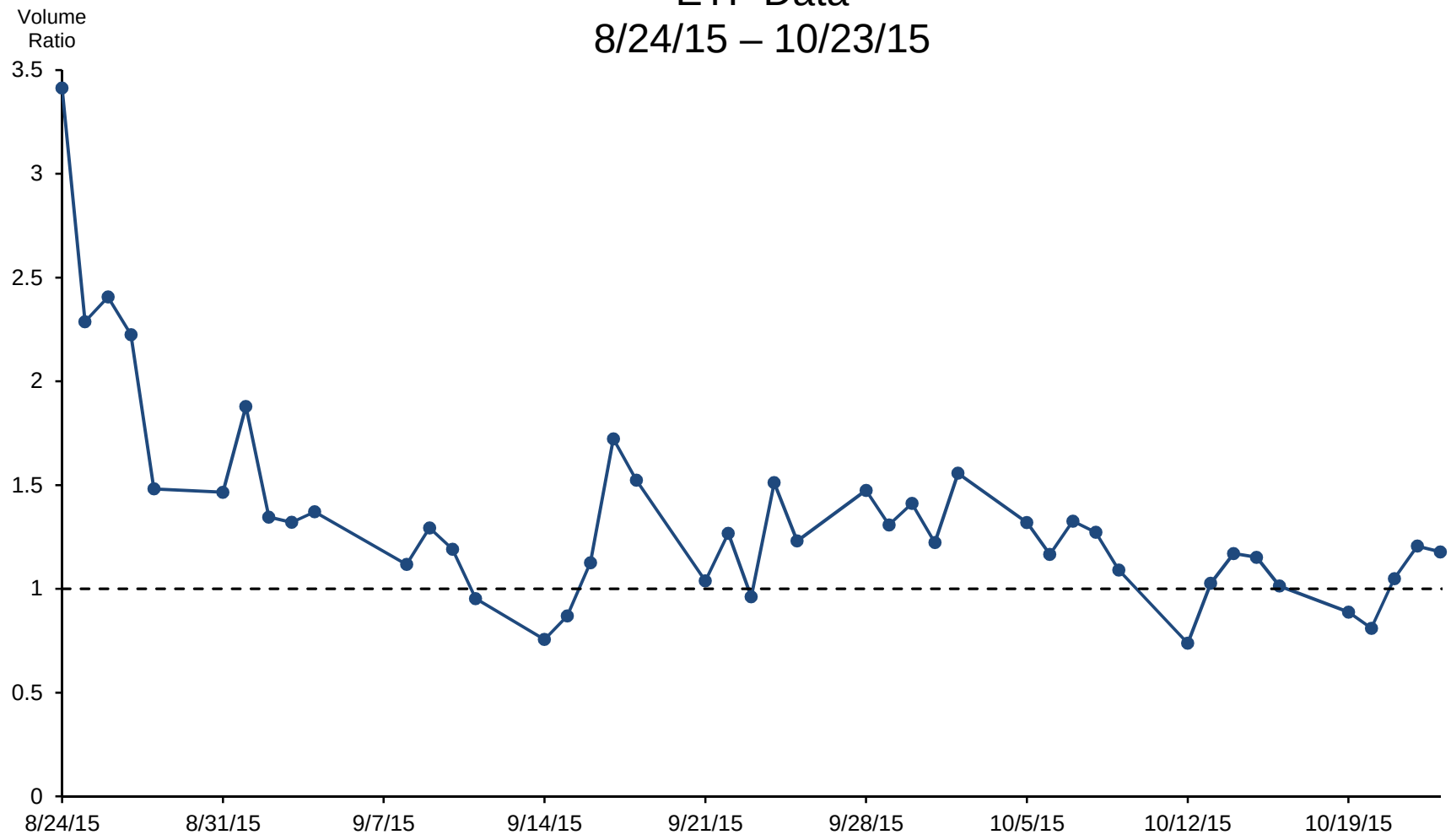
Source: CRSP.

Note: Based on a sample of 462 ETFs with listed options, for which volume data are available in CRSP. For each ETF the percentile rank of the 8/24/15 volume is defined as the percentage of days in 2015 prior to 8/24/15 for which the volume was less than the 8/24/15 volume. All 462 ETFs had volume on 8/24/15. The volume on 8/24/15 was the highest for 130 or 28.1% of the ETFs.

Ratio of Total Daily Volume to YTD Average Daily Trading Volume

ETF Data

8/24/15 – 10/23/15



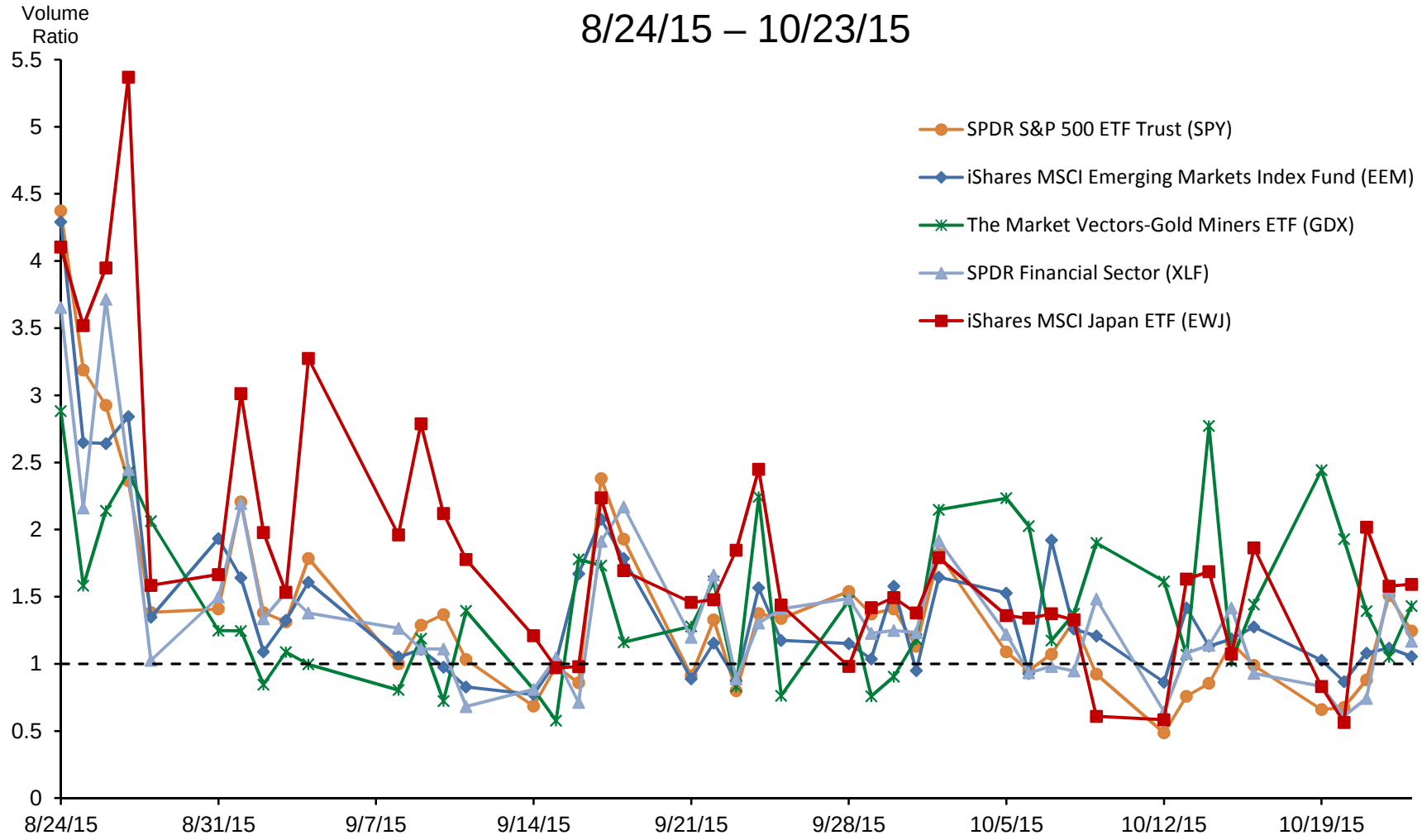
Source: CRSP.

Note: Based on a sample of 435 ETFs with listed options, for which volume data are available in CRSP for at least 250 trading days between 1/2/15 and 12/31/15. YTD average daily trading volume is defined as the average daily trading volume for 1/2/15 – 8/21/15. "Volume Ratio" is the ratio of volume on a given day to the average daily trading volume from 1/2/15 to 8/21/15.

Ratio of Daily Volume to YTD Average Daily Trading Volume

ETF Data

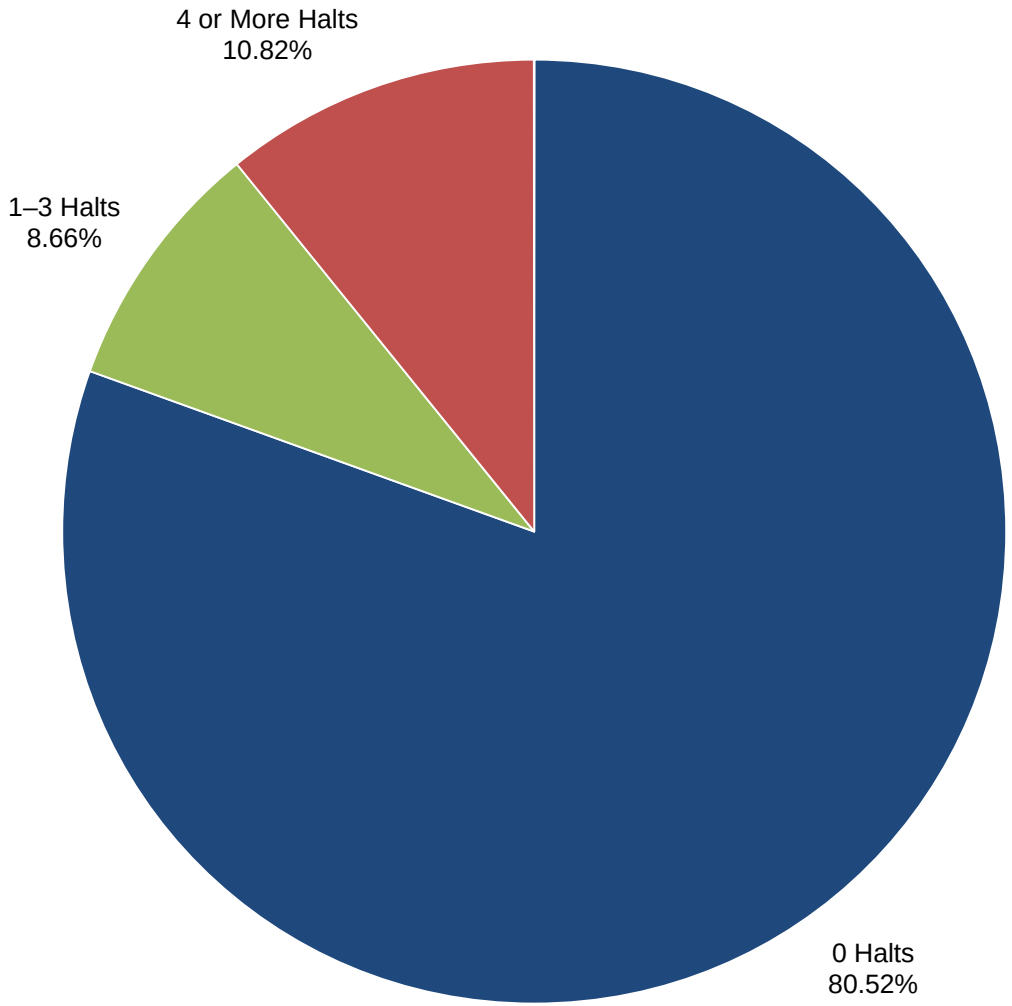
8/24/15 – 10/23/15



Source: CRSP.

Note: Graph displays the five ETFs with the highest YTD average daily trading volume in the sample of 462 ETFs with listed options. YTD average daily trading volume is defined as the average daily volume for 1/2/15 – 8/21/15. "Volume Ratio" is the ratio of volume on a given day to the average daily trading volume from 1/2/15 to 8/21/15.

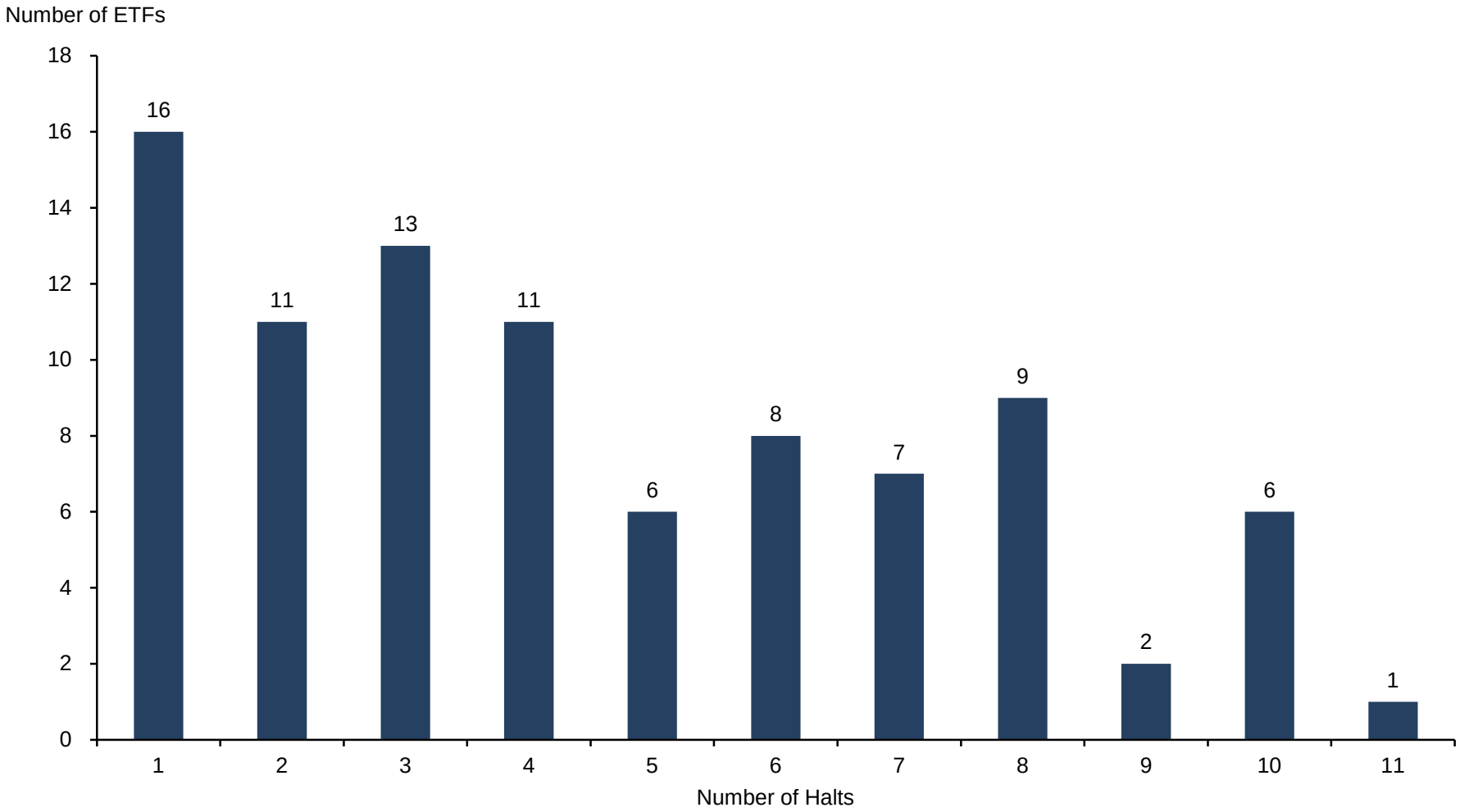
Many ETFs Experienced No Trading Halts on 8/24/15



Source: SEC Halts Data.

Note: Based on a sample of 462 ETFs with listed options, for which volume data are available in CRSP.

Of the ETFs That Experienced at Least One Trading Halt on 8/24/15, Many Experienced Multiple Trading Halts



Source: SEC Halts Data.

Note: Based on a sample of 462 ETFs with listed options, for which volume data are available in CRSP. 372 ETFs had no trading halts on 8/24/15.

ETF Summary Statistics Grouped by ETF Size and Number of Halts on 8/24/15

ETF Size	Number of Halts on 8/24/15			All
	0	1–3	4+	
Number of Observations				
SPY	1	–	–	1
Large	37	5	6	48
Medium	107	9	38	154
Small	227	26	6	259
All	372	40	50	462
YTD Average Daily Trading Volume				
SPY	115,981,416	–	–	115,981,416
Large	8,670,923	1,690,105	840,954	6,965,008
Medium	3,192,137	1,546,977	376,440	2,401,209
Small	855,363	177,113	131,524	770,507
All	2,614,332	674,456	402,792	
Mean 8/24/15 Volume Ratio				
SPY	4.373	–	–	4.373
Large	3.704	3.838	5.483	3.941
Medium	3.445	4.051	5.651	4.025
Small	3.651	3.884	3.484	3.670
All	3.599	3.916	5.371	
Median 8/24/15 Volume Ratio				
SPY	4.373	–	–	3.769
Large	3.649	3.774	5.947	3.526
Medium	2.976	3.149	5.384	2.627
Small	2.513	3.253	3.287	4.373
All	2.830	3.417	5.155	3.023

Source: CRSP; SEC Halts Data.

Note: Based on a sample of 462 ETFs with listed options, for which price and volume data are available from CRSP. "Volume Ratio" is the ratio of 8/24/15 volume to the YTD average daily trading volume. "ETF Size" is defined as the number of shares outstanding for the ETF multiplied by the closing price on 8/21/15. ETFs with an ETF size of (i) $1 billion or less are grouped as "Small"; (ii) between $1 billion and $10 billion are grouped as "Medium"; and (iii) greater than $10 billion are grouped as "Large."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15

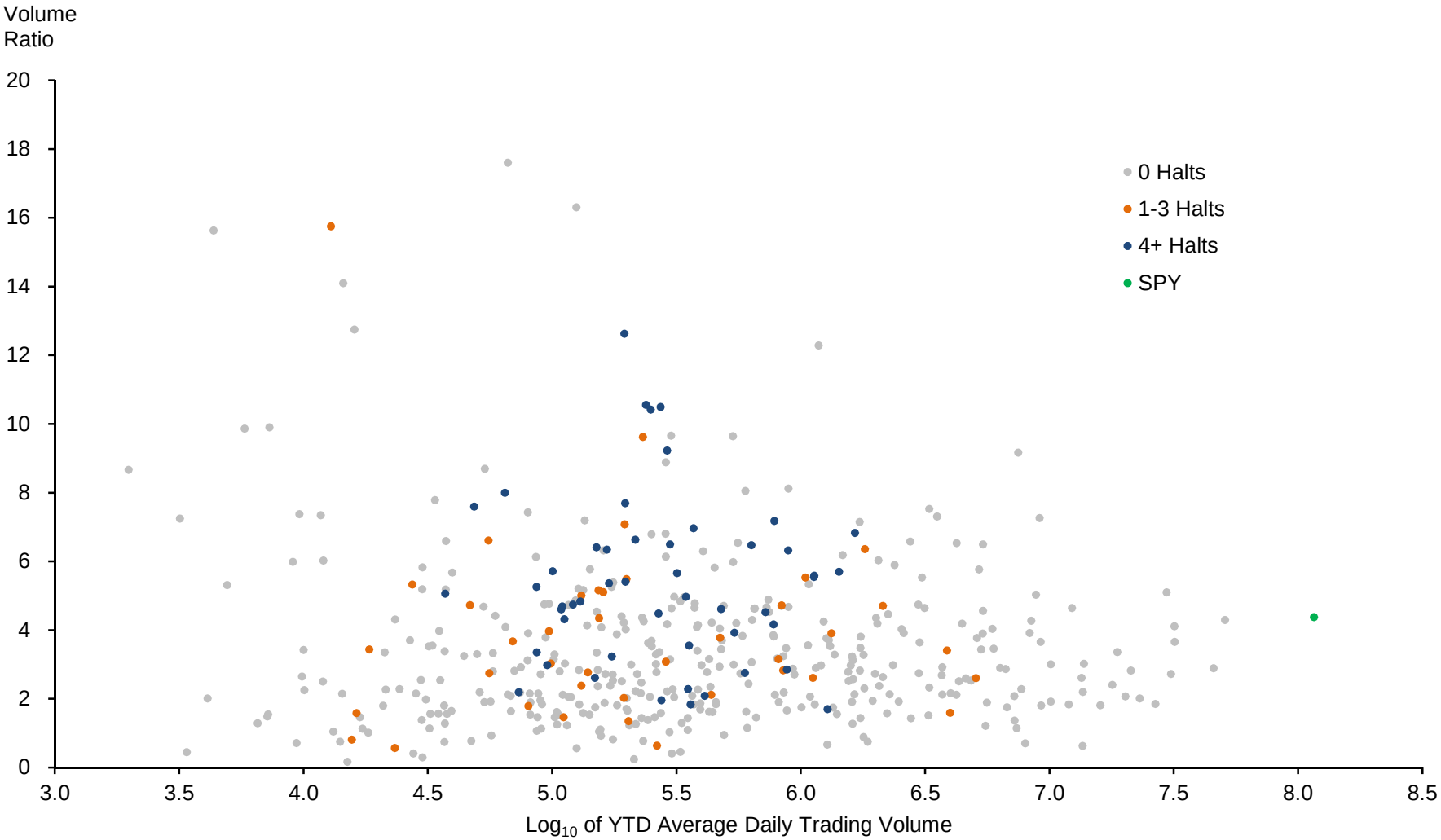
Average Daily Trading Volume	Number of Halts on 8/24/15			All
	0	1–3	4+	
Number of Observations				
SPY	1	0	0	1
High Volume	46	1	0	47
Medium Volume	104	10	13	127
Low Volume	221	29	37	287
All	372	40	50	462
YTD Average Daily Trading Volume				
SPY	115,981,416	–	–	115,981,416
High Volume	13,856,799	5,068,900	–	13,669,822
Medium Volume	1,772,718	1,782,057	958,216	1,690,079
Low Volume	157,352	140,993	207,643	162,182
All	2,614,332	674,456	402,792	
Mean 8/24/15 Volume Ratio				
SPY	4.373	–	–	4.373
High Volume	3.205	2.599	–	3.193
Medium Volume	3.545	3.876	4.882	3.708
Low Volume	3.703	3.975	5.543	3.968
All	3.599	3.916	5.371	
Median 8/24/15 Volume Ratio				
SPY	4.373	–	–	4.373
High Volume	2.889	2.599	–	2.882
Medium Volume	3.023	3.651	5.539	3.237
Low Volume	2.703	3.432	5.058	2.990
All	2.830	3.417	5.155	3.023

Source: CRSP; SEC Halts Data.

Note: Based on a sample of 462 ETFs with listed options, for which volume data are available from CRSP. "Volume Ratio" is the ratio of 8/24/15 volume to the YTD average daily trading volume. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Volume Ratio on 8/24/15 vs. YTD Average Daily Trading Volume

ETF Data



Source: CRSP; SEC Halts Data.

Note: Based on a sample of 462 ETFs with listed options, for which volume data are available from CRSP. "Volume Ratio" is the ratio of 8/24/15 volume to the YTD average daily trading volume. Two ETFs, both with zero halts, have volume ratios above 20.

Options Data

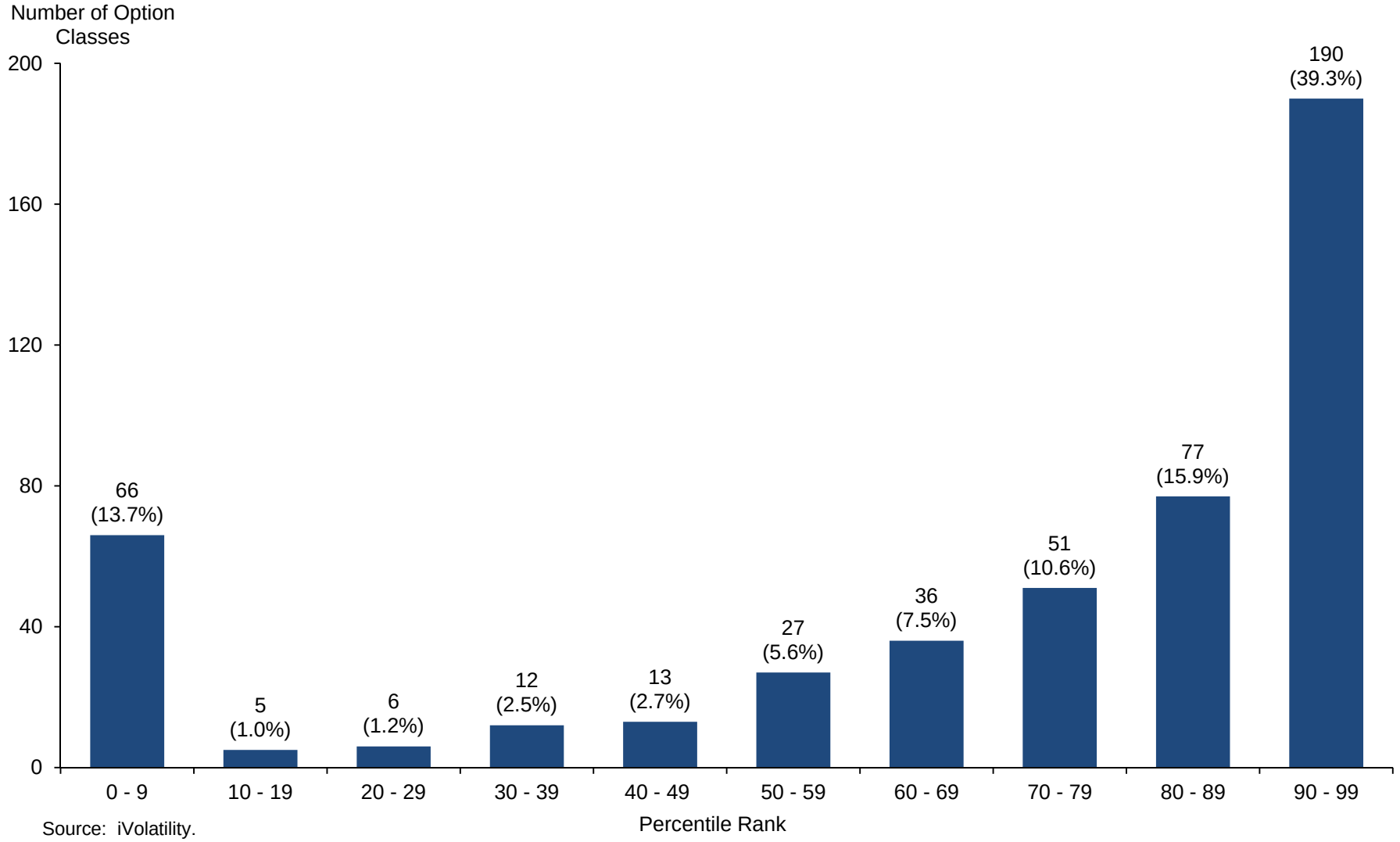
Source: iVolatility

Number of Symbols in Sample: 483

Time Range: 1/2/15 – 12/31/15

Percentile Rank of Volume on 8/24/15 Relative to YTD Daily Volume

Options Data

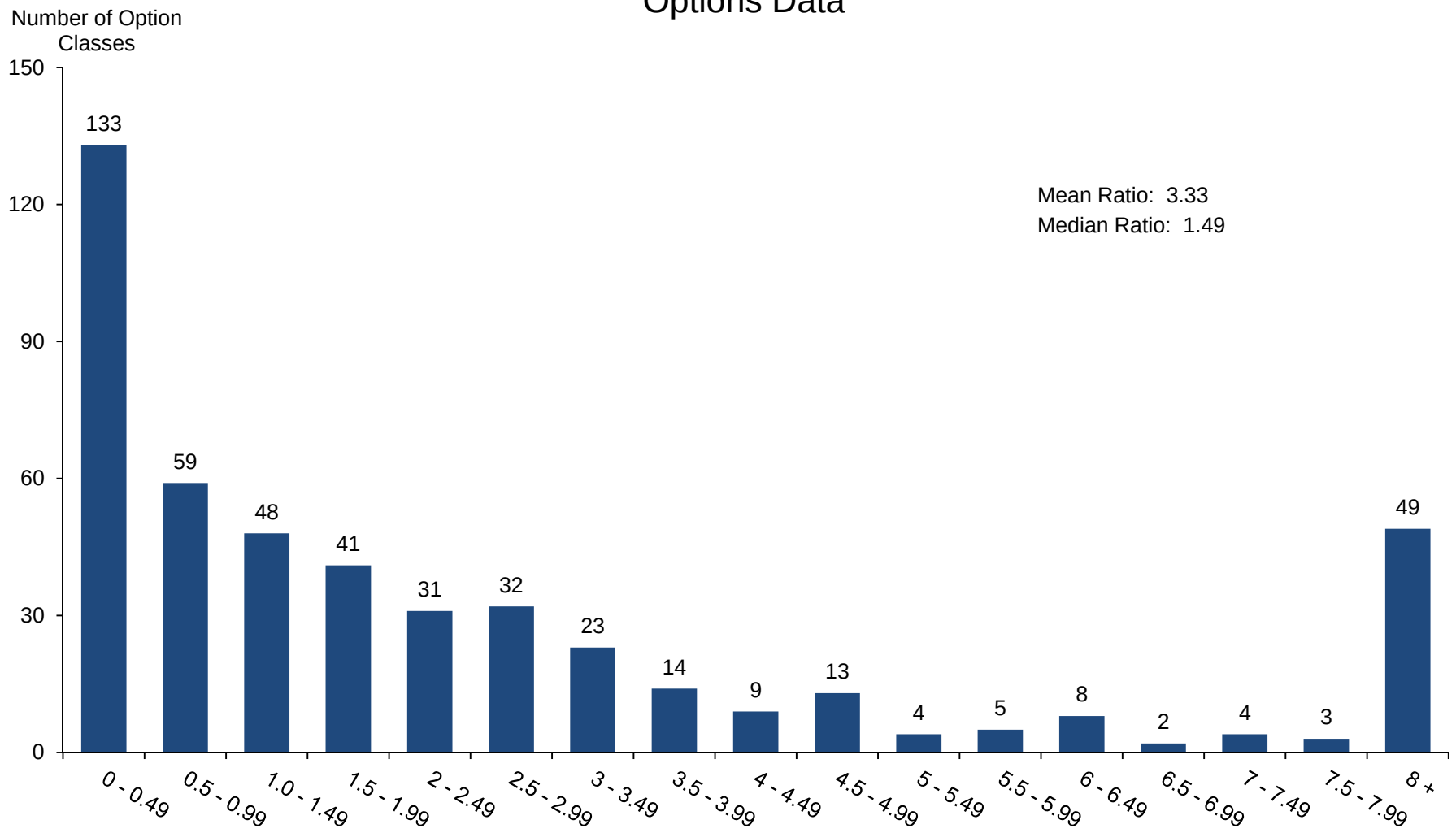


Source: iVolatility.

Note: Based on a sample of 483 option classes on ETFs and indexes, for which volume data are available from iVolatility. For each option class the percentile rank of the 8/24/15 volume is defined as the percentage of days in 2015 prior to 8/24/15 for which the volume was less than the 8/24/15 volume. 65 or 13.5% of option classes in the sample had no volume on 8/24/15. The volume on 8/24/15 was the highest for 26 or 5.4% of the option classes in the sample.

Ratio of 8/24/15 Volume to YTD Average Daily Trading Volume

Options Data

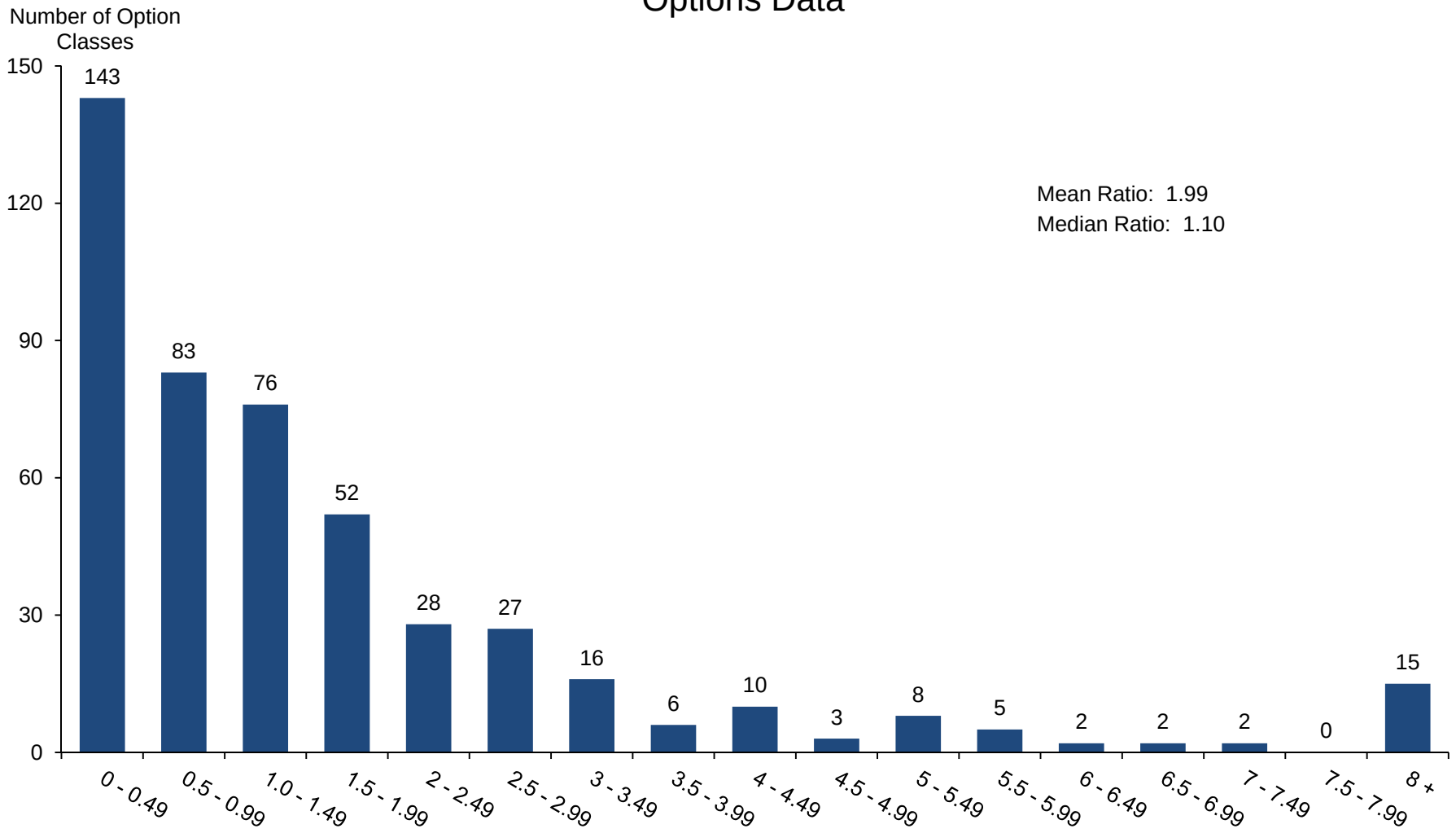


Source: iVolatility.

Note: Based on a sample of 478 option classes on ETFs and indexes, for which volume data are available from iVolatility and pre-8/24/15 volume was non-zero. YTD average daily trading volume is defined as the average daily trading volume for 1/2/15 – 8/21/15.

Ratio of 8/25/15 – 8/28/15 Daily Volume to YTD Average Daily Trading Volume

Options Data



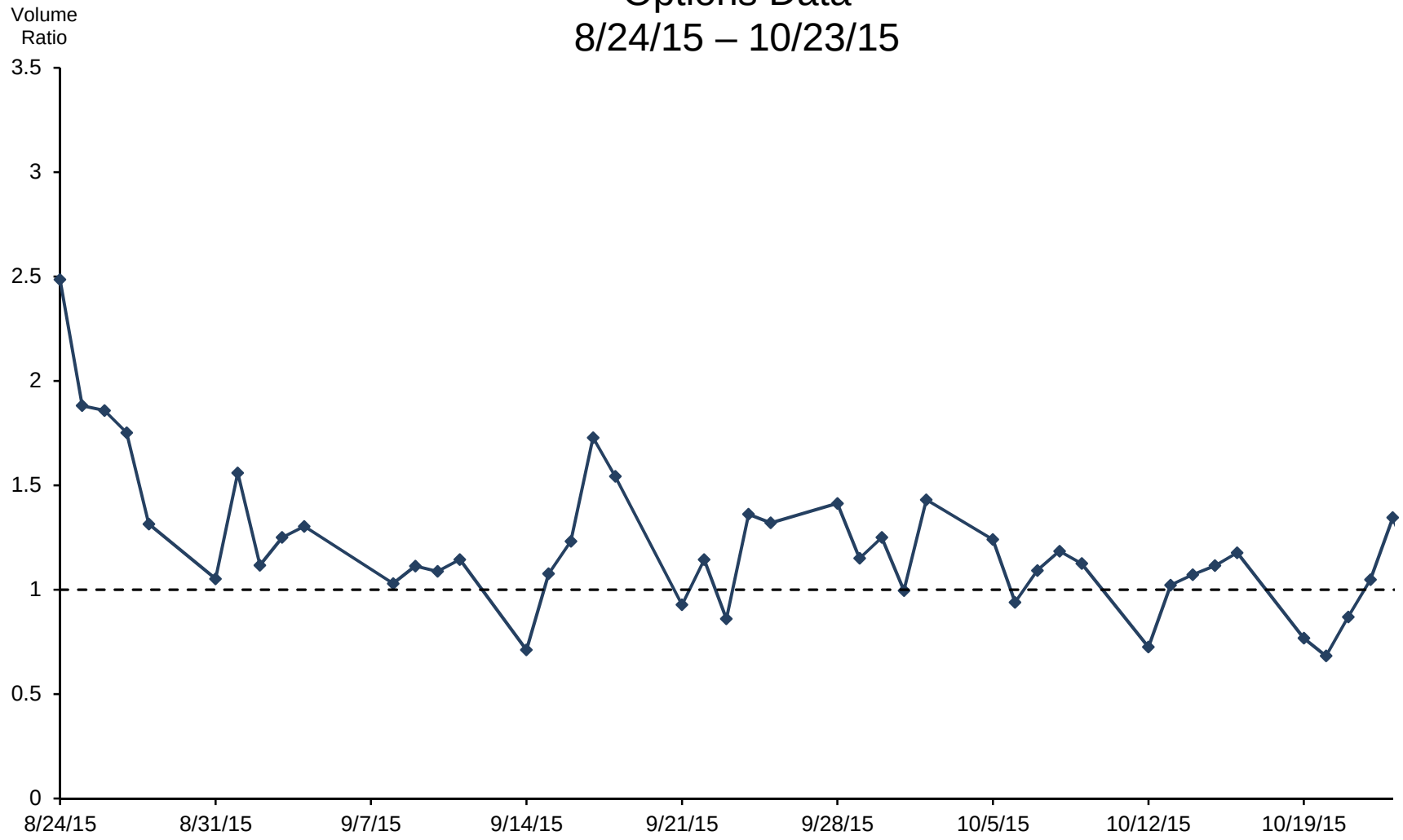
Source: iVolatility.

Note: Based on a sample of 478 option classes on ETFs and indexes, for which volume data are available from iVolatility and pre-8/24/15 volume was non-zero. YTD average daily trading volume is defined as the average daily trading volume for 1/2/15 – 8/21/15.

Ratio of Total Daily Volume to YTD Average Daily Trading Volume

Options Data

8/24/15 – 10/23/15



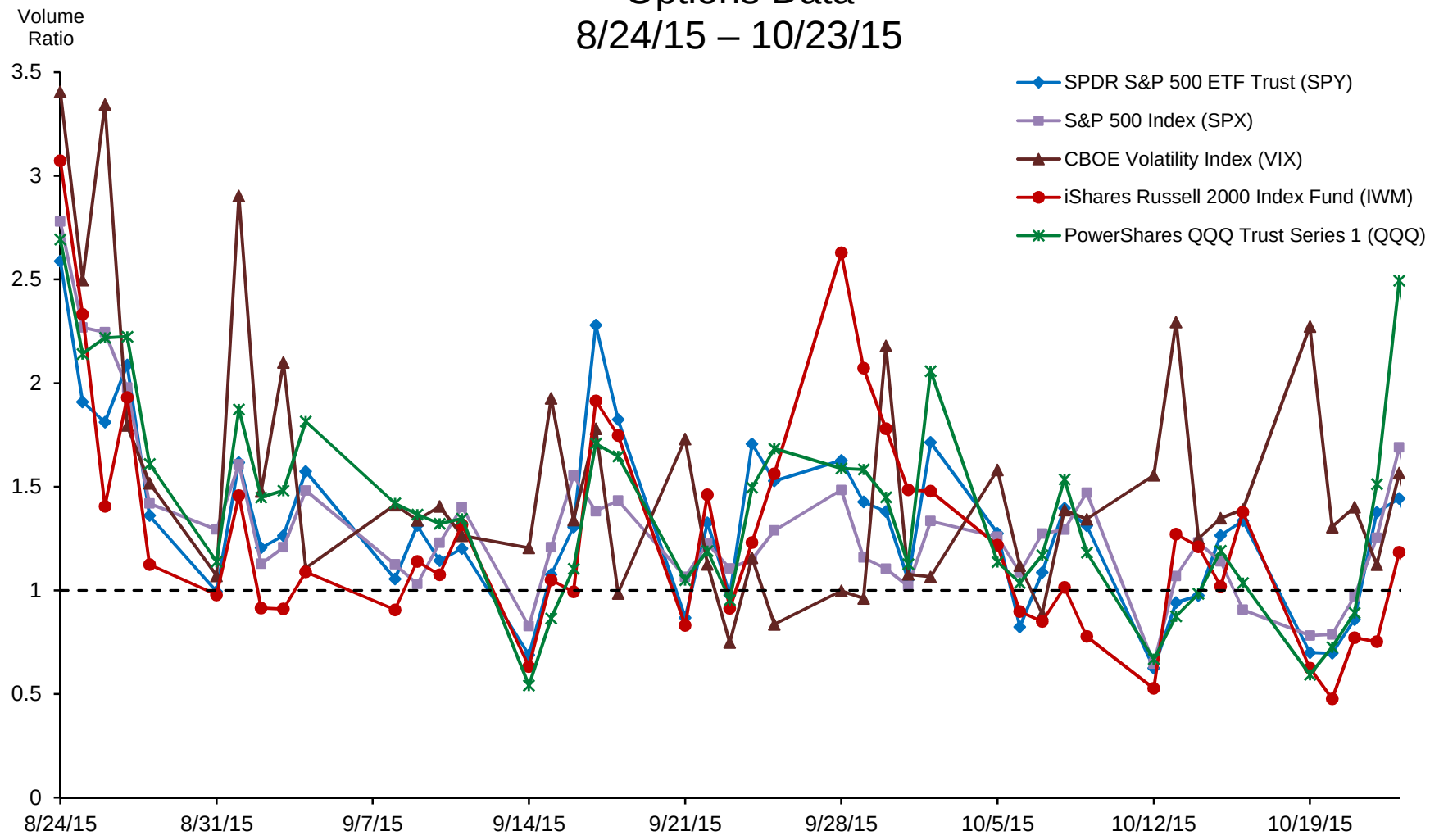
Source: iVolatility.

Note: Based on a sample of 450 option classes on ETFs and indexes, for which volume data are available from iVolatility for at least 250 trading days between 1/2/15 and 12/31/15. YTD average daily trading volume is defined as the average daily trading volume for 1/2/15 – 8/21/15. "Volume Ratio" is the ratio of volume on a given day to the average daily trading volume from 1/2/15 to 8/21/15.

Ratio of Daily Volume to YTD Average Daily Trading Volume

Options Data

8/24/15 – 10/23/15



Source: iVolatility.

Note: Graph displays the five option classes with the highest YTD average daily trading volume in the sample of 483 option classes on ETFs and Indexes. YTD average daily trading volume is defined as the average daily volume for 1/2/15 – 8/21/15. "Volume Ratio" is the ratio of volume on a given day to the average daily trading volume from 1/2/15 to 8/21/15.

Options Summary Statistics Grouped by ETF Size and Number of Halts on 8/24/15

ETF Size	Number of Halts on 8/24/15			All
	0	1–3	4+	
Number of Observations				
SPY	1	–	–	1
Large	37	5	6	48
Medium	106	9	37	152
Small	225	25	6	256
All	369	39	49	457
YTD Average Daily Trading Volume				
SPY	2,417,177	–	–	2,417,177
Large	47,082	142	102	36,320
Medium	8,870	500	40	6,225
Small	1,144	480	20	1,053
All	14,517	441	45	
Mean 8/24/15 Volume Ratio				
SPY	2.589	–	–	2.589
Large	2.460	4.224	2.846	2.692
Medium	2.153	2.877	6.842	3.338
Small	3.525	2.421	6.734	3.493
All	3.022	2.757	6.339	
Median 8/24/15 Volume Ratio				
SPY	2.589	–	–	2.395
Large	2.372	2.952	3.245	1.309
Medium	1.262	1.014	1.534	1.232
Small	1.192	1.316	0.864	2.589
All	1.463	1.473	1.534	1.473

Source: iVolatility; CRSP; SEC Halts Data.

Note: Based on a sample of 457 option classes on ETFs, for which volume data are available from iVolatility, pre-8/24/15 volume was non-zero, and market capitalization data for the underlying ETF are available from CRSP. "Volume Ratio" is the ratio of 8/24/15 volume to the YTD average daily trading volume. "ETF Size" is defined as the number of shares outstanding for the ETF multiplied by the closing price on 8/21/15. ETFs with an ETF size of (i) $1 billion or less are grouped as "Small"; (ii) between $1 billion and $10 billion are grouped as "Medium"; and (iii) greater than $10 billion are grouped as "Large."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15

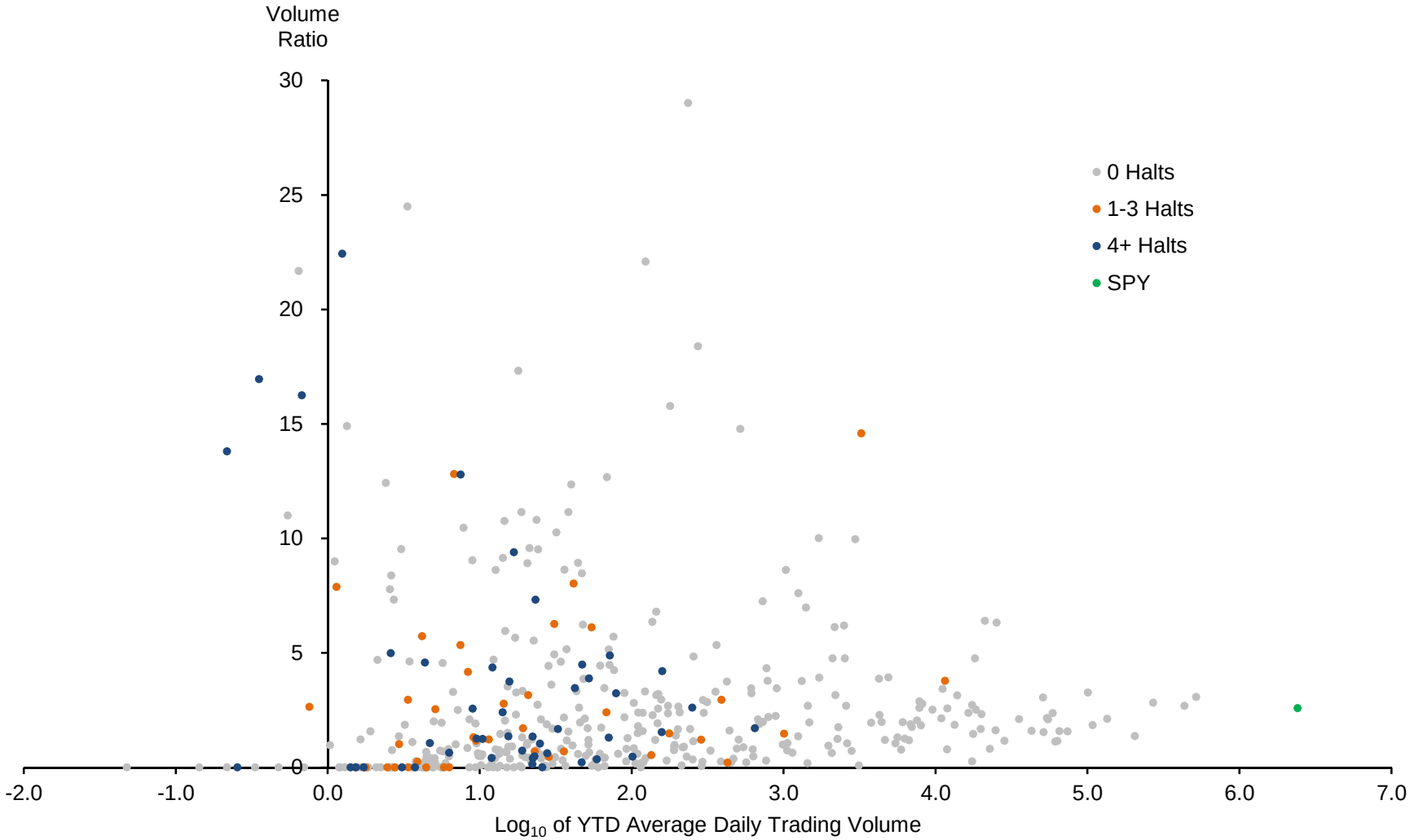
Underlying ETF ADTV	Number of Halts on 8/24/15			All
	0	1–3	4+	
Number of Observations				
SPY	1	0	0	1
High Volume	46	1	0	47
Medium Volume	104	10	13	127
Low Volume	218	28	36	282
All	369	39	49	457
YTD Average Daily Trading Volume				
SPY	2,417,177	–	–	2,417,177
High Volume	58,686	1,010	–	57,459
Medium Volume	2,148	1,562	107	1,893
Low Volume	77	37	22	66
All	14,517	453	45	
Mean 8/24/15 Volume Ratio				
SPY	2.589	–	–	2.589
High Volume	2.441	1.473	–	2.420
Medium Volume	3.038	3.327	2.681	3.024
Low Volume	3.139	2.600	7.660	3.662
All	3.022	2.757	6.339	
Median 8/24/15 Volume Ratio				
SPY	2.589	–	–	2.589
High Volume	2.104	1.473	–	2.101
Medium Volume	1.974	1.941	1.706	1.966
Low Volume	0.786	1.267	1.447	0.916
All	1.463	1.473	1.534	1.473

Source: iVolatility; CRSP; SEC Halts Data.

Note: Based on a sample of 457 option classes on ETFs, for which volume data are available from iVolatility, pre-8/24/15 volume was non-zero. "Volume Ratio" is the ratio of 8/24/15 volume to the YTD average daily trading volume. Option classes for which the average daily trading volume for the underlying ETF is (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Volume Ratio on 8/24/15 vs. YTD Average Daily Trading Volume

Options Data



Source: iVolatility; SEC Halts Data.

Note: Based on a sample of 457 option classes on ETFs, for which volume data are available from iVolatility and pre-8/24/15 volume was non-zero. "Volume Ratio" is the ratio of 8/24/15 volume to the YTD average daily trading volume. Five option classes, three with zero halts and two with 4+ halts, have volume ratios above 30.

Futures Data

Source: Bloomberg

Number of Futures in Sample: 10

Time Range: 1/1/15 – 12/31/15

Summary Trading Volume Statistics

Futures Data

Rank	Contract	Average Daily Volume (1/1/15 - 8/21/15)	Median Daily Volume (1/1/15 - 8/21/15)	St. Dev Daily Volume (1/1/15 - 8/21/15)	8/24/15 Volume	8/24/15 Relative to Average	8/24 Rank (Out of 162 Trading Days)	8/25/15 - 8/28/15 Relative to Average
1	S&P 500 E-Mini	1,568,109	1,424,303	540,375	5,309,704	3.39	1	1.94
2	Nasdaq E-Mini	250,104	226,292	86,102	752,763	3.01	1	2.08
3	VIX	178,571	172,555	63,565	724,459	4.06	1	2.17
4	Dow Jones E-mini	150,643	140,335	53,053	559,035	3.71	1	2.30
5	Russell 2000 Mini	103,816	93,335	45,478	259,121	2.50	2	1.71
6	MSCI Emerging Markets Mini	40,807	28,495	43,644	147,152	3.61	6	2.31
7	S&P 400 E-Mini	19,654	16,696	11,500	55,988	2.85	7	1.68
8	MSCI EAFE Mini	13,831	8,884	19,518	23,030	1.67	12	1.08
9	S&P 500	10,490	6,343	14,235	34,997	3.34	11	1.55
10	Russell 1000 Mini	1,027	779	956	265	0.26	158	1.55

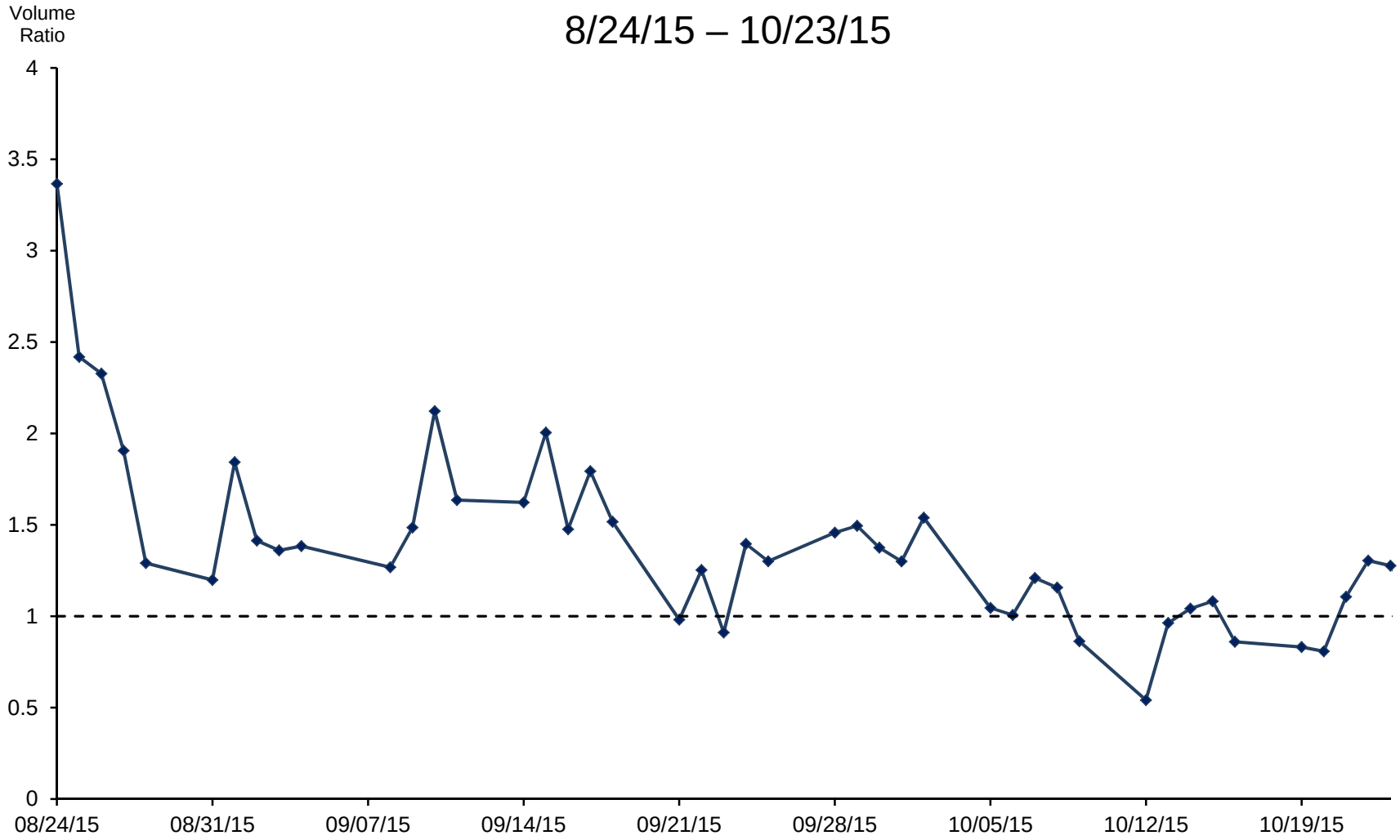
Source: Bloomberg.

Note: Based on a sample of 10 equity index futures listed on US exchanges, for which intraday data are available from TickData. Data on CME Trading holidays have been excluded.

Ratio of Total Daily Volume to YTD Average Daily Trading Volume

Futures Data

8/24/15 – 10/23/15



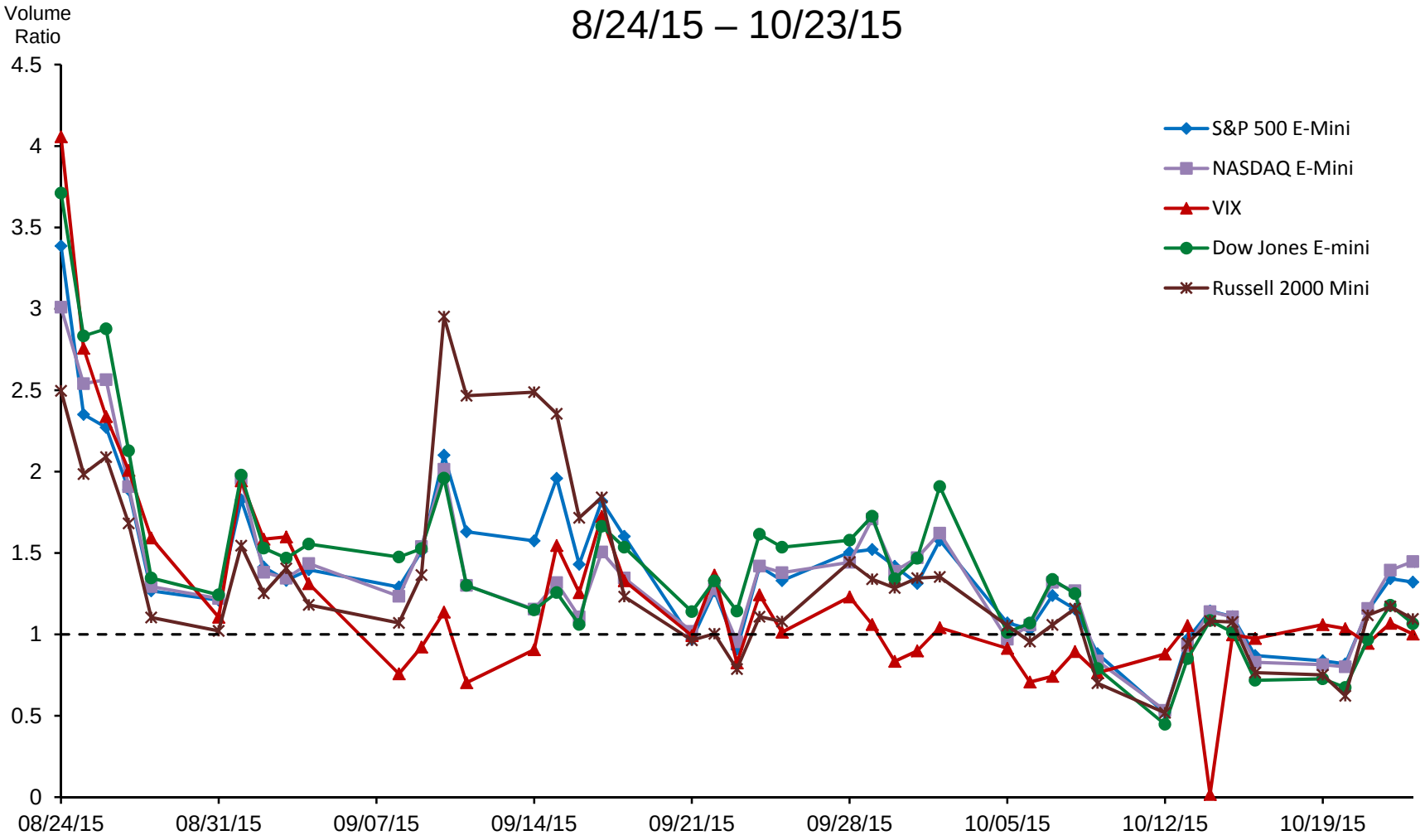
Source: Bloomberg.

Note: Based on a sample of 10 equity index futures listed on US exchanges, for which intraday data are available from TickData. YTD average daily trading volume is defined as the average daily trading volume for 1/2/15 – 8/21/15. "Volume Ratio" is the ratio of volume on a given day to the average daily trading volume from 1/2/15 to 8/21/15.

Ratio of Daily Volume to YTD Average Daily Trading Volume

Futures Data

8/24/15 – 10/23/15



Source: Bloomberg.

Note: Graph displays the five futures with the highest YTD average daily trading volume in the sample of 10 equity index futures listed on US exchanges, for which intraday data are available from TickData. YTD average daily trading volume is defined as the average daily volume for 1/2/15 – 8/21/15. "Volume Ratio" is the ratio of volume on a given day to the average daily trading volume from 1/2/15 to 8/21/15.

Analysis of Market Events on August 24, 2015

Intraday Data

Overall Objective and Sample Selection

Objective: Produce graphs and summary statistics relevant to understanding how the liquidity shock in the morning of August 24, 2015 impacted linked options and futures markets

Intraday Data Sample: Same as End-of-Day Sample

- Options Sample:
  - List of ETFs and Indexes with listed options were acquired from iVolatility
  - 68 options with no trading volume between 8/24/15 and 8/31/15 were removed
  - Sample consists of the remaining 483 ETFs and Indexes with listed options
- ETF Sample:
  - Sample includes all ETFs with listed options in the options sample for which CRSP has data
  - Sample contains 462 ETFs
- Futures Sample:
  - Sample includes 10 futures for which intraday data are available from TickData

Table of Contents

Section 1: Full Sample Liquidity Metrics

- Calculated liquidity metrics between 9:30 AM and 10:00 AM on 8/24/15 and the following five trading days (8/25/15 – 8/31/15)
  - Average quoted spread and percentage of time without a firm bid and offer are presented here
- On average, ETFs in the sample had spreads that were more than seven times wider than during the control period
  - ETFs that halted had wider spreads than those that did not halt
- Quoting stopped on many options, even though no halts were in place on the underlying ETF
  - For option series that continued quoting, spreads were approximately two times wider than during the control period
  - Options for which the underlying ETF halted had similar spreads to those that did not halt

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Quoted Spread[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Quoted Spread on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	0.058	–	–	0.058
High Volume	0.059	0.086	–	0.059
Medium Volume	0.205	0.722	0.906	0.246
Low Volume	1.094	2.548	3.542	1.269
All	0.715	2.025	2.953	0.844
Average Quoted Spread from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.011	–	–	0.011
High Volume	0.018	0.015	–	0.018
Medium Volume	0.051	0.040	0.055	0.051
Low Volume	0.171	0.154	0.147	0.166
All	0.118	0.122	0.123	0.119
Ratio of Average Quoted Spread on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	5.525	–	–	5.525
High Volume	3.195	5.730	–	3.233
Medium Volume	4.005	18.102	16.614	4.852
Low Volume	6.387	16.589	24.095	7.628
All	6.037	16.652	24.020	7.084

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average quoted spread is calculated as the difference between the NBO and NBB in dollars. Intervals during trading halts and intervals in which there are no firm bids or firm offers are excluded from the average spread calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Percentage of Time the ETF was Halted
9:30 AM – 10:00 AM

Average Daily Trading Volume[2]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Percentage of Time the ETF was Halted on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	–	–	–	–
High Volume	–	17.5%	–	0.4%
Medium Volume	–	36.7%	85.8%	11.7%
Low Volume	–	35.1%	82.6%	14.2%
All	–	35.1%	83.4%	12.1%

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Quoted Spread[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Quoted Spread on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	4.221	–	–	4.221
High Volume	2.096	3.161	–	2.096
Medium Volume	3.135	4.218	4.414	3.199
Low Volume	3.970	4.519	5.180	3.995
All	3.043	4.319	4.813	3.081
Average Quoted Spread from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.329	–	–	0.329
High Volume	0.539	0.416	–	0.538
Medium Volume	1.452	2.072	1.675	1.527
Low Volume	2.351	2.700	2.746	2.451
All	1.368	2.413	2.453	1.527
Ratio of Average Quoted Spread on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	12.825	–	–	12.825
High Volume	3.892	7.593	–	3.895
Medium Volume	2.159	2.035	2.635	2.095
Low Volume	1.688	1.674	1.886	1.630
All	2.225	1.790	1.962	2.018

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Average quoted spread is calculated as the difference between the NBO and NBB in dollars. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are no firm bids or firm offers are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Percentage of Time without a Firm Bid and Firm Offer[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Percentage of Time the ETF was Halted on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	–	–	–	–
High Volume	–	17.5%	–	0.4%
Medium Volume	–	36.7%	85.8%	11.7%
Low Volume	–	35.1%	82.6%	14.2%
All	–	35.1%	83.4%	12.1%
Percentage of Time without a Firm Bid and Offer on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	4.6%	–	–	4.6%
High Volume	1.7%	18.3%	–	1.7%
Medium Volume	1.1%	45.7%	92.0%	13.2%
Low Volume	3.5%	71.0%	95.9%	24.3%
All	2.3%	60.4%	94.8%	14.1%
Percentage of Time without a Firm Bid and Offer from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.0%	–	–	0.0%
High Volume	0.0%	0.0%	–	0.0%
Medium Volume	0.4%	0.0%	0.0%	0.3%
Low Volume	1.5%	3.4%	0.5%	1.5%
All	0.7%	2.1%	0.3%	0.7%

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Calculated as the percentage of time for which there was no firm bid and no firm offer on any exchange. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts are treated as intervals in which there are no firm bids and offers.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

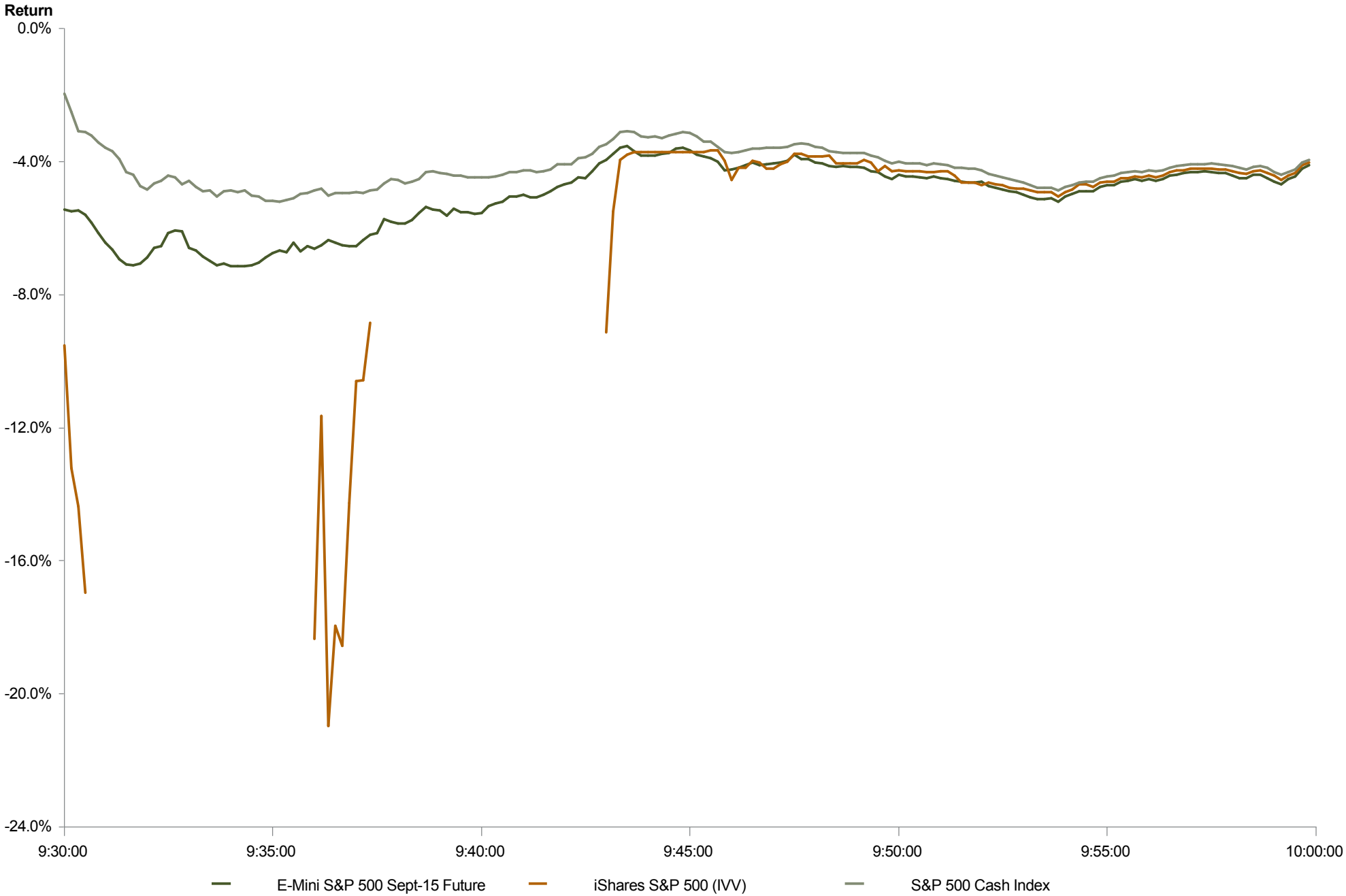
Section 2: Case Studies of Linked ETFs, Options, and Futures

S&P 500

- S&P 500 Linked Securities and Indexes
  - SPDR S&P 500 (SPY)
  - iShares S&P 500 (IVV)
  - Vanguard S&P 500 (VOO)
  - S&P 500 Cash Index (SPX)
  - E-Mini S&P 500 Sept-15 Future ($50)
- iShares S&P 500 (IVV) declined more than 20% below the August 21 close and trading was halted twice
- The other two ETFs and the E-mini futures traded loosely in the same range, trading as low as 7% below the August 21 close
- The S&P 500 Cash Index (SPX) slowly converged to the other three ETFs due to late openings in underlying stocks

Price Return Chart

S&P 500: iShares S&P 500 (IVV)

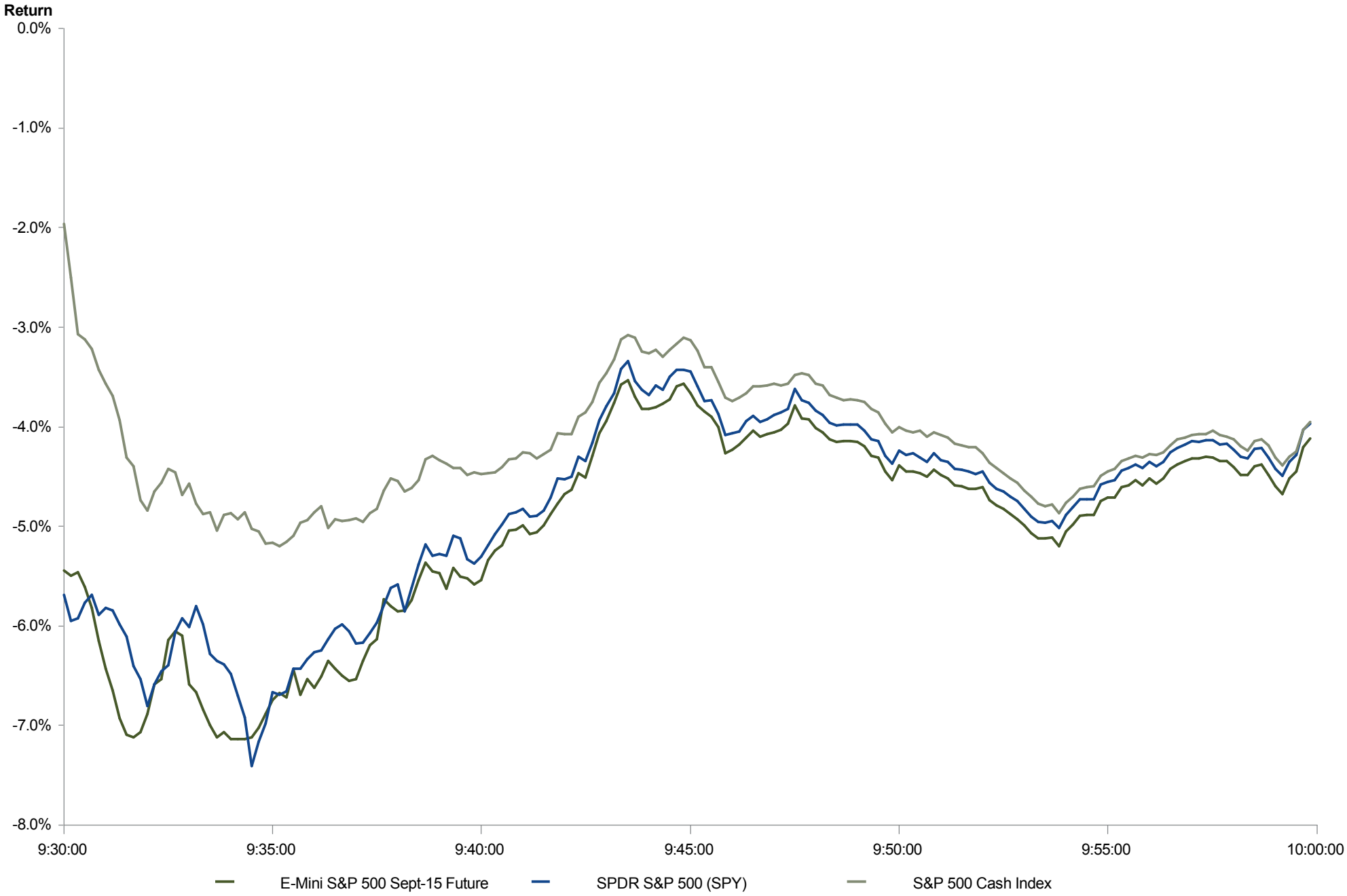


Source: TickData; Bloomberg; CRSP.

Note: Returns are calculated from the price at closing on August 21 and reflect the midpoint of the bid-ask spread at 10 second intervals.

Price Return Chart

S&P 500: SPDR S&P 500 (SPY)

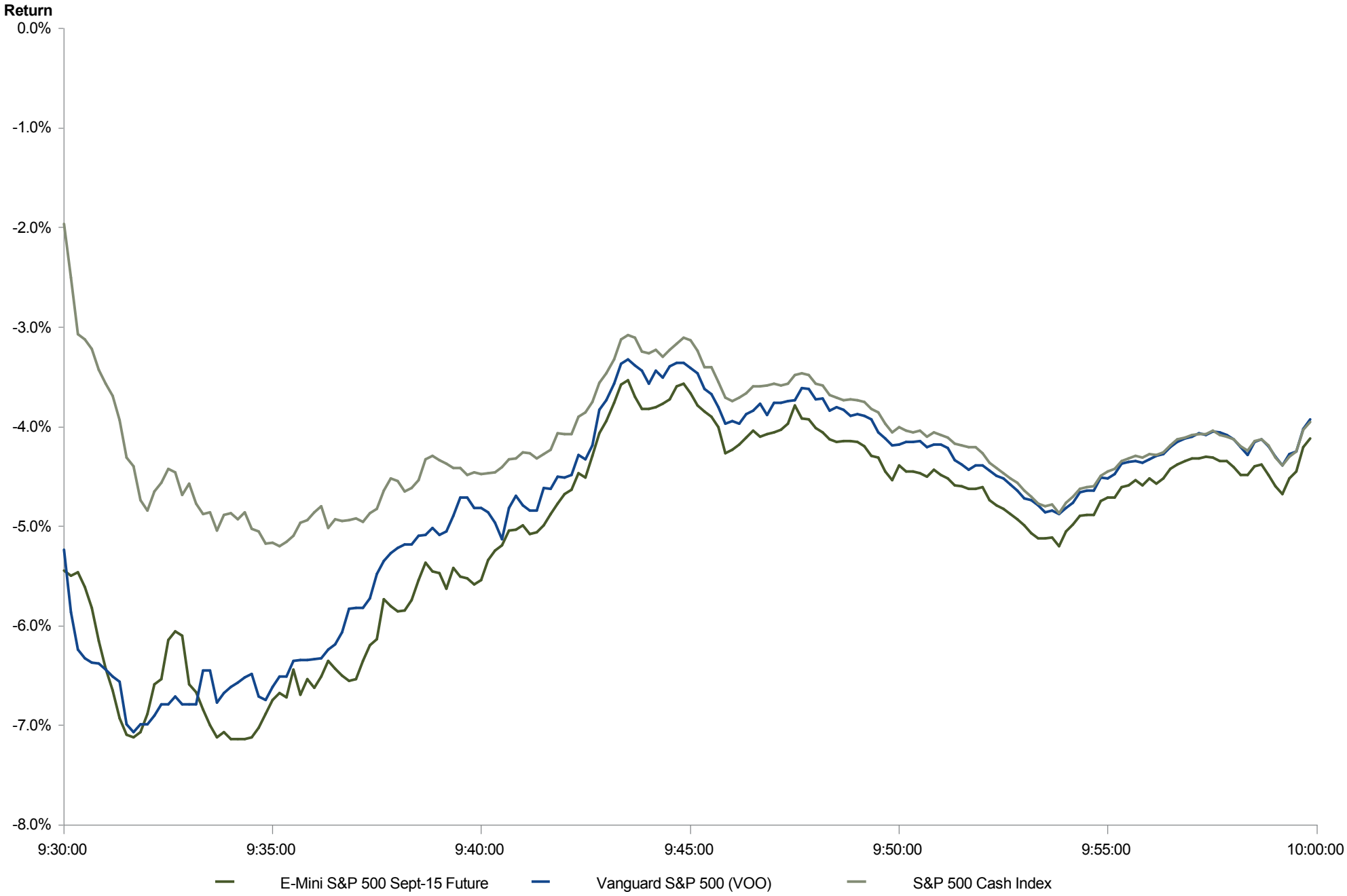


Source: TickData; Bloomberg; CRSP.

Note: Returns are calculated from the price at closing on August 21 and reflect the midpoint of the bid-ask spread at 10 second intervals.

Price Return Chart

S&P 500: Vanguard S&P 500 (VOO)



Source: TickData; Bloomberg; CRSP.

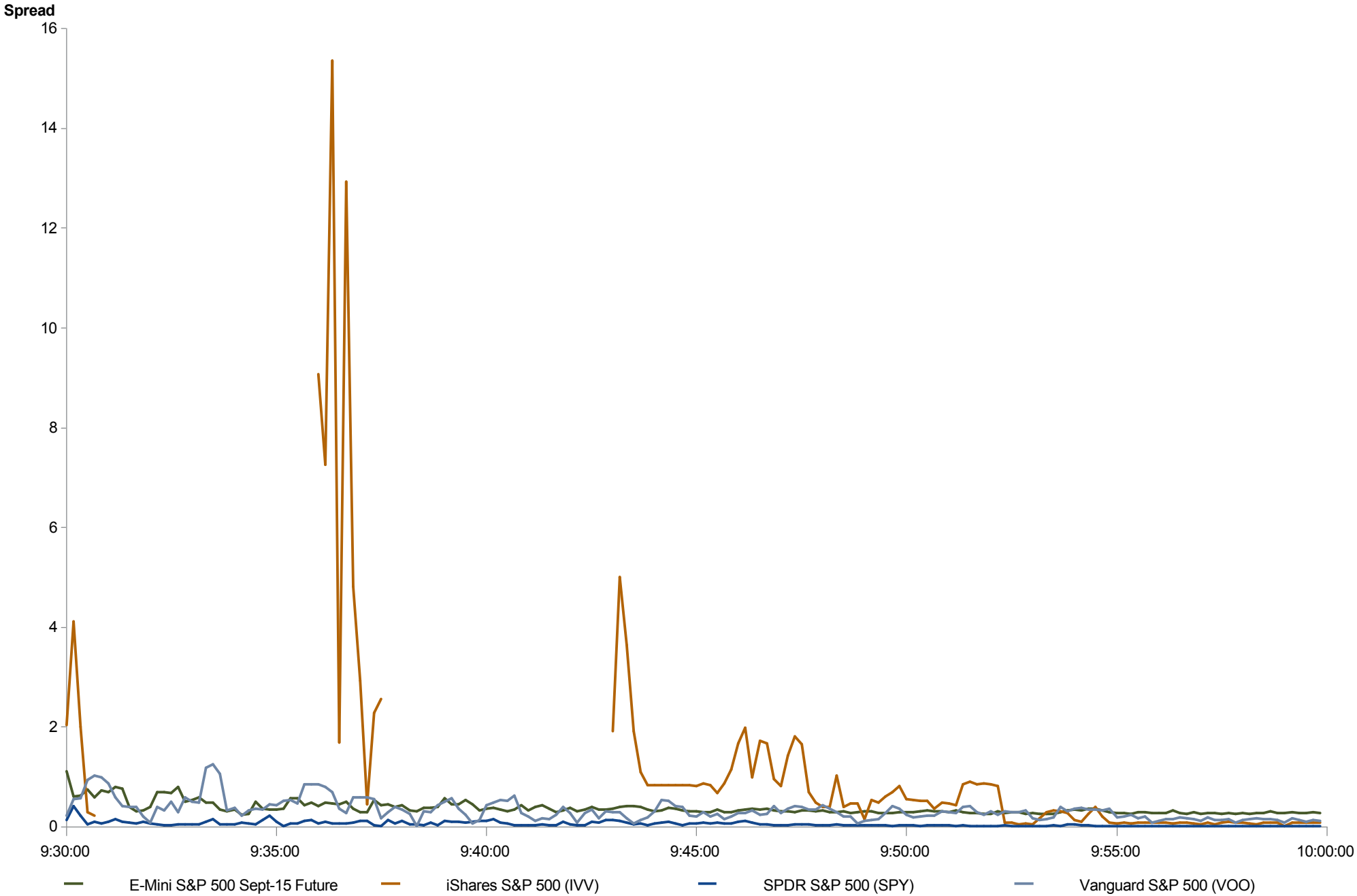
Note: Returns are calculated from the price at closing on August 21 and reflect the midpoint of the bid-ask spread at 10 second intervals.

Section 2: Case Studies of Linked ETFs, Options, and Futures
S&P 500 *(cont.)*

- The IVV spread was significantly wider than its average during the control period
  - Spread spiked to more than 250x average between the two halts
  - Spread remained above 10x average past 9:50 AM
- The VOO and SPY spreads were approximately 6x their average during the control period
- S&P 500 E-Mini September 2015 future spread was only 50% greater than its average

Average Spread on 8/24/15

S&P 500: ETF and Futures Data

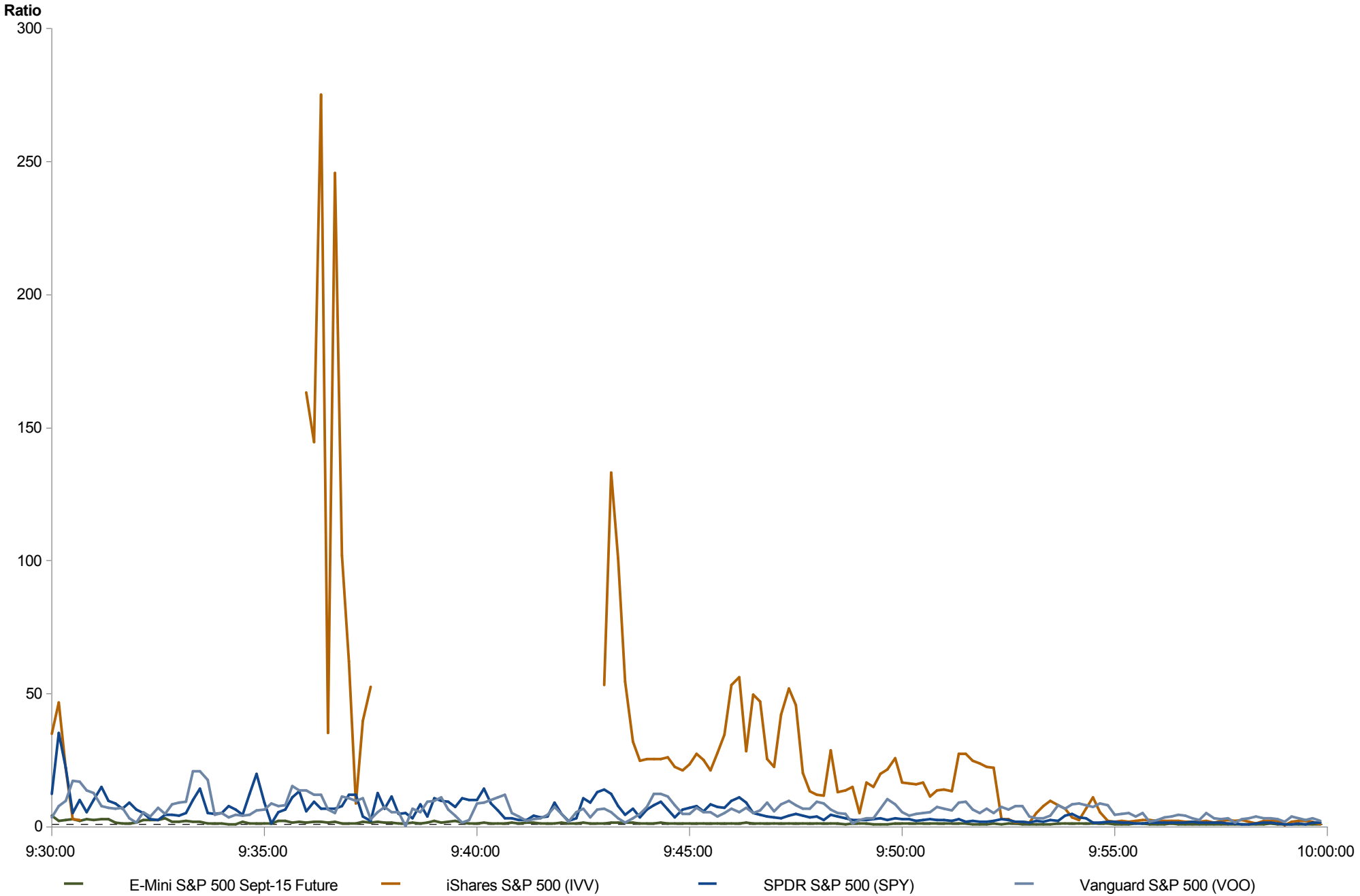


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 500: ETF and Futures Data



Source: TickData.

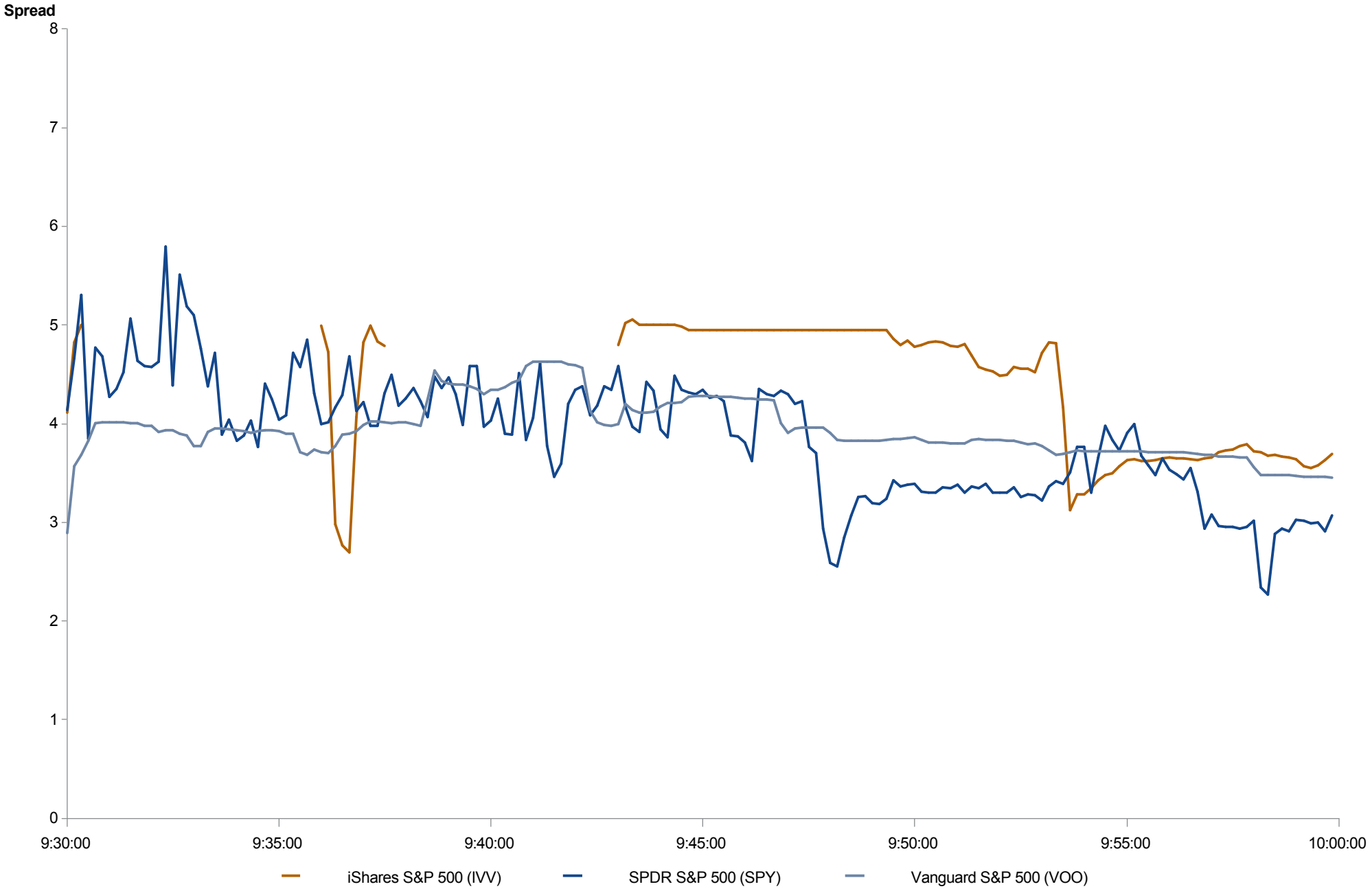
Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation.

Section 2: Case Studies of Linked ETFs, Options, and Futures
S&P 500 *(cont.)*

- Spreads for the IVV options experienced a smaller increase relative to the control period than SPY
  - IVV options experienced a similar increase relative to the control period to VOO and SPX
- Many options on IVV stopped quoting during rapid declines in the stock price
  - However, most option series continued quoting at other times when IVV traded at a discount to the other S&P 500 securities

Average Spread on 8/24/15

S&P 500 ETF Options (Calls)

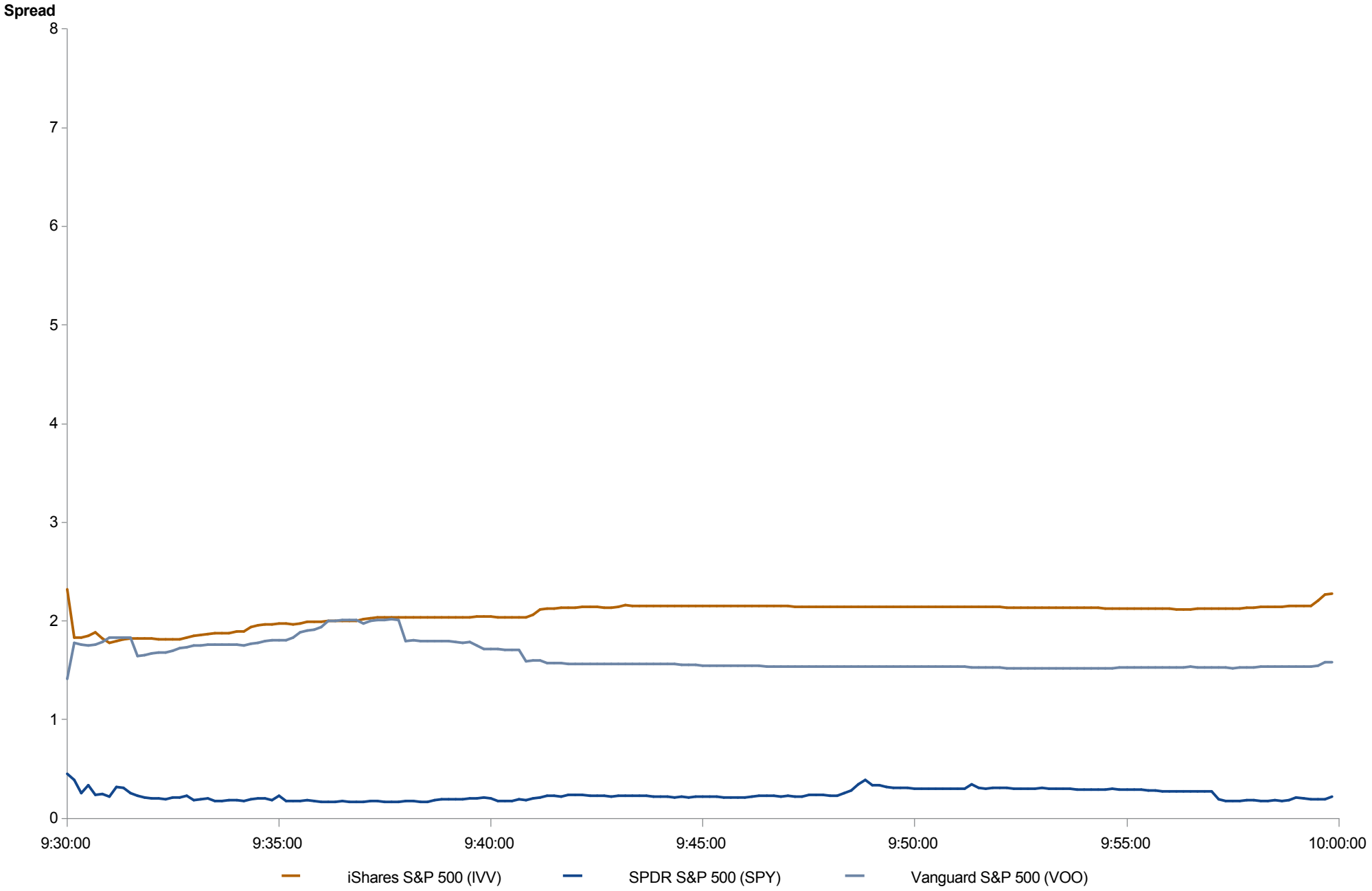


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Spread from 8/25/15 through 8/31/15

S&P 500 ETF Options (Calls)



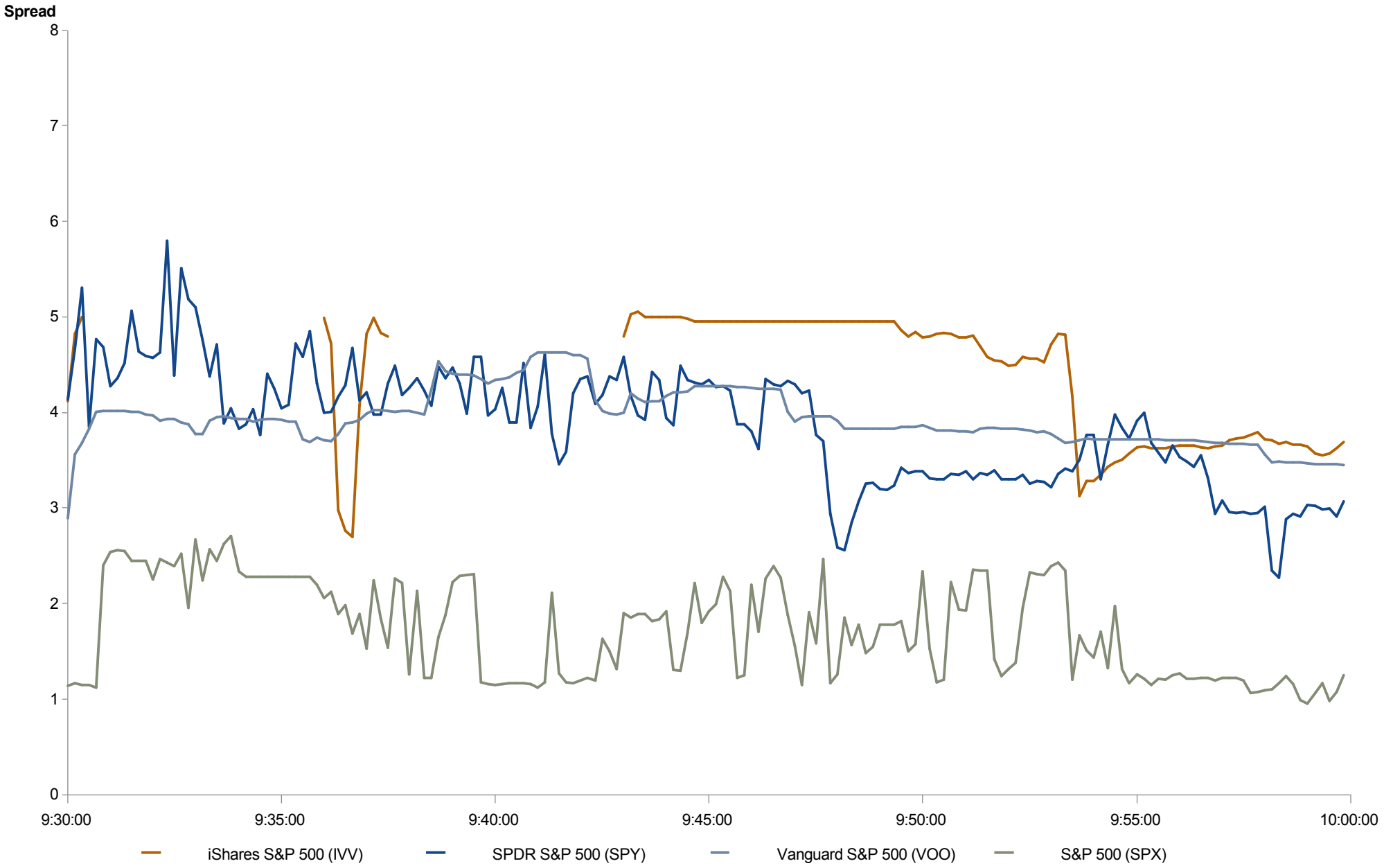
Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Spread on 8/24/15

S&P 500 Options (Calls)

SPX Adjusted for Notional Size

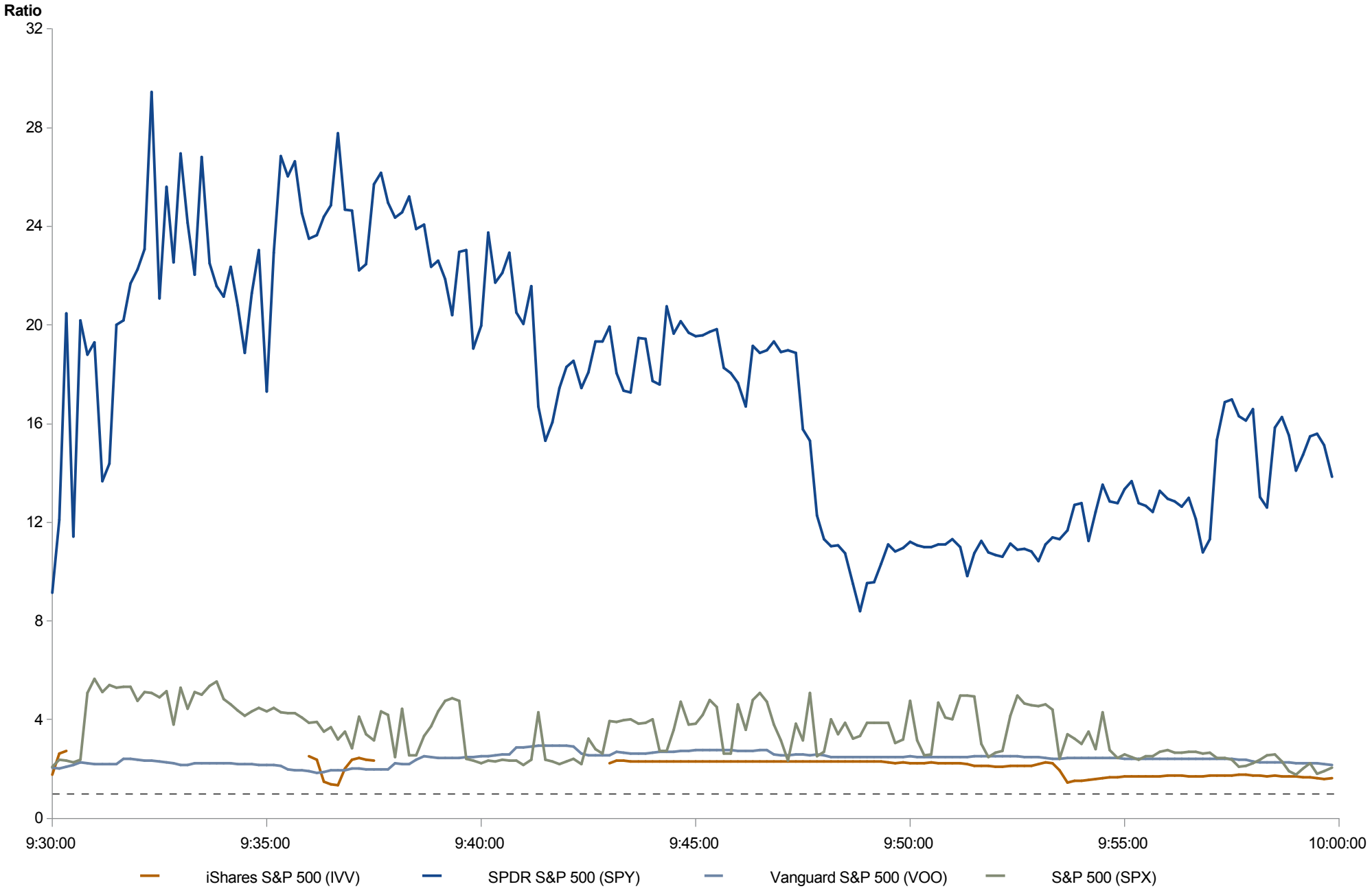


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 500 Options (Calls)

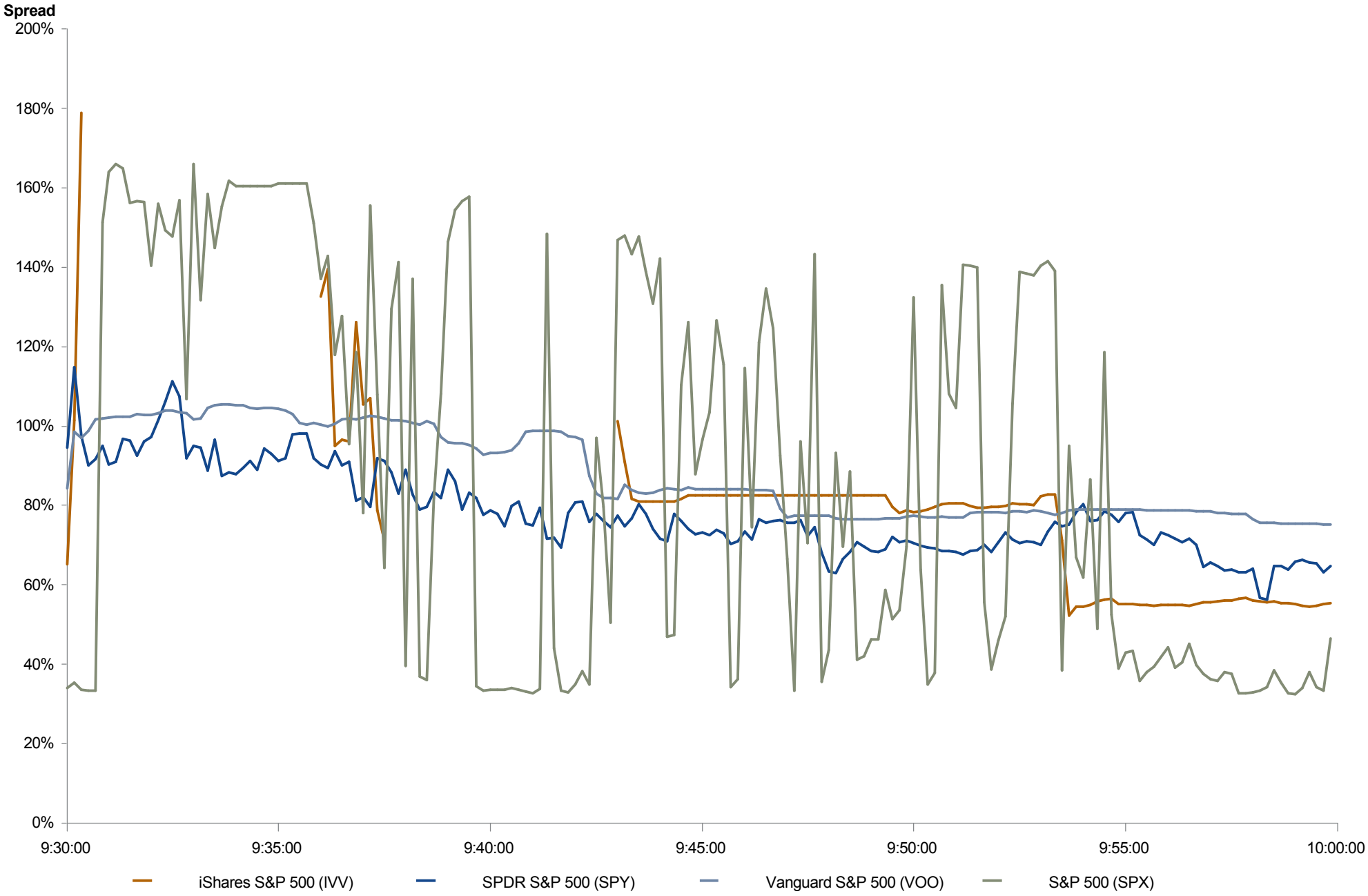


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Relative Spread on 8/24/15

S&P 500 Options (Calls)

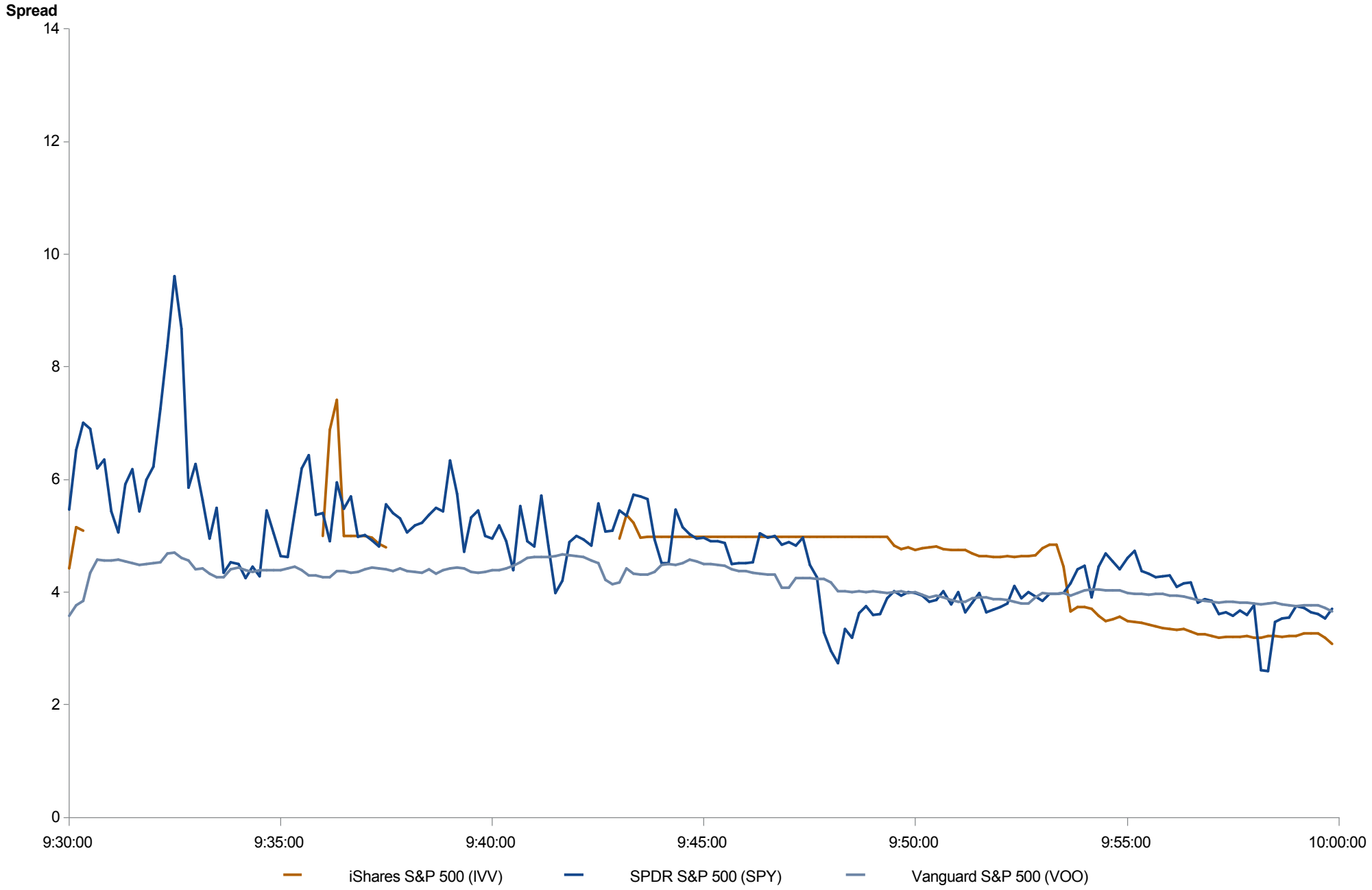


Source: TickData.

Note: Average relative spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average relative spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Spread on 8/24/15

S&P 500 ETF Options (Puts)

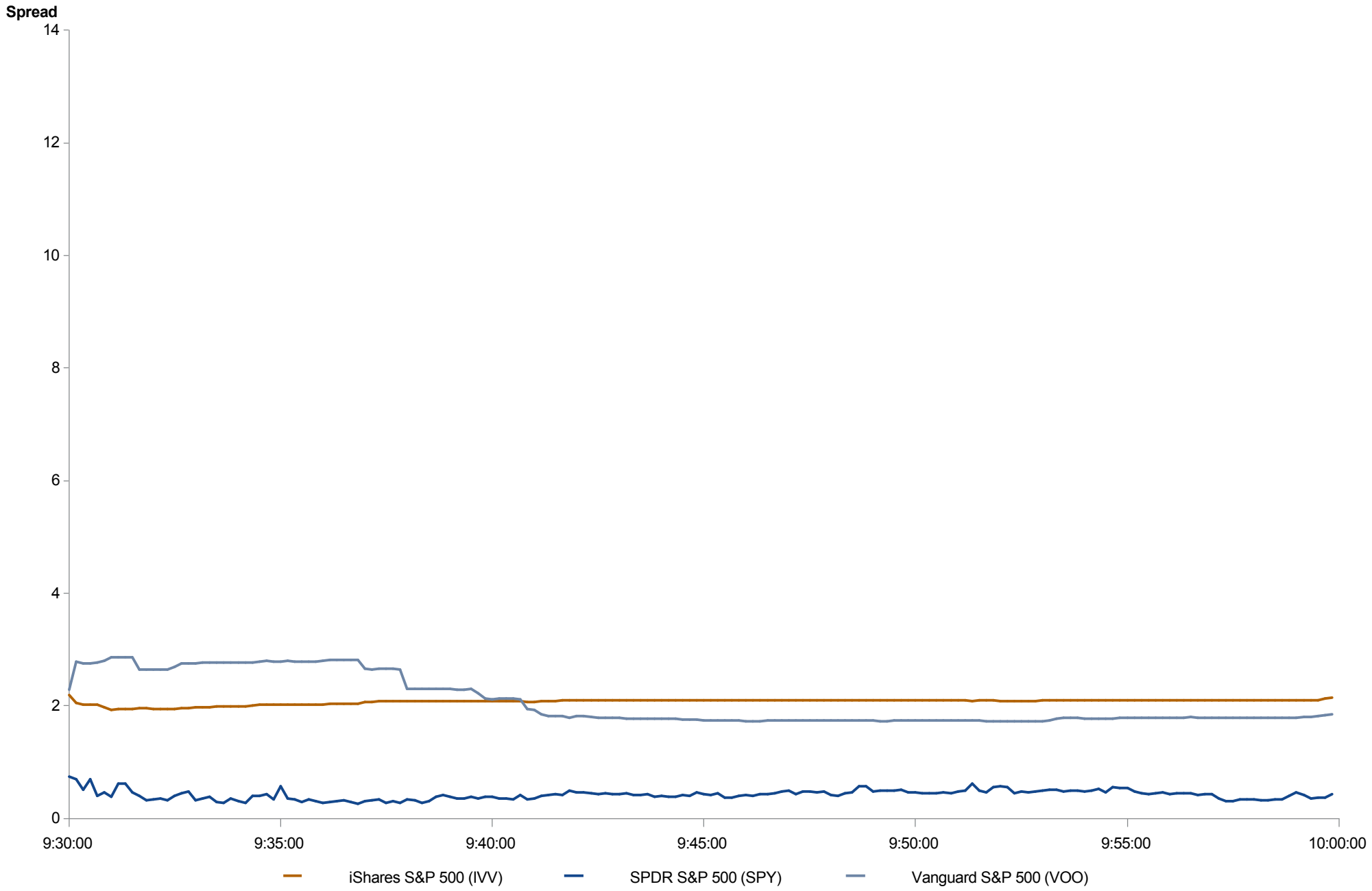


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Spread from 8/25/15 through 8/31/15

S&P 500 ETF Options (Puts)

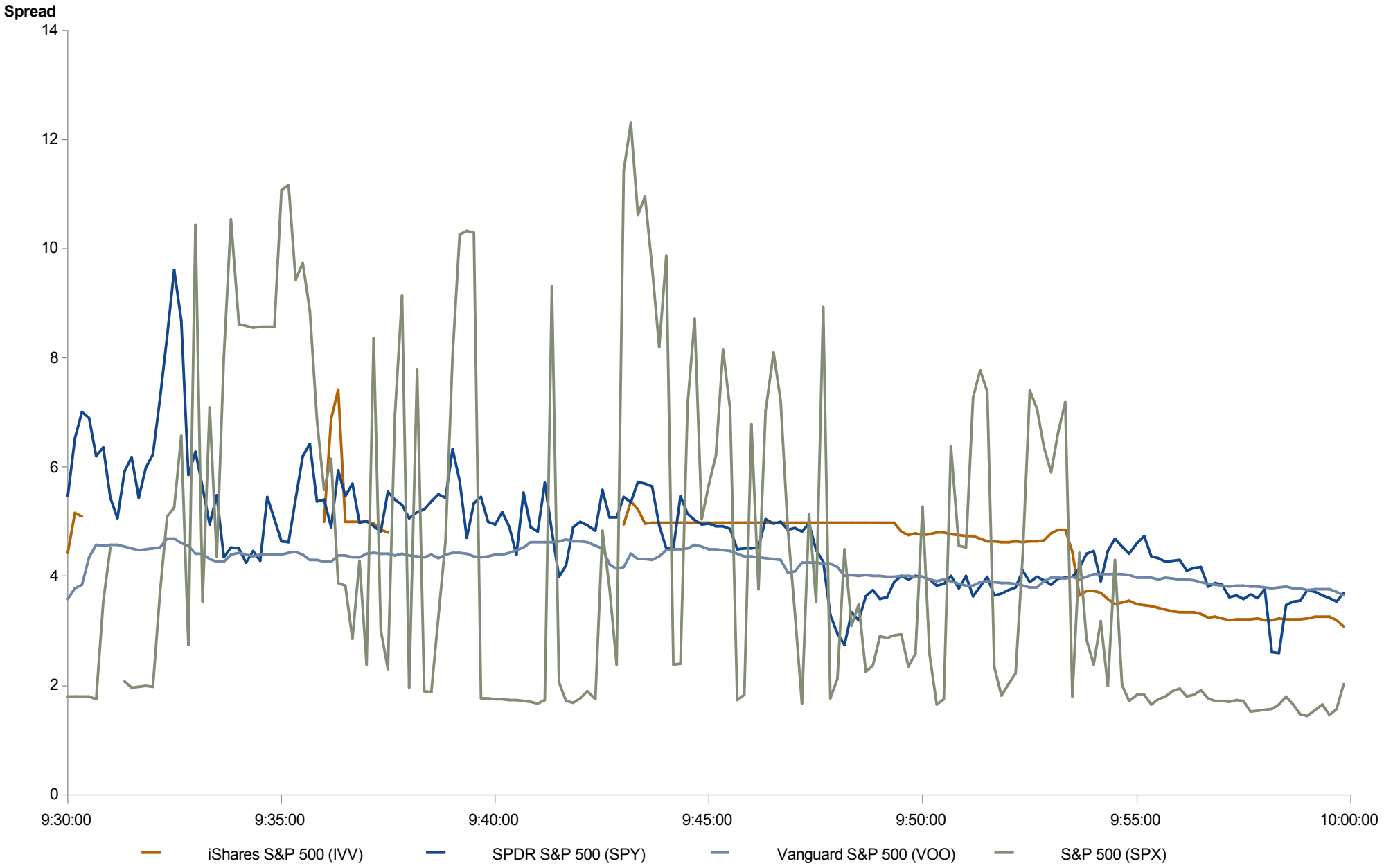


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Spread on 8/24/15

S&P 500 Options (Puts)
SPX Adjusted for Notional Size

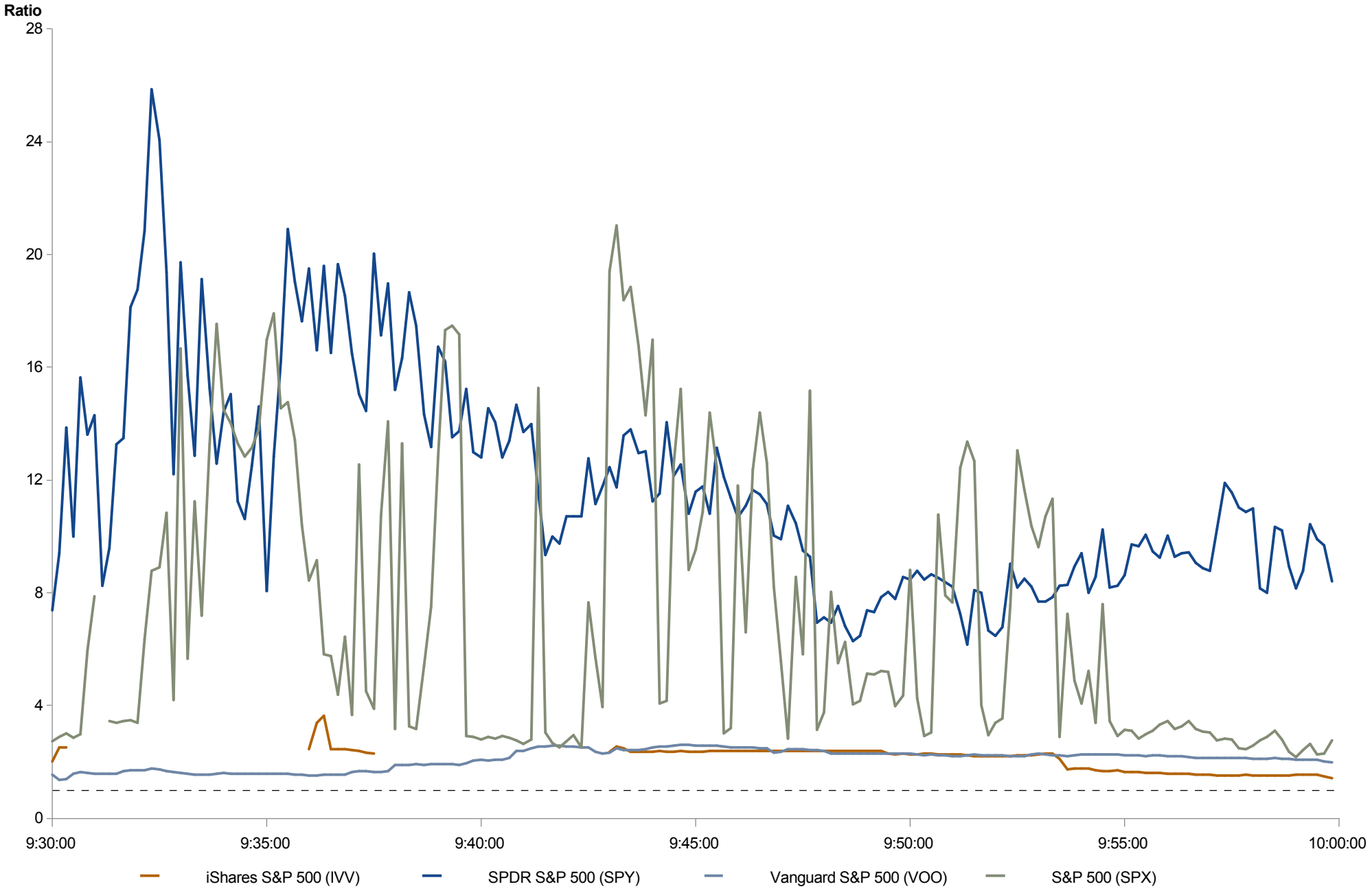


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 500 Options (Puts)

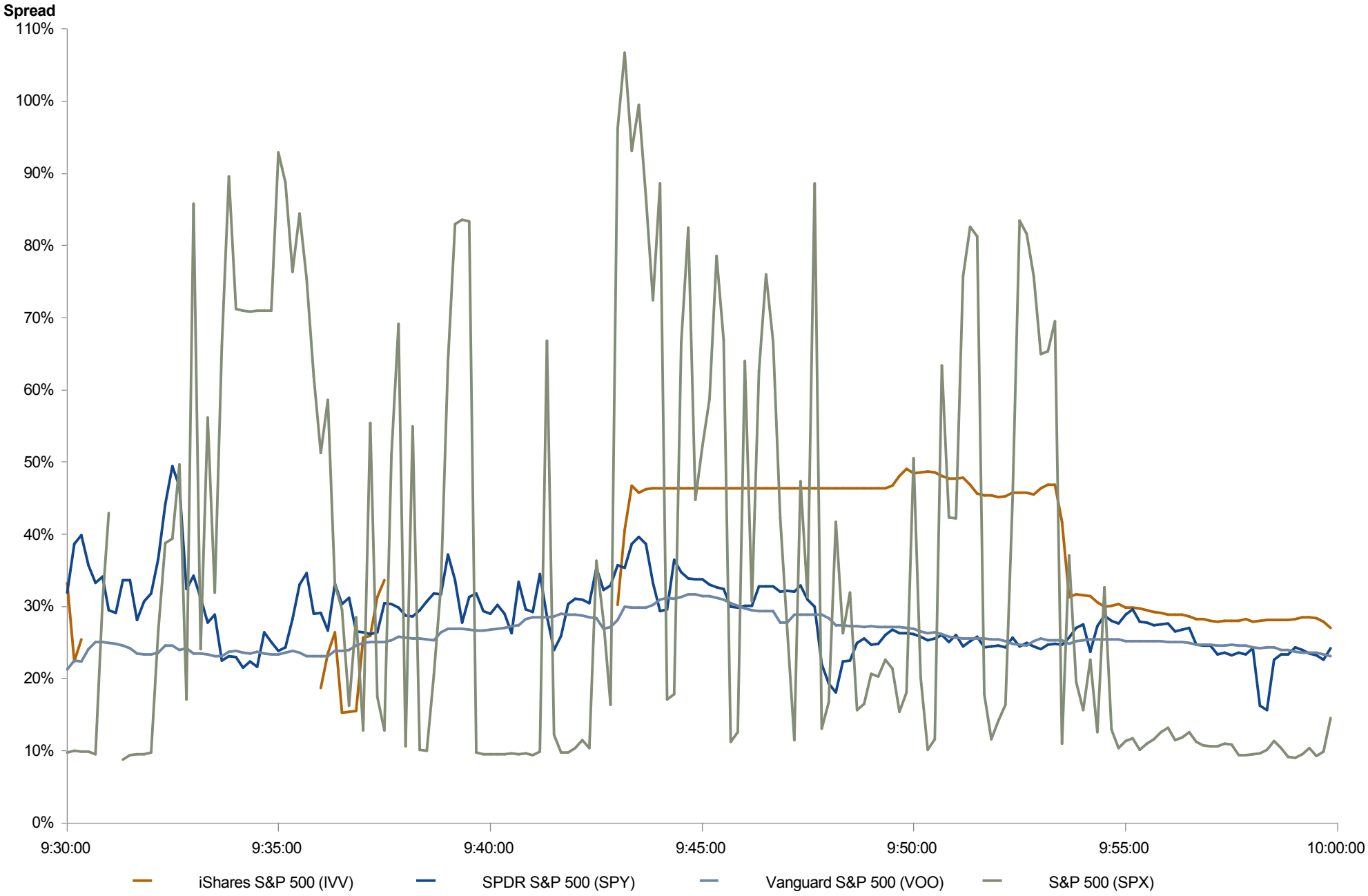


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Relative Spread on 8/24/15

S&P 500 Options (Puts)

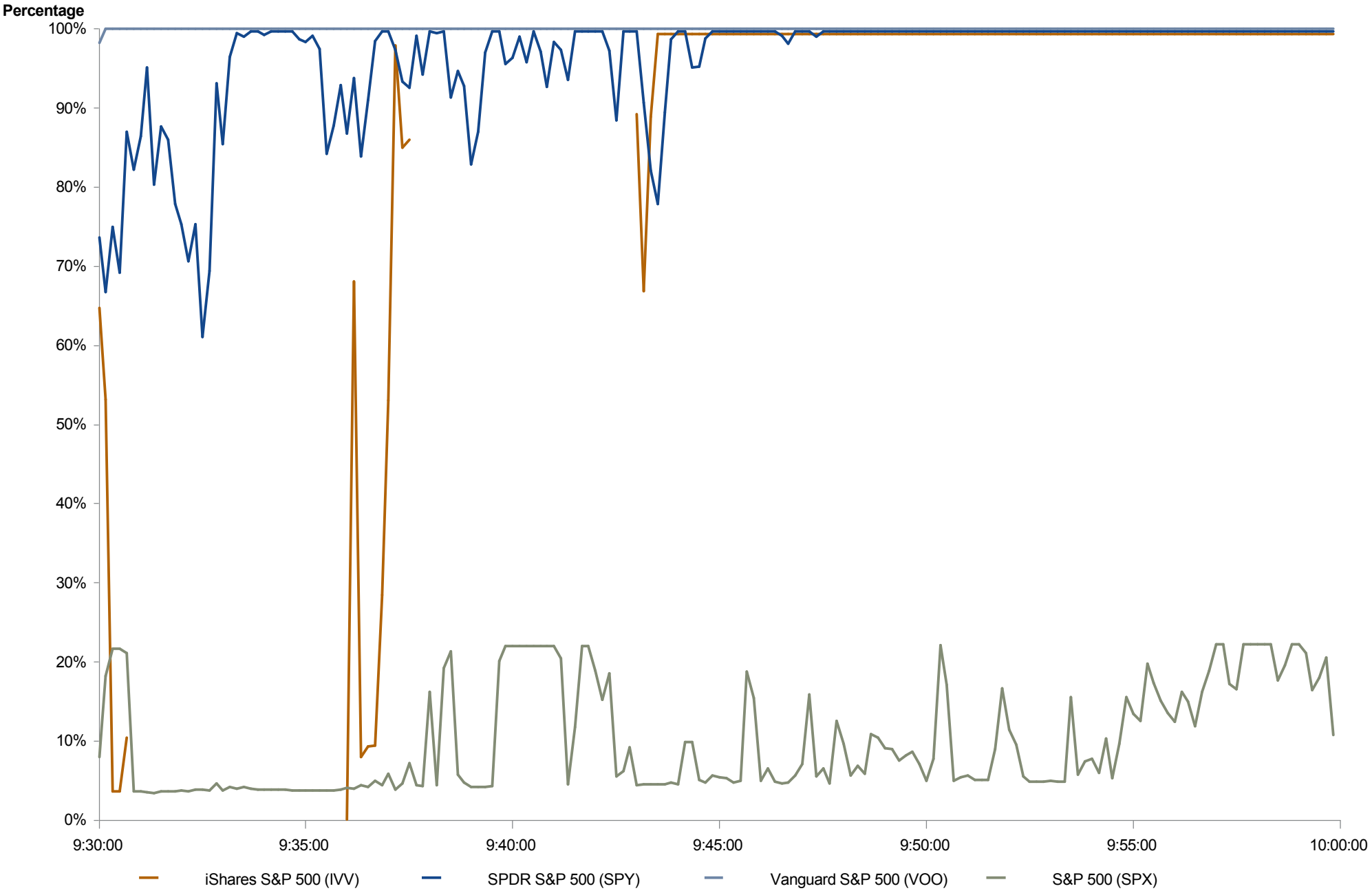


Source: TickData.

Note: Average relative spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average relative spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Percentage of Series with a Firm Bid or Offer on 8/24/15

S&P 500 Options (Calls)

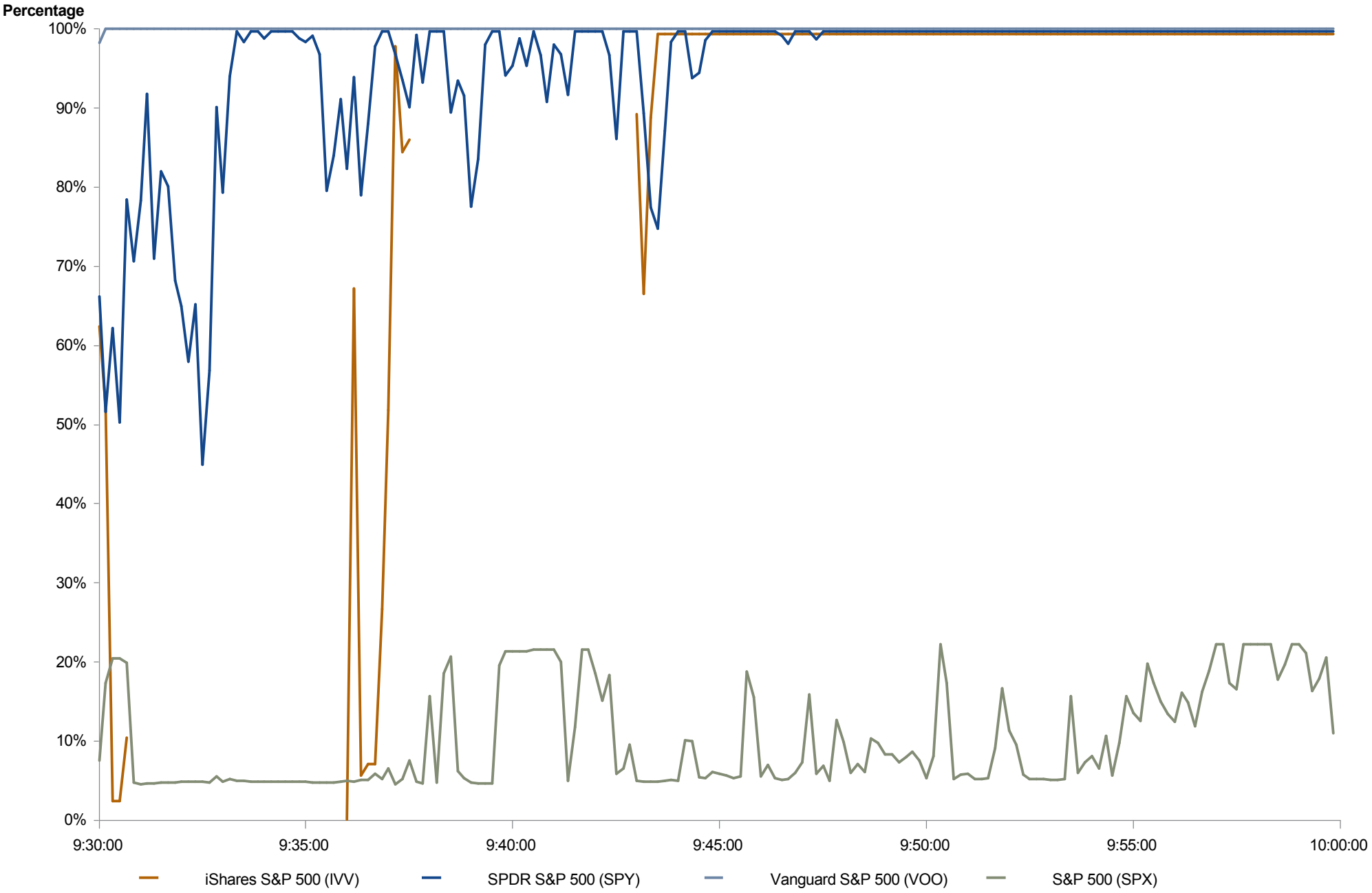


Source: TickData.

Note: Percentage of series with a firm bid or offer is calculated over 10 second intervals. Intervals during trading halts are treated as intervals in which there are no firm bids and offers. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Percentage of Series with a Firm Bid or Offer on 8/24/15

S&P 500 Options (Puts)



Source: TickData.

Note: Percentage of series with a firm bid or offer is calculated over 10 second intervals. Intervals during trading halts are treated as intervals in which there are no firm bids and offers. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Section 2: Case Studies of Linked ETFs, Options, and Futures
S&P 400

- S&P 400 Linked Securities and Indexes
  - SPDR S&P Mid Cap 400 (MDY)
  - iShares Core S&P Mid Cap (IJH)
  - S&P 400 Cash Index (MID)
  - E-Mini S&P 400 Sept-15 Future ($100)
- S&P 400 linked securities exhibited similar patterns to the S&P 500

Section 2: Case Studies of Linked ETFs, Options, and Futures
S&P 400 *(cont.)*

- iShares S&P 500 (IJH) declined more than 20% below the August 21 close; trading was halted three times

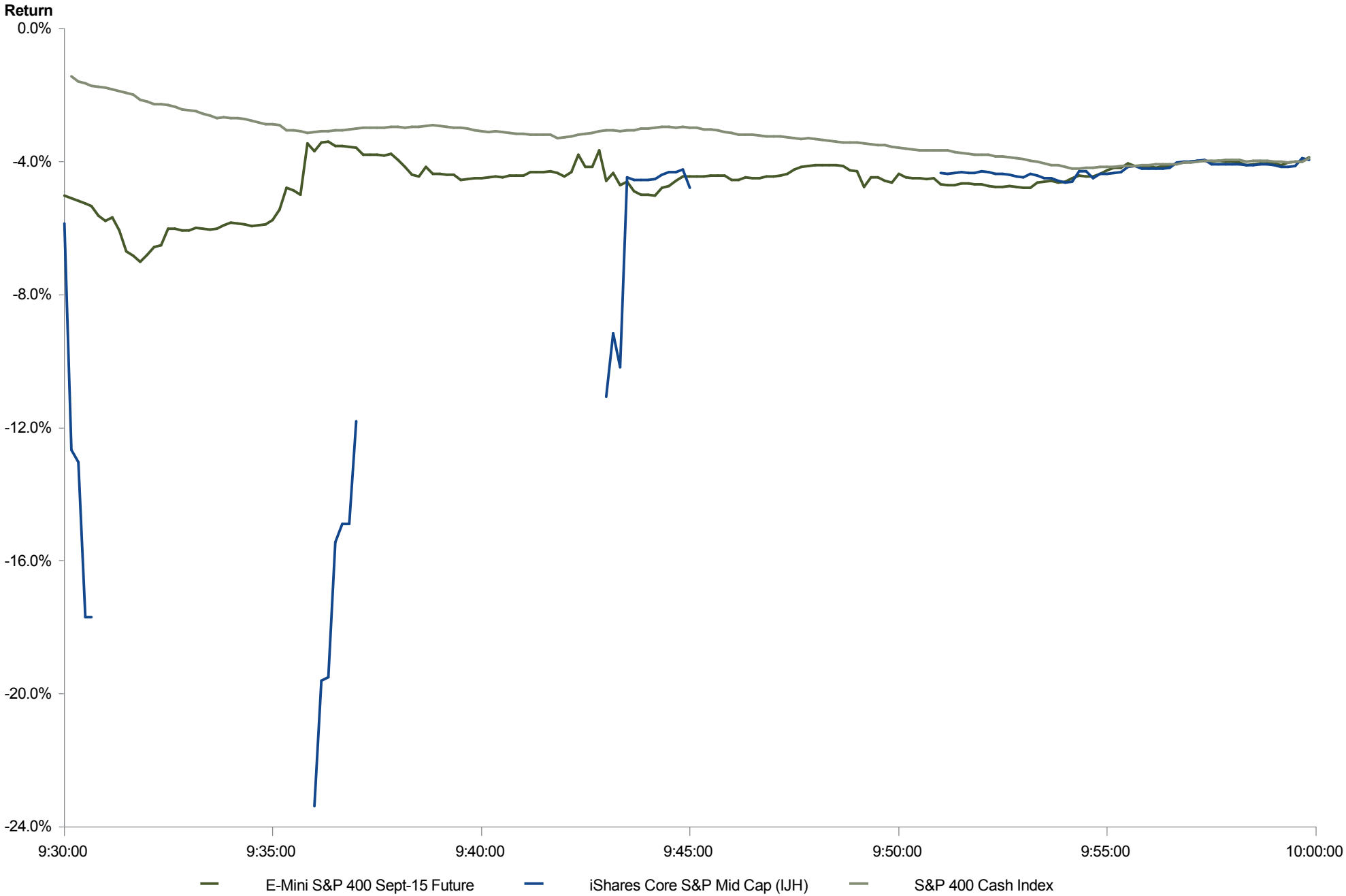
- MDY and the E-Mini futures traded loosely in the same range, although they temporarily deviated after the first trading halt in IJH

- Market participants seemed more willing to arbitrage with MDY than the E-Mini futures

  - From the 30 seconds prior to the end of IJH's first trading halt until the second trading halt occured, MDY volume was 6% of the YTD average daily trading volume while the near-month E-mini future was 1%

Price Return Chart

S&P 400: iShares Core S&P Mid Cap (IJH)

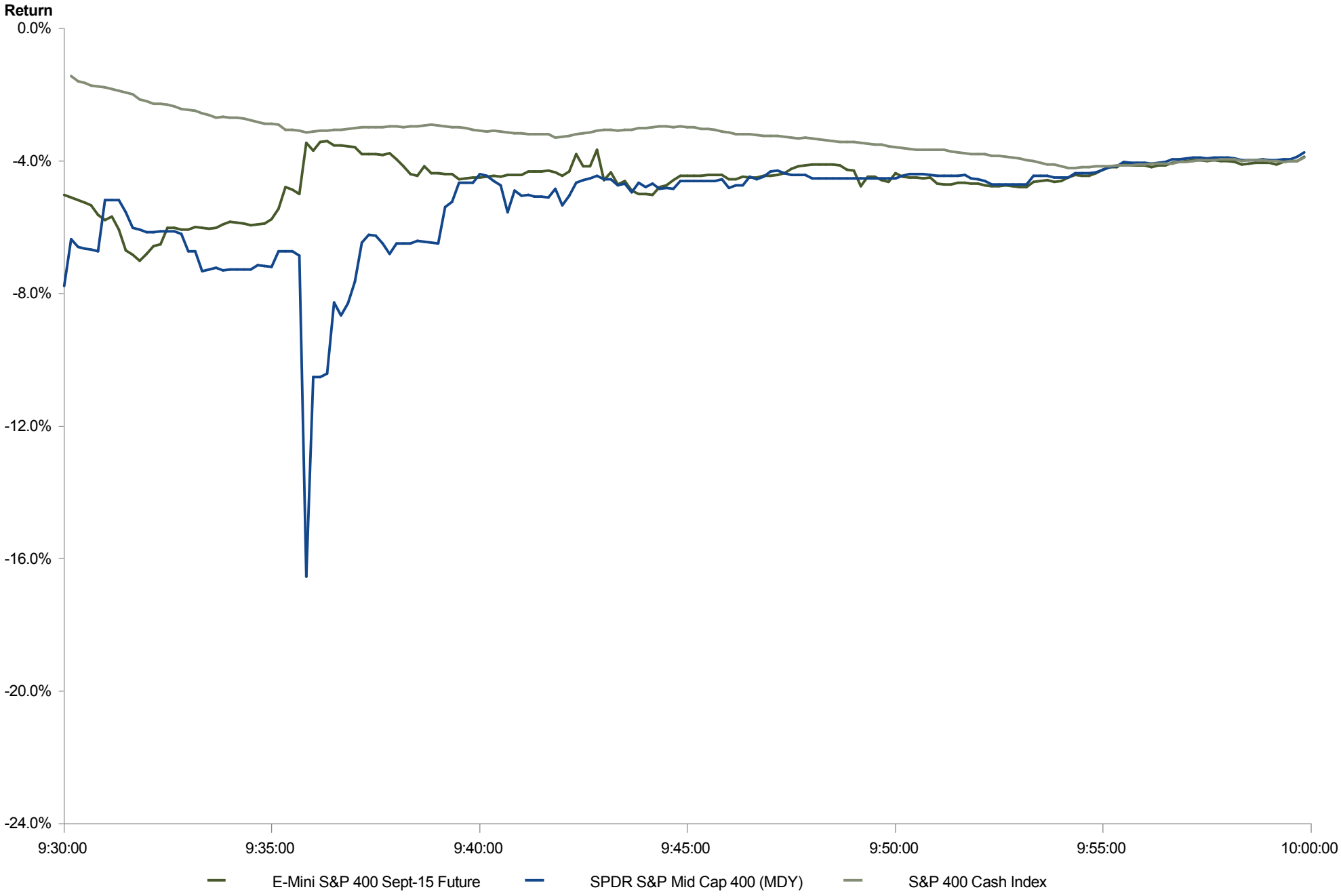


Source: TickData; Bloomberg; CRSP.

Note: Returns are calculated from the price at closing on August 21 and reflect the midpoint of the bid-ask spread at 10 second intervals.

Price Return Chart

S&P 400: SPDR S&P Mid Cap 400 (MDY)



Source: TickData; Bloomberg; CRSP.

Note: Returns are calculated from the price at closing on August 21 and reflect the midpoint of the bid-ask spread at 10 second intervals.

Section 2: Case Studies of Linked ETFs, Options, and Futures
S&P 400 *(cont.)*

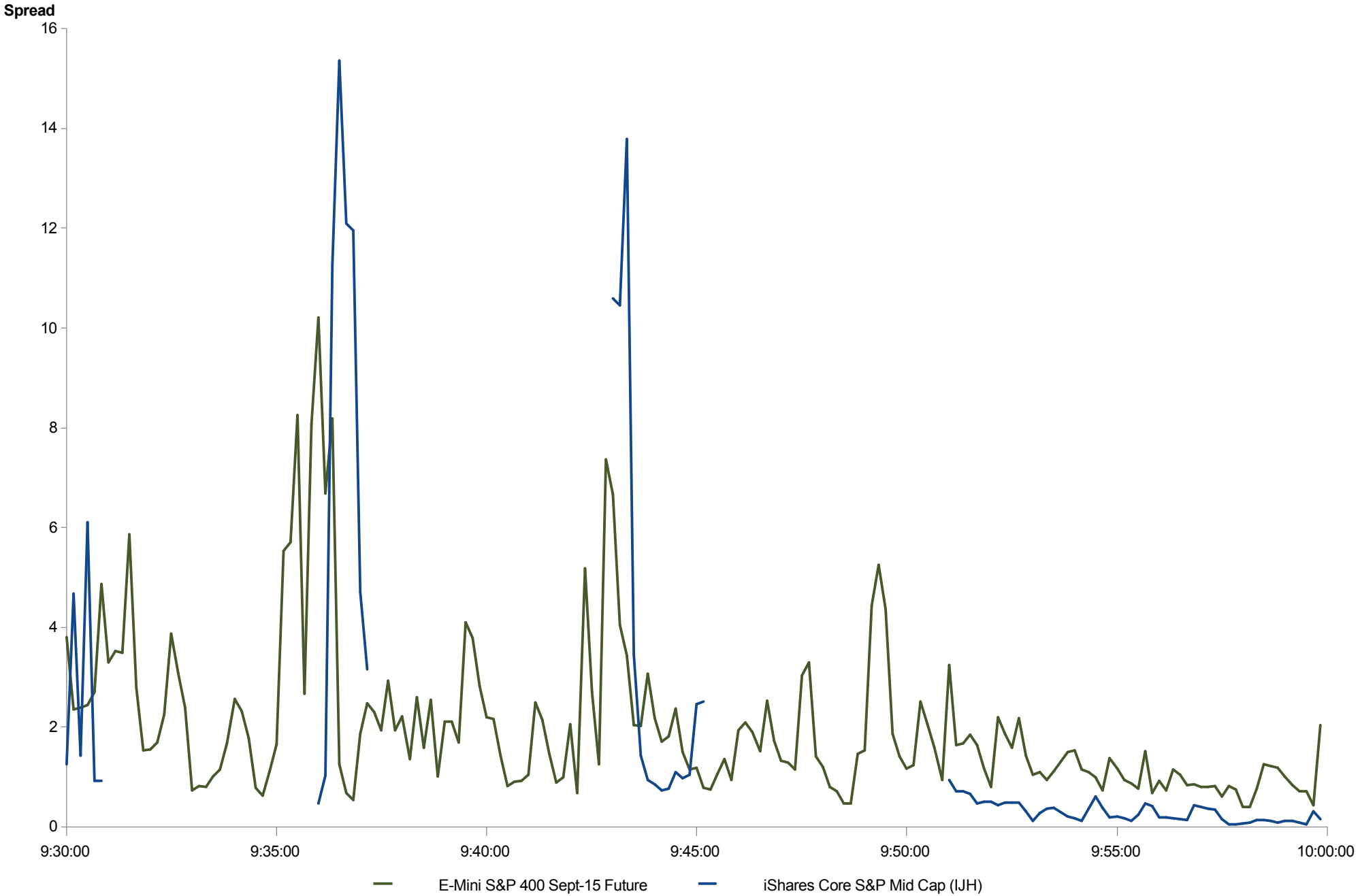
- The spread for IJH was especially wide, though the spread for MDY and the E-Mini futures was wider as well

- The increase in the IJH option spreads was similar to the increase in the MDY spreads
  - Spreads in the MDY put options quickly widened during rapid price declines

- Many options on IJH and MDY stopped quoting during rapid declines in the stock price
  - However, many options continued quoting at other times when IJH and MDY traded at a discount to the S&P 400 Cash Index (MID) and E-Mini futures

Average Spread on 8/24/15

S&P 400: iShares Core S&P Mid Cap (IJH)

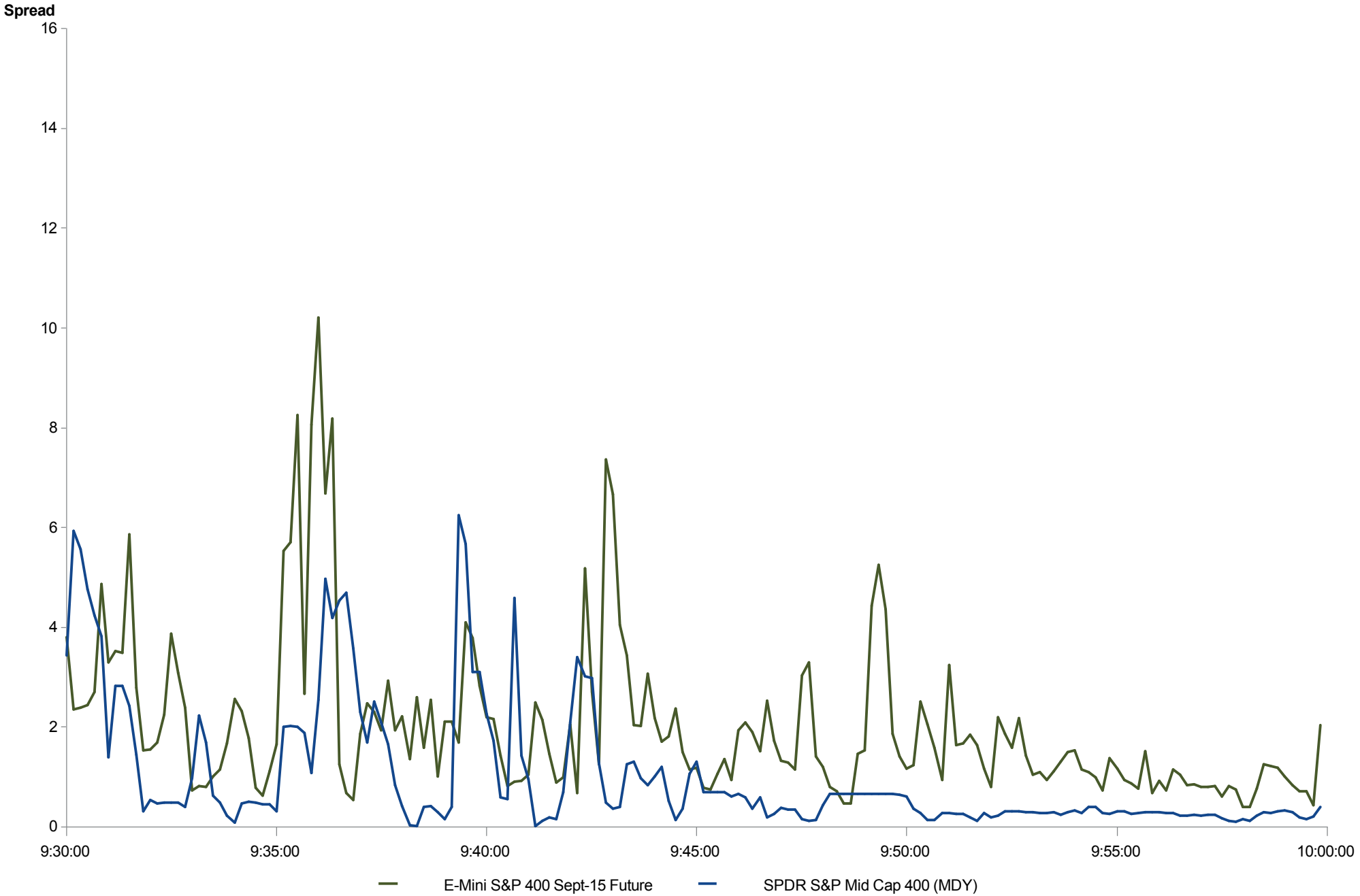


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation.

Average Spread on 8/24/15

S&P 400: SPDR S&P Mid Cap 400 (MDY)

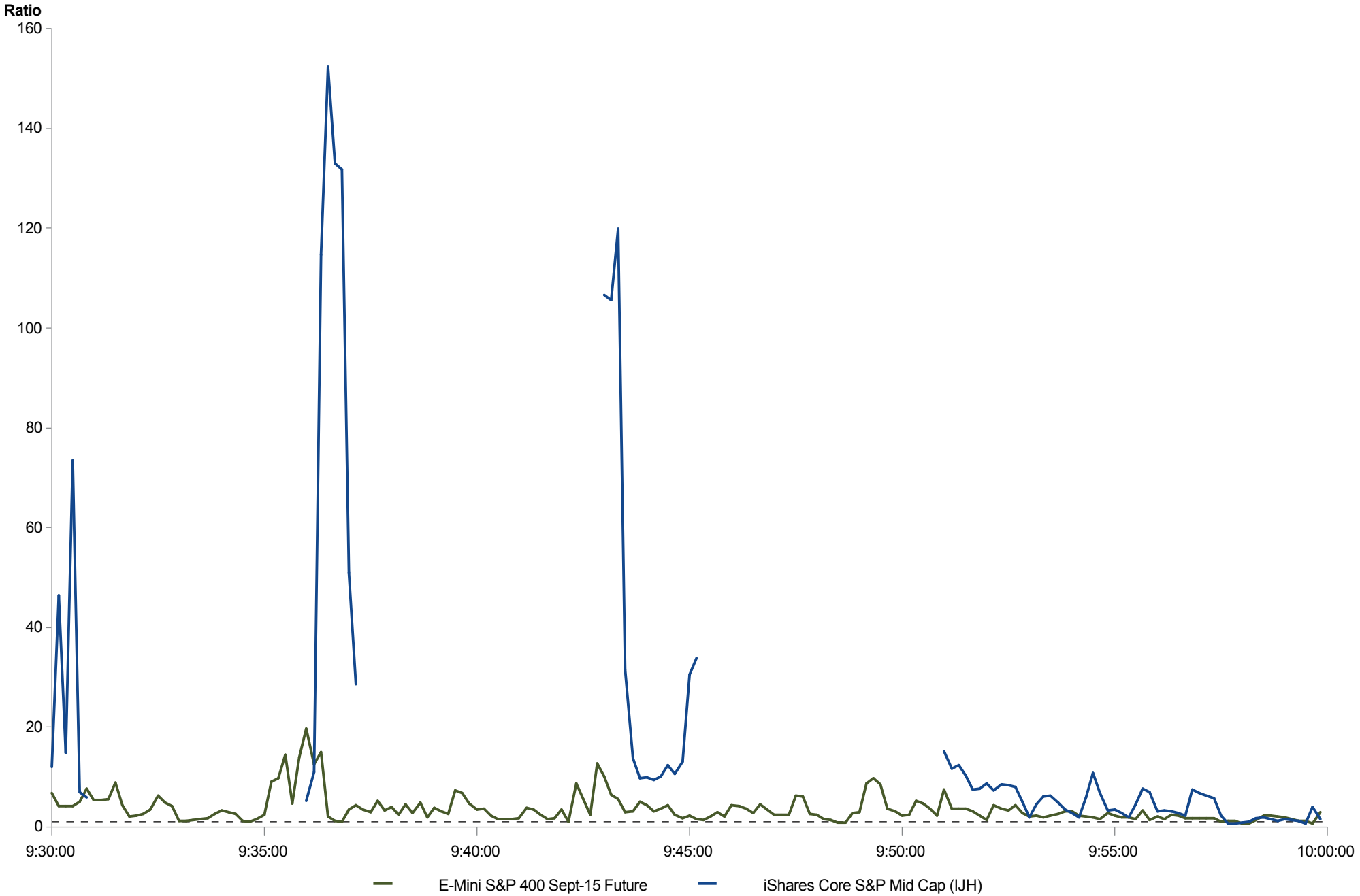


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 400: iShares Core S&P Mid Cap (IJH)

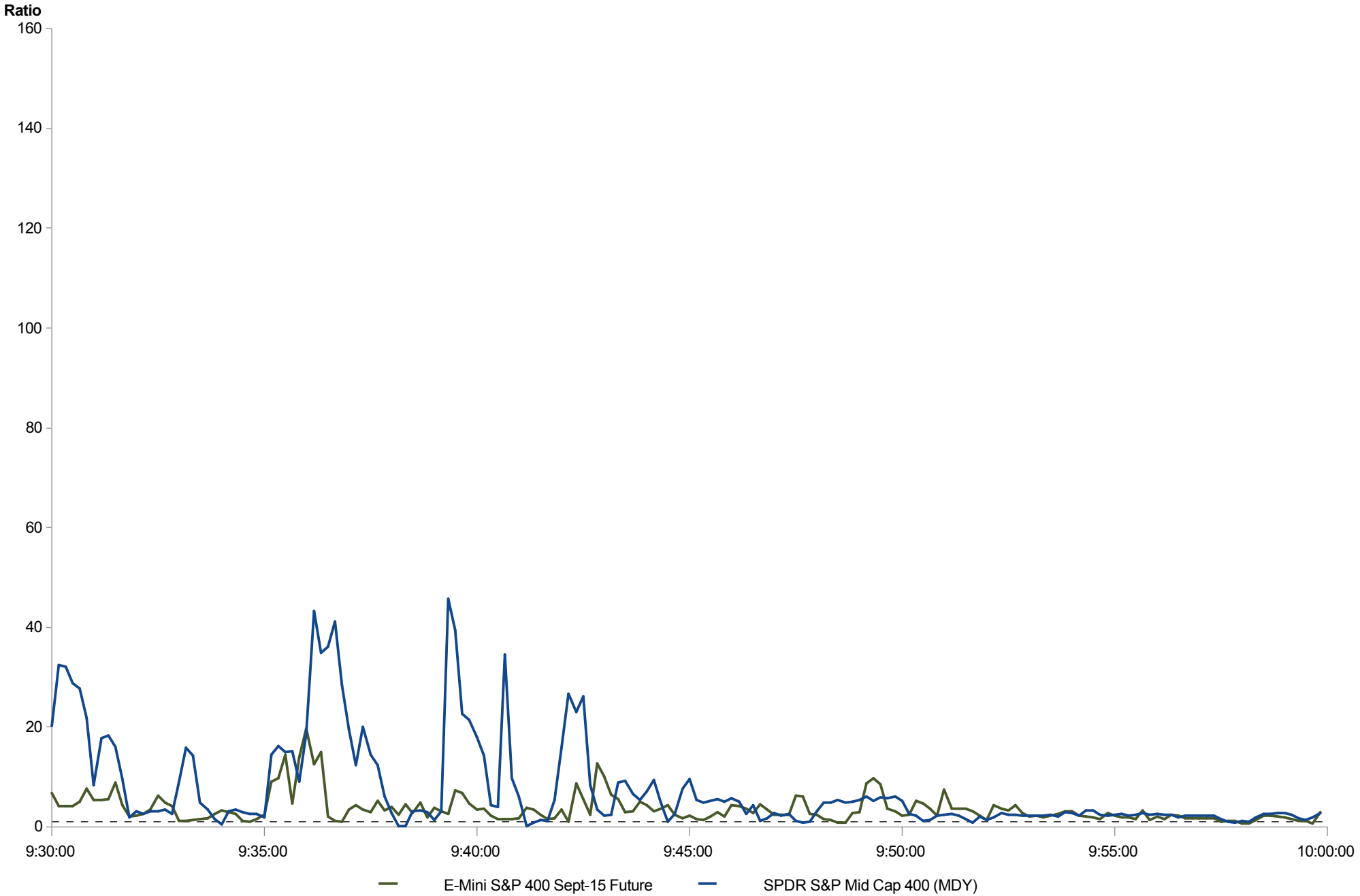


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 400: SPDR S&P Mid Cap 400 (MDY)

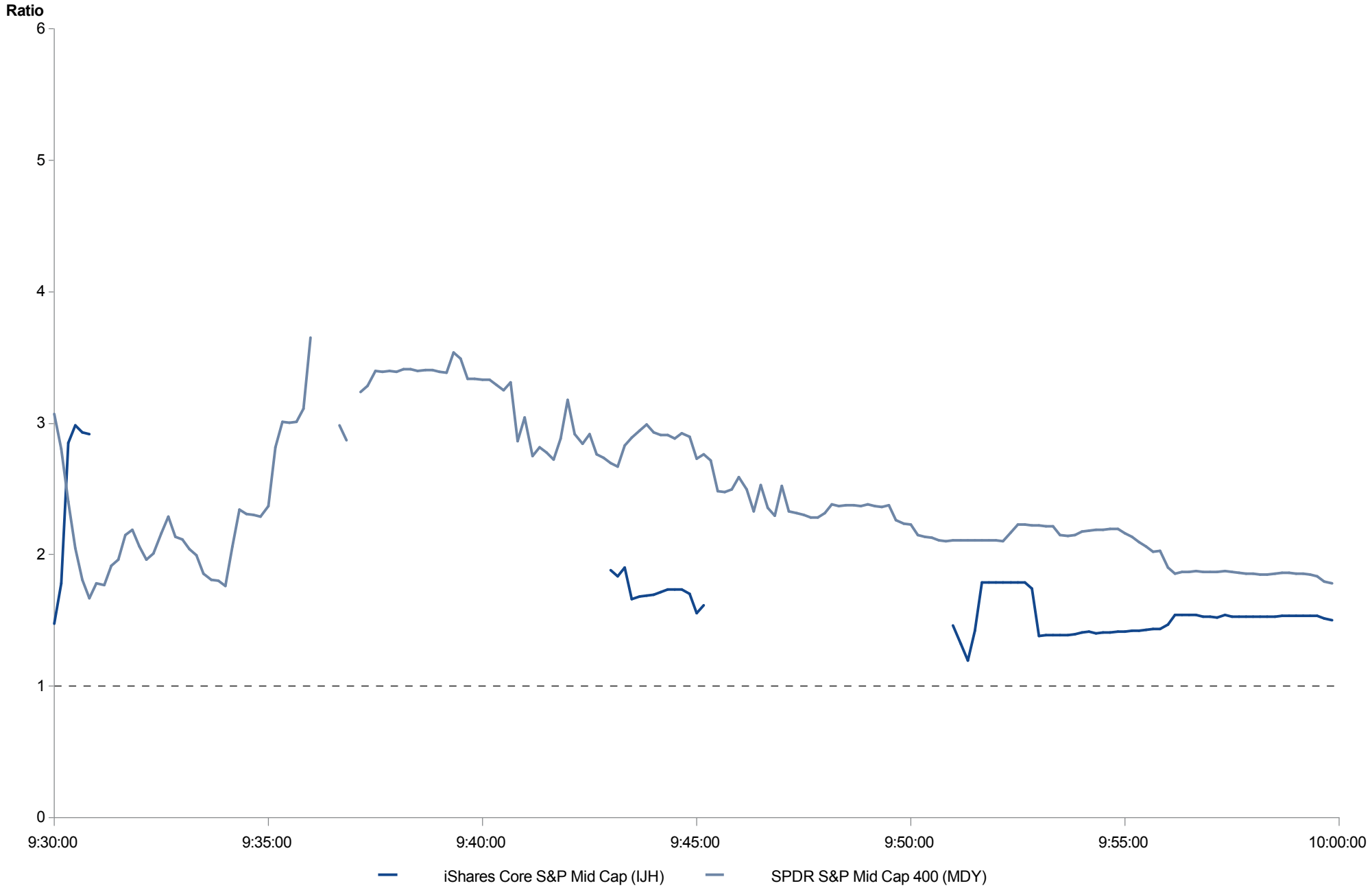


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 400 ETF Options (Calls)

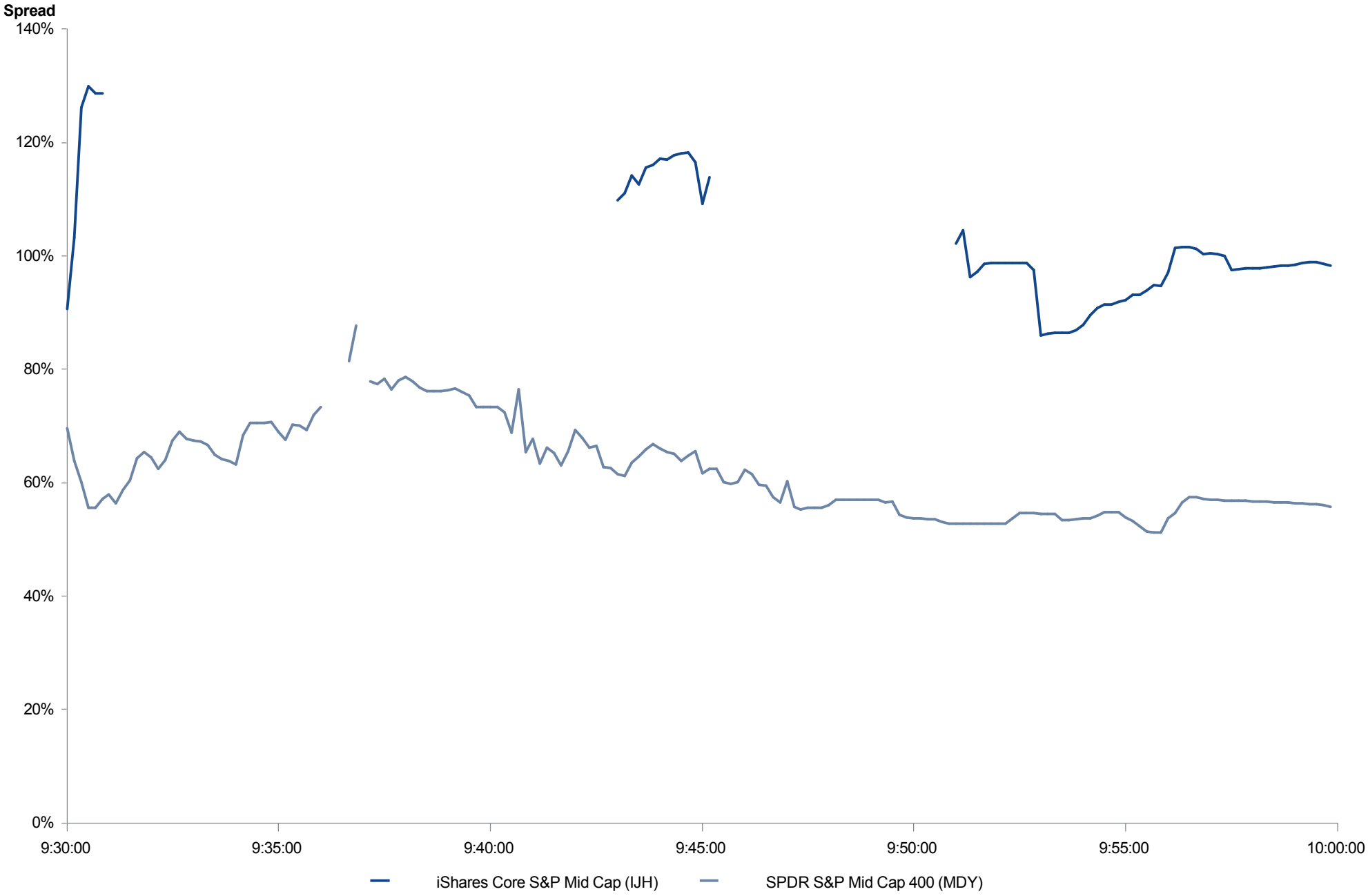


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Relative Spread on 8/24/15

S&P 400 ETF Options (Calls)

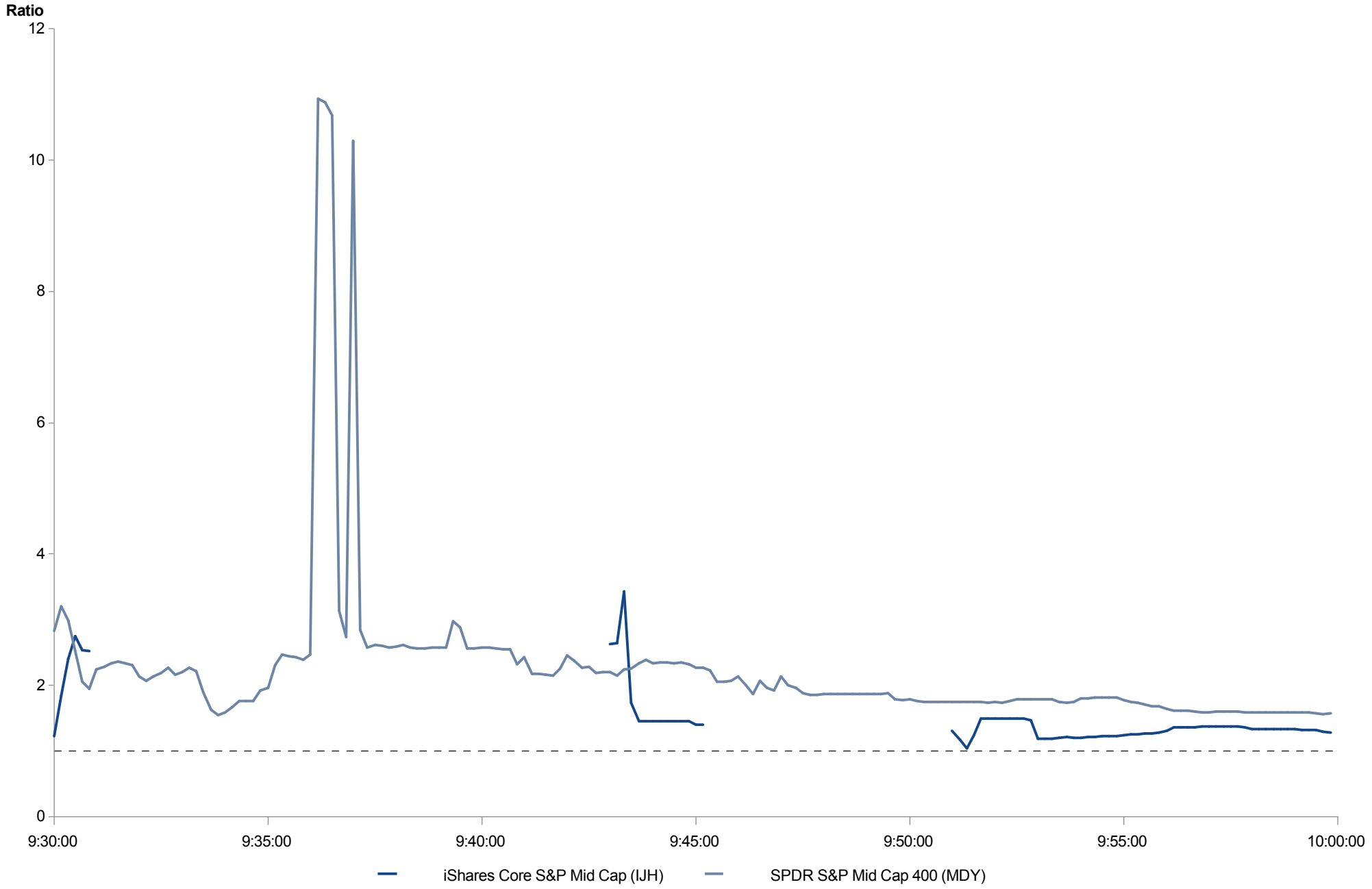


Source: TickData.

Note: Average relative spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average relative spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Ratio of Average Spread on 8/24/15 to Average Spread from 8/25/15 to 8/31/15

S&P 400 ETF Options (Puts)

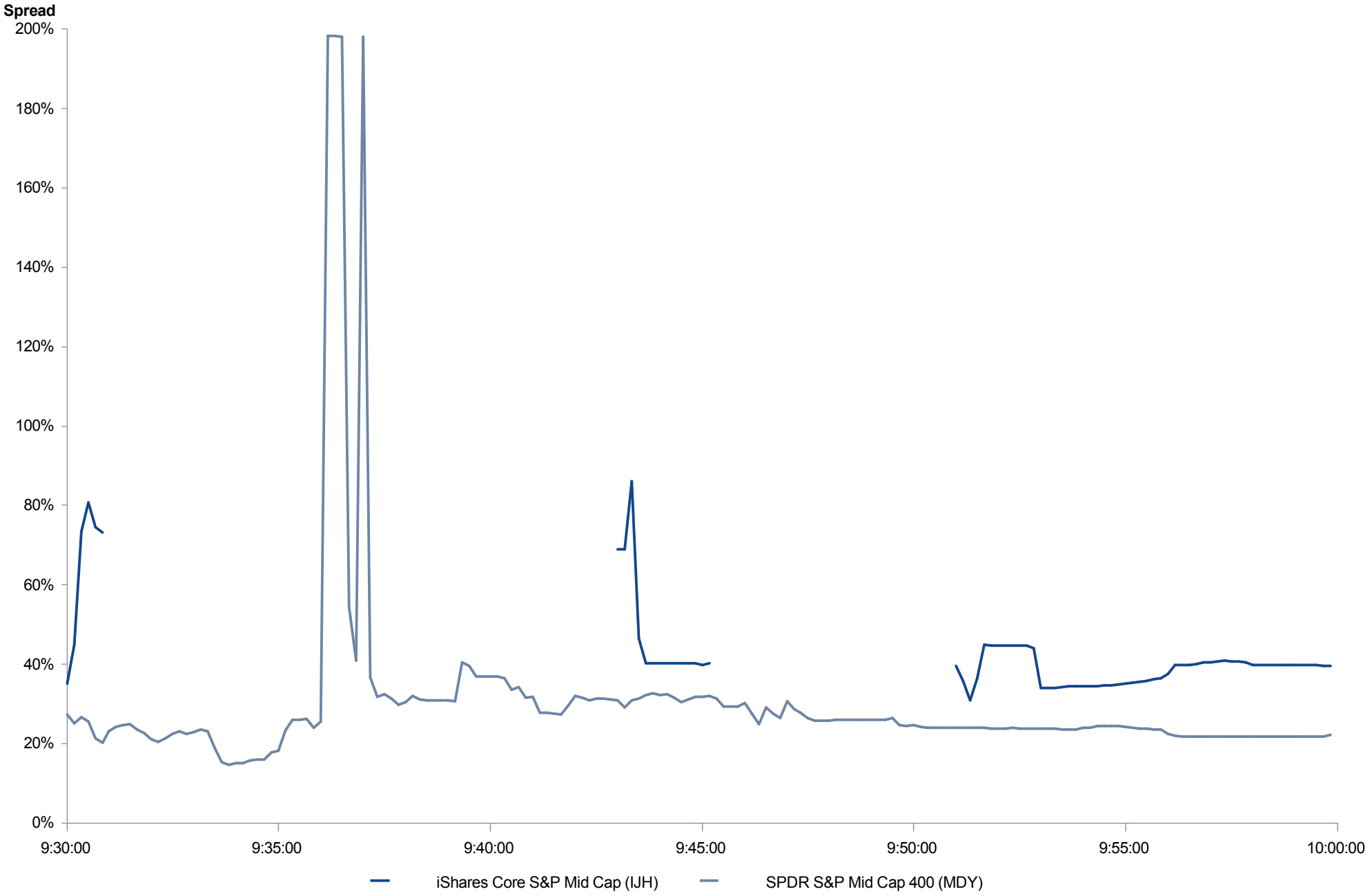


Source: TickData.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Average Relative Spread on 8/24/15

S&P 400 ETF Options (Puts)

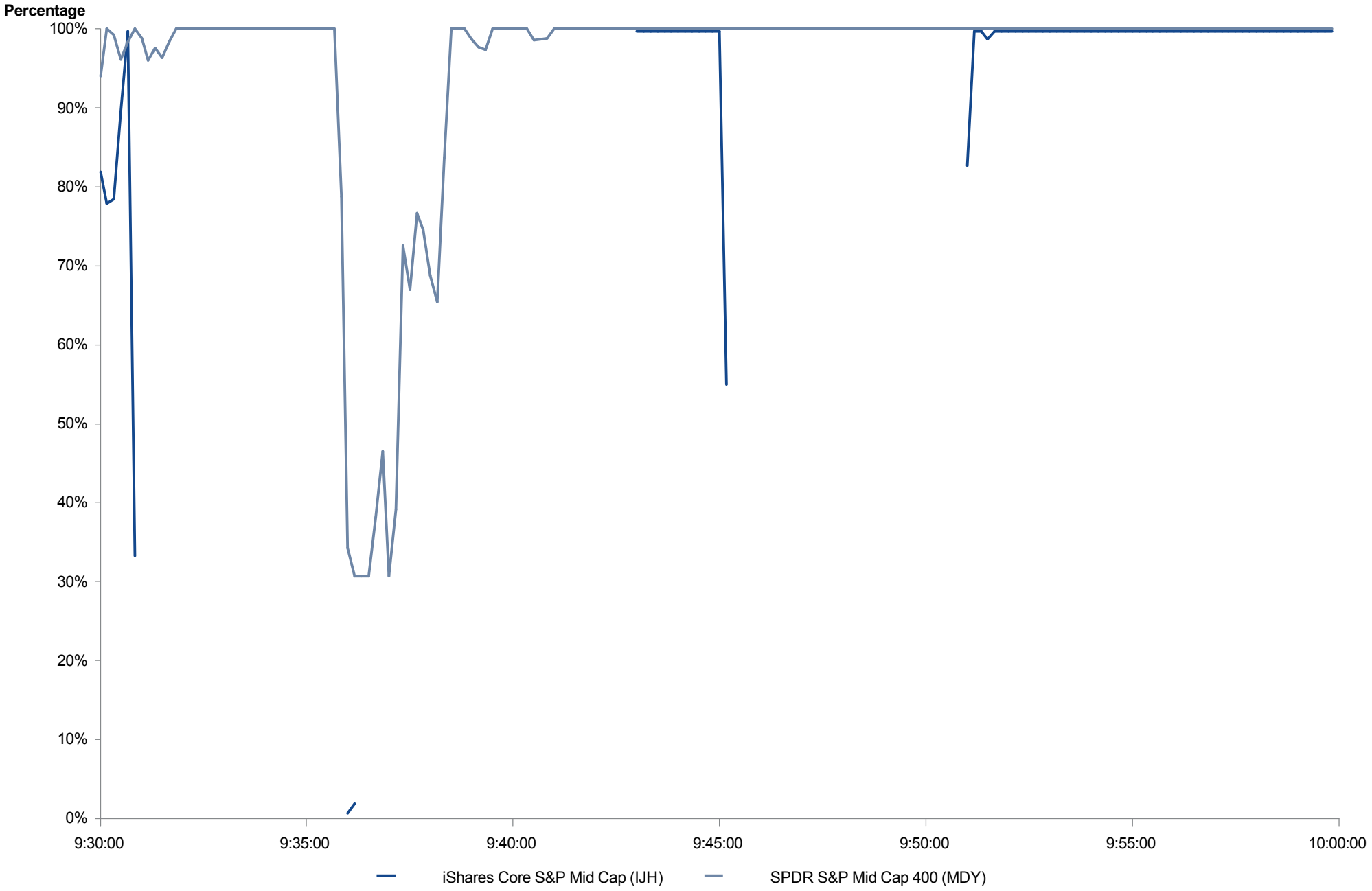


Source: TickData.

Note: Average relative spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average relative spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Percentage of Series with a Firm Bid or Offer on 8/24/15

S&P 400 ETF Options (Calls)

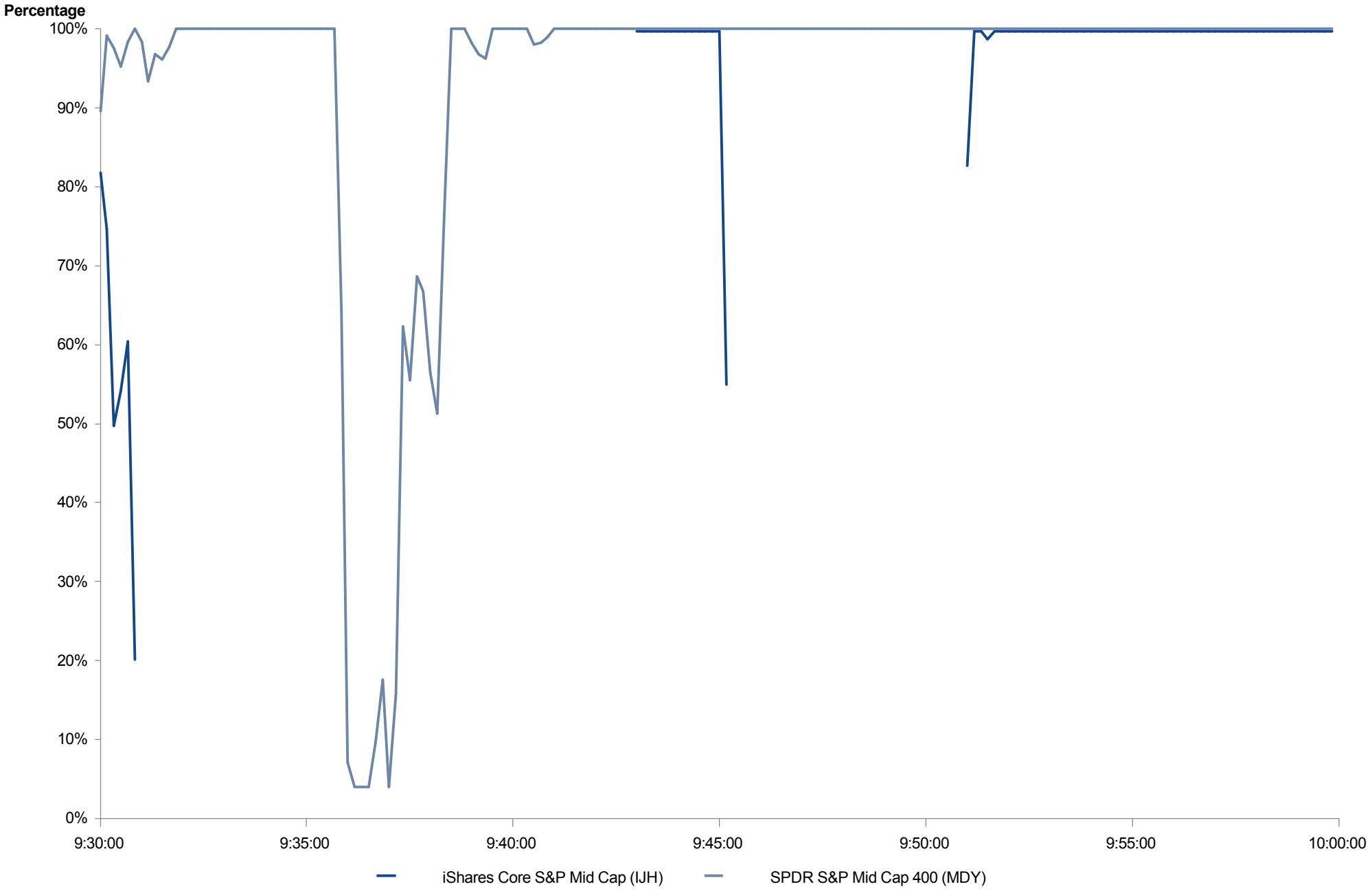


Source: TickData.

Note: Percentage of series with a firm bid or offer is calculated over 10 second intervals. Intervals during trading halts are treated as intervals in which there are no firm bids and offers. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Percentage of Series with a Firm Bid or Offer on 8/24/15

S&P 400 ETF Options (Puts)



Source: TickData.

Note: Percentage of series with a firm bid or offer is calculated over 10 second intervals. Intervals during trading halts are treated as intervals in which there are no firm bids and offers. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Section 2: Case Studies of Linked ETFs, Options, and Futures
NASDAQ 100

- NASDAQ 100 Linked Securities and Indexes
  - PowerShares QQQ Trust (QQQ)
  - NASDAQ 100 Cash Index (NDX)
  - E-Mini NASDAQ Sept-15 Future ($20)

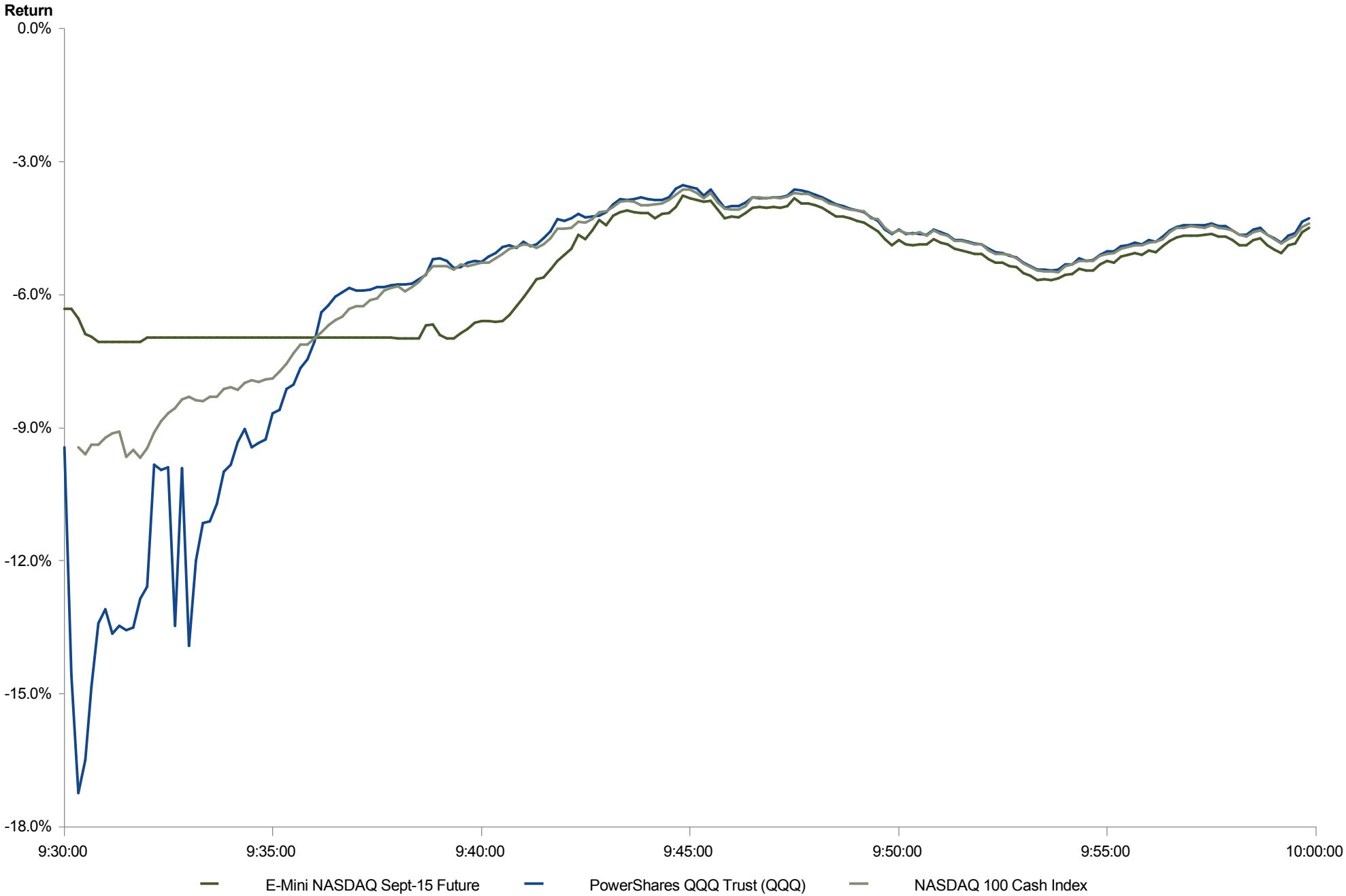
- PowerShares QQQ Trust (QQQ) declined more than 17% below the August 21 close, trading at a discount until approximately 9:36 AM
  - QQQ also experienced a series of price reversals in the first five minutes of the trading day

- E-Mini NASDAQ Sept-15 future trading did not pause, remaining just above the price limit level until shortly after 9:38 AM

- Even after NDX and QQQ recovered past the E-Mini futures, the E-Mini futures offer did not change for over two minutes

Price Return Chart

NASDAQ 100: Powershares Trust QQQ (QQQ)



Source: TickData; Bloomberg; CRSP.

Note: Returns are calculated from the price at closing on August 21 and reflect the midpoint of the bid-ask spread at 10 second intervals.

Section 2: Case Studies of Linked ETFs, Options, and Futures
NASDAQ 100 *(cont.)*

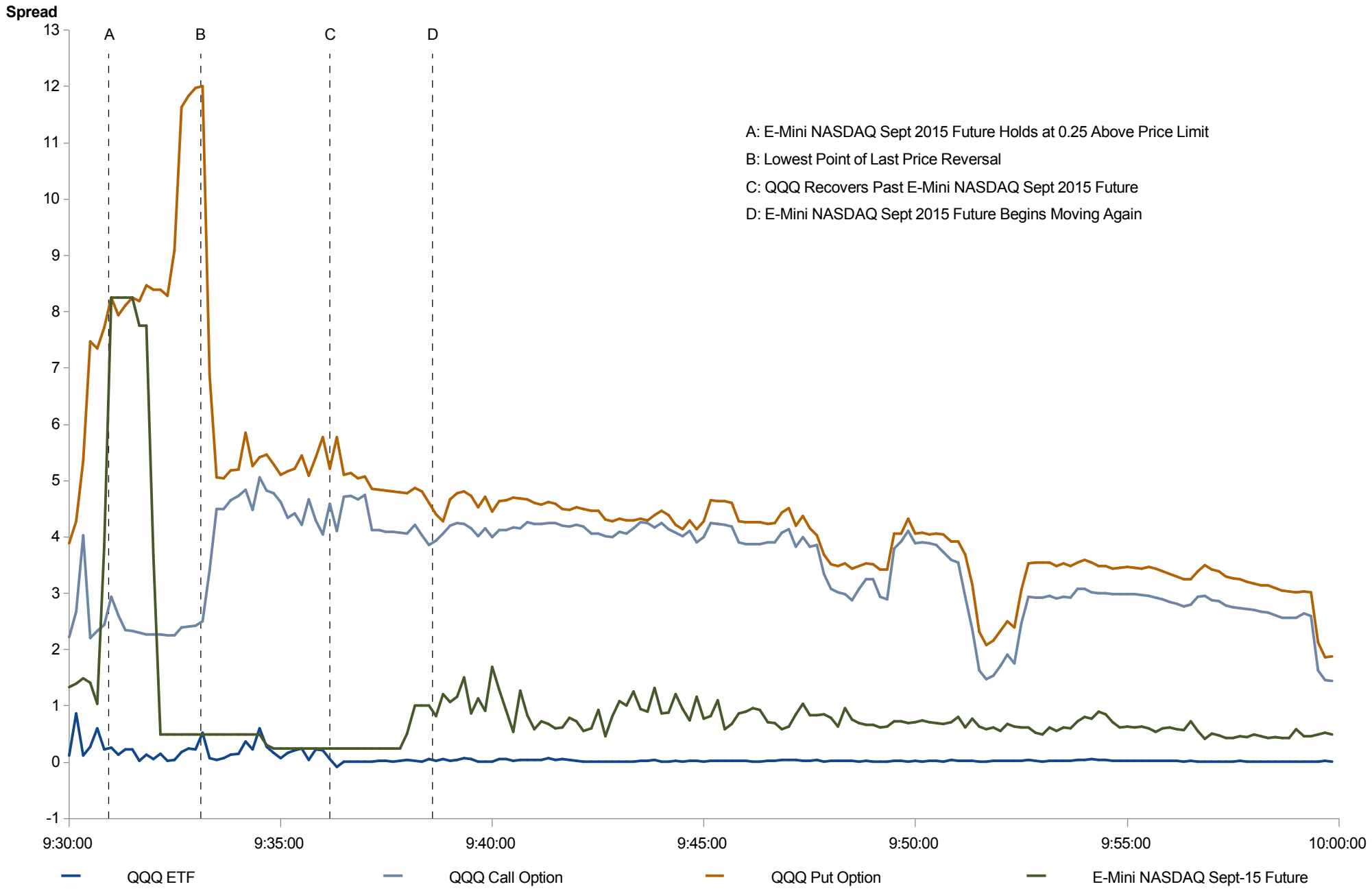
- Reg SHO short sale restrictions for QQQ were triggered immediately after the open

- Put option spreads widened during the price decline and ensuing price reversals
  - Only 5% of call and put options continued quoting during this time

- Future spreads widened to over 8 index points as the E-Mini offer stalled at 0.25 index points above the limit price, before eventually narrowing to the minimum spread (0.25 index points)
  - While the offer is stalled, the offer size at the NBO increased to over 1,400 contracts

Average Spread on 8/24/15

NASDAQ 100: QQQ

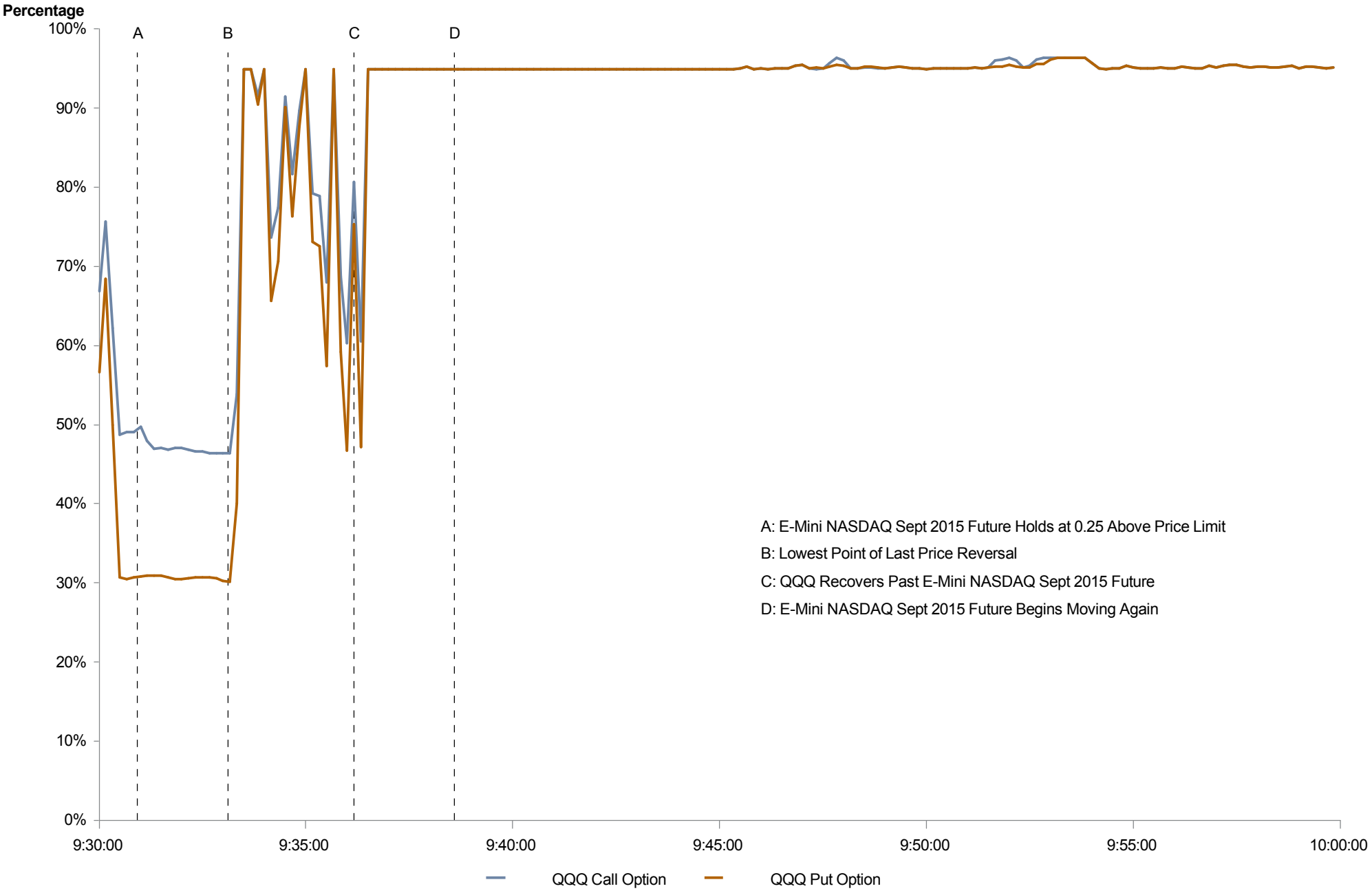


Source: TickData; Bloomberg; CRSP.

Note: Average spreads are calculated over ten second intervals. Intervals in which there are no firm quotes are excluded from the average spread calculation. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

Percentage of Series with a Firm Bid or Offer on 8/24/15

NASDAQ 100 ETF Options

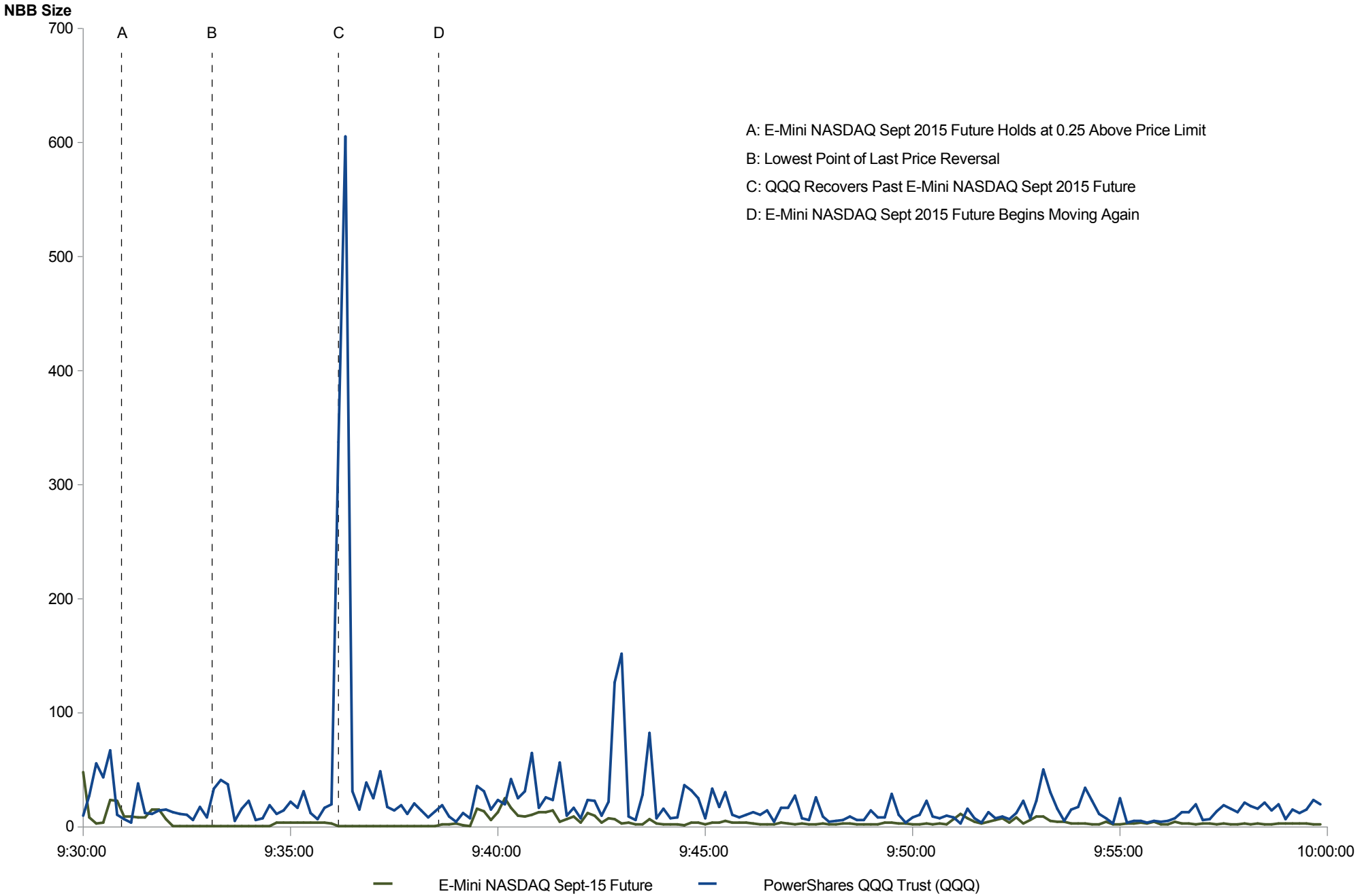


Source: TickData; Bloomberg; CRSP.

Note: Percentage of series with a firm bid or offer is calculated over 10 second intervals. Intervals during trading halts are treated as intervals in which there are no firm bids and offers. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included.

NBB Size on 8/24/15

Nasdaq 100: ETF and Futures Data

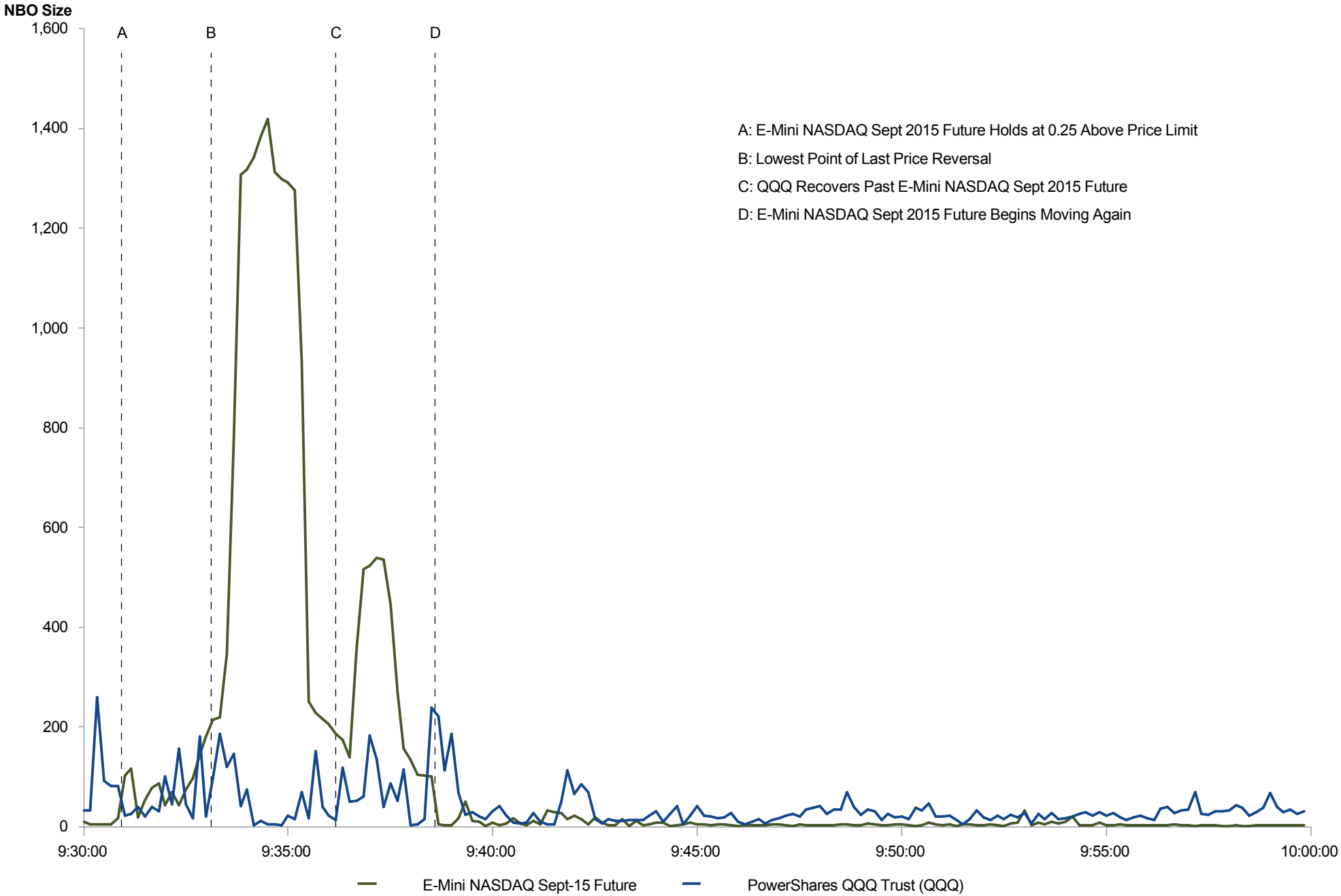


Source: TickData; Bloomberg; CRSP.

Note: Average NBB size is calculated as the total number of shares offered at the NBB across all exchanges. Non-firm quotes are excluded.

NBO Size on 8/24/15

Nasdaq 100: ETF and Futures Data



Source: TickData; Bloomberg; CRSP.

Note: Average NBO size is calculated as the total number of shares offered at the NBO across all exchanges. Non-firm quotes are excluded.

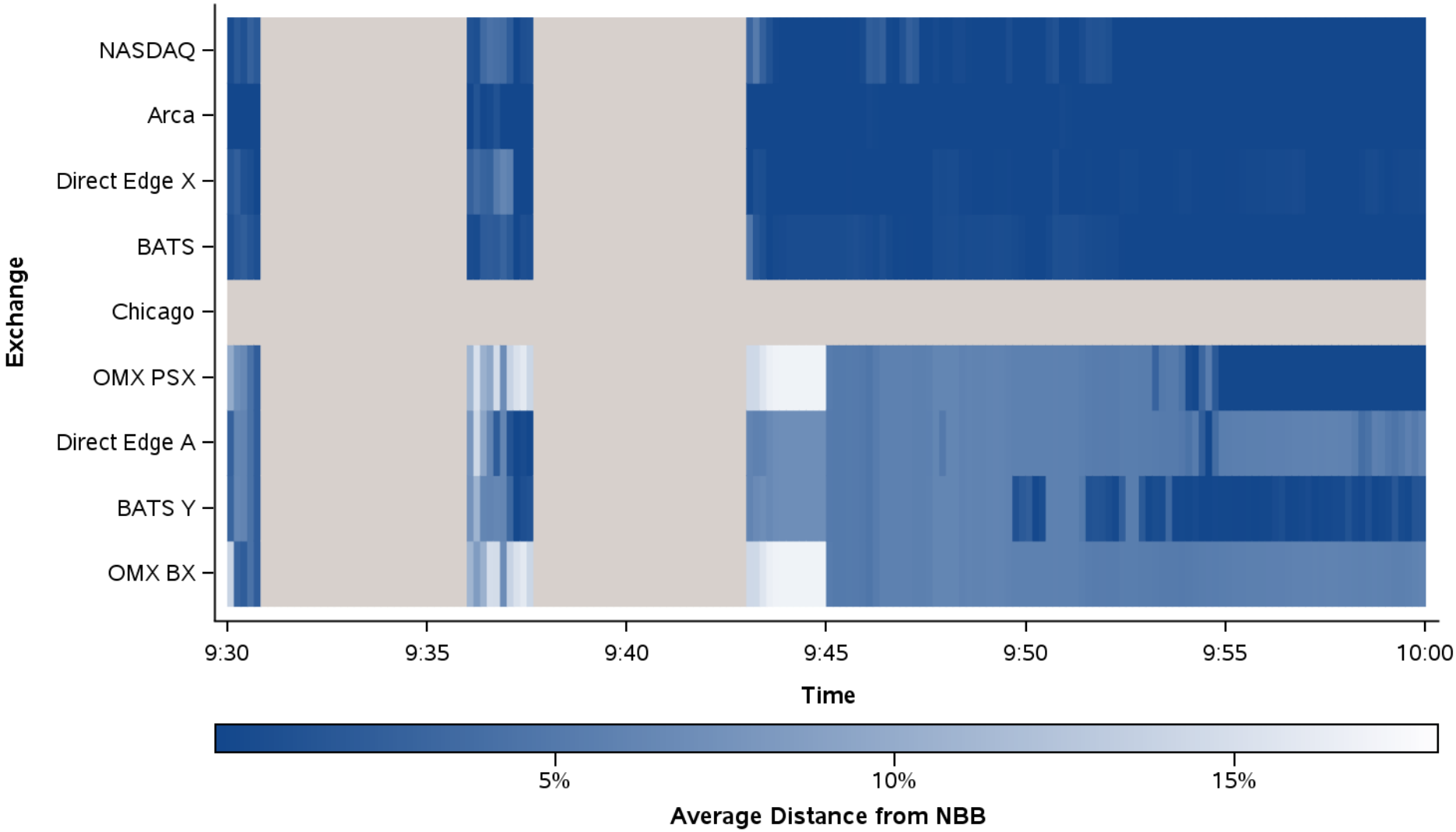
Section 3: Exchange-Specific Responses

- Summary information is provided showing which equity and option exchanges were quoting closer and further from the NBBO on August 24 and during the benchmark period.

Average Distance from NBB by Exchange

S&P 500: IVV ETF

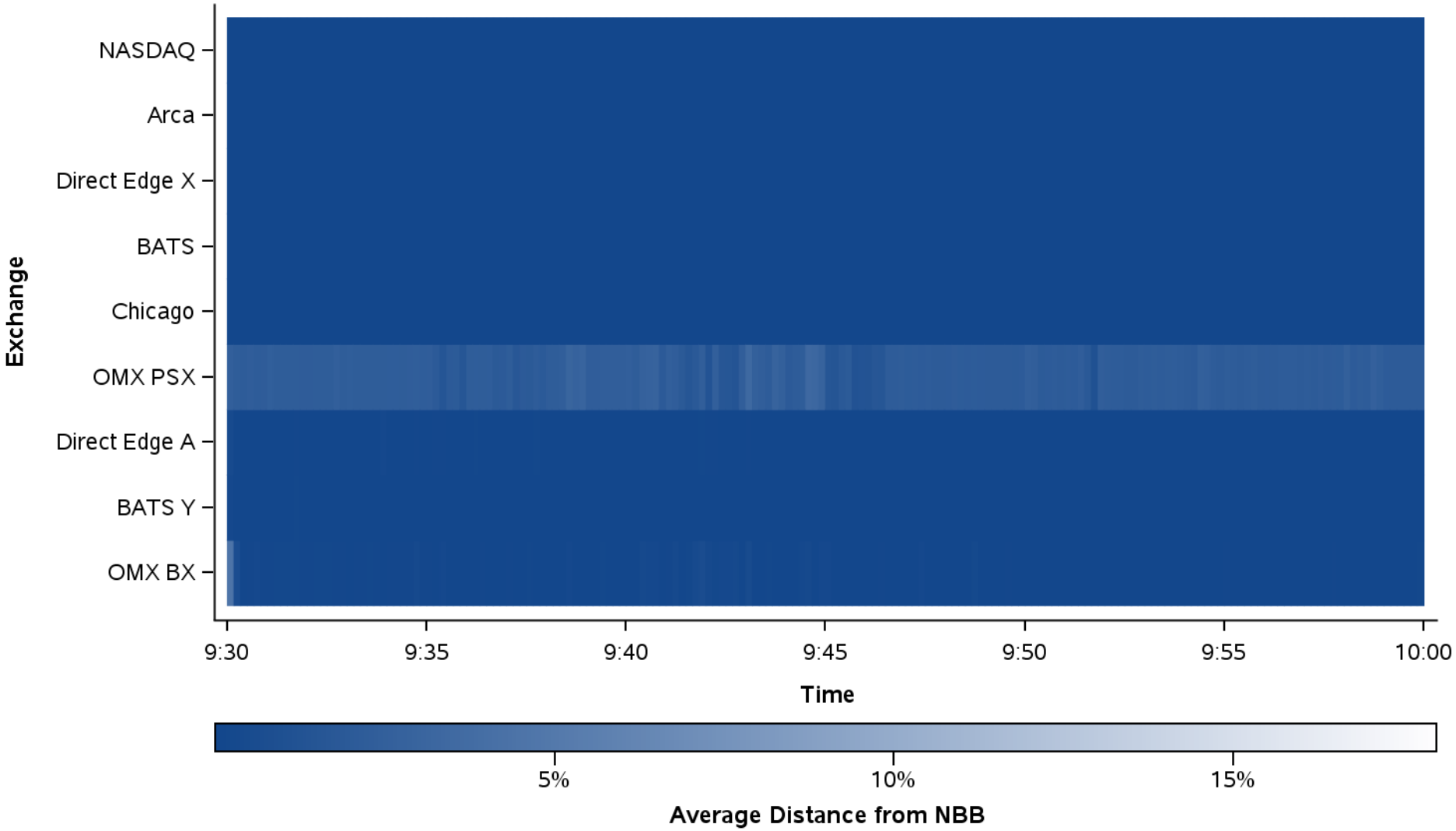
8/24/15



Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange
S&P 500: IVV ETF
8/25/15 - 8/31/15



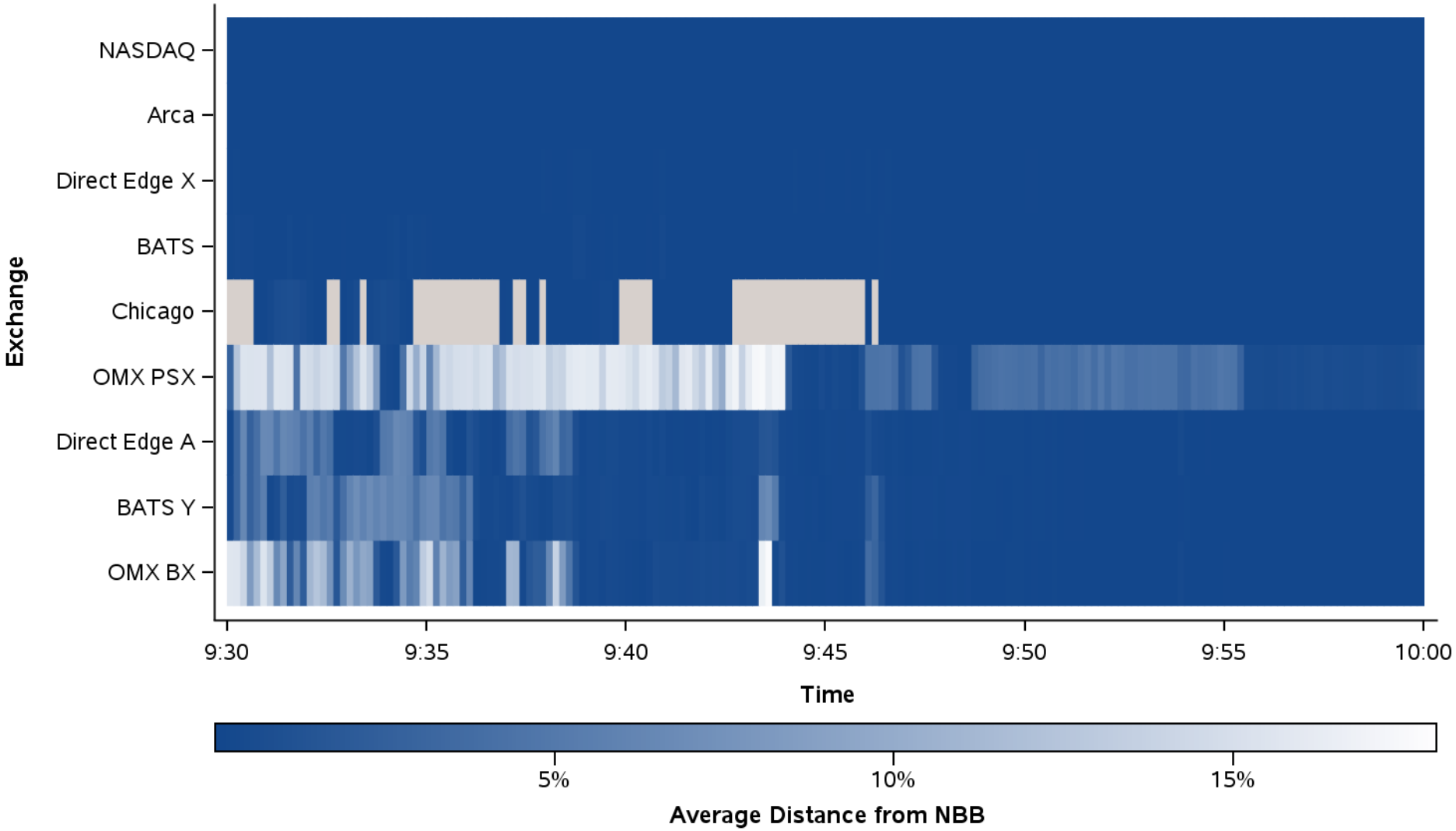
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: SPY ETF

8/24/15



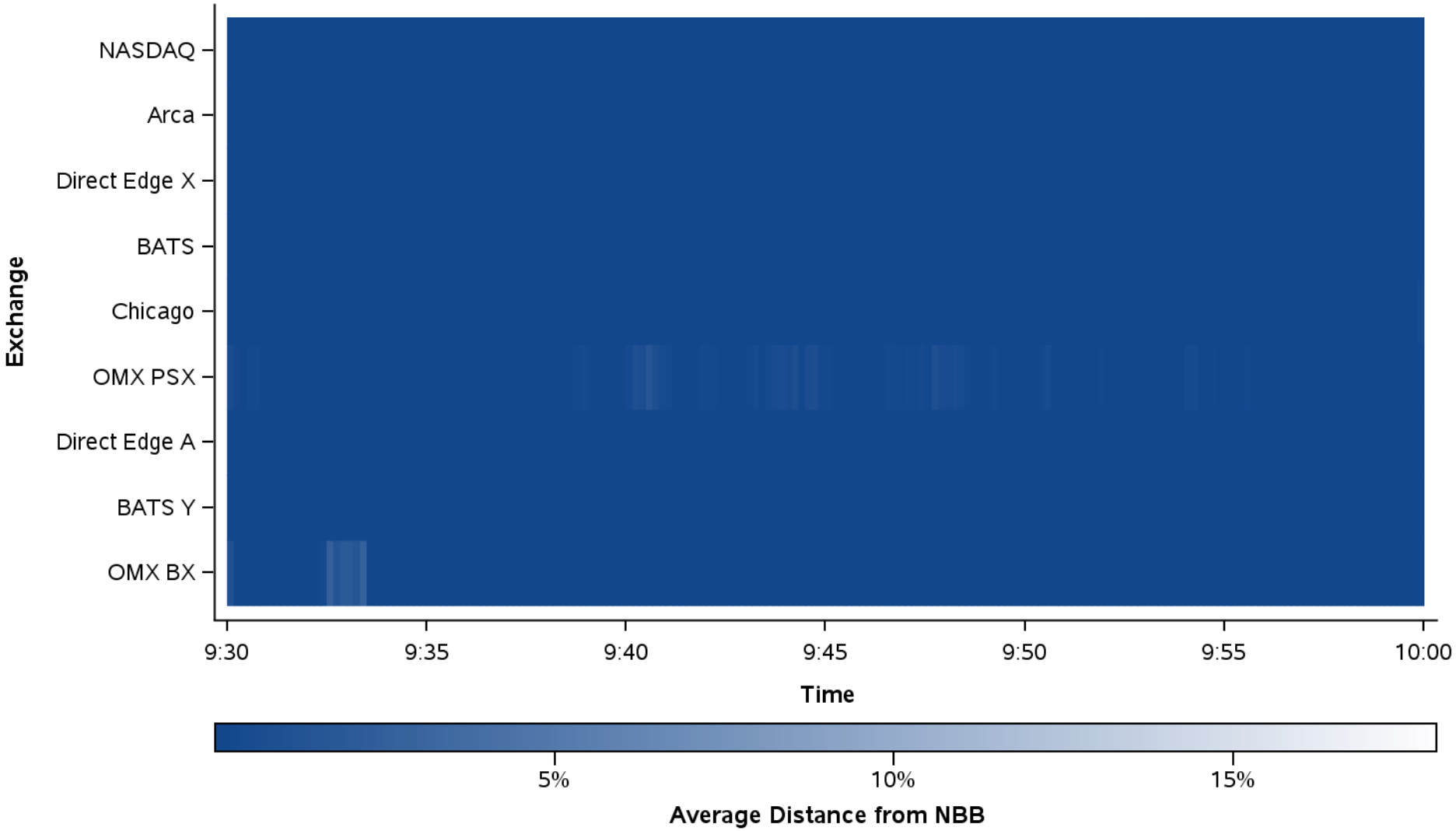
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: SPY ETF

8/25/15 - 8/31/15



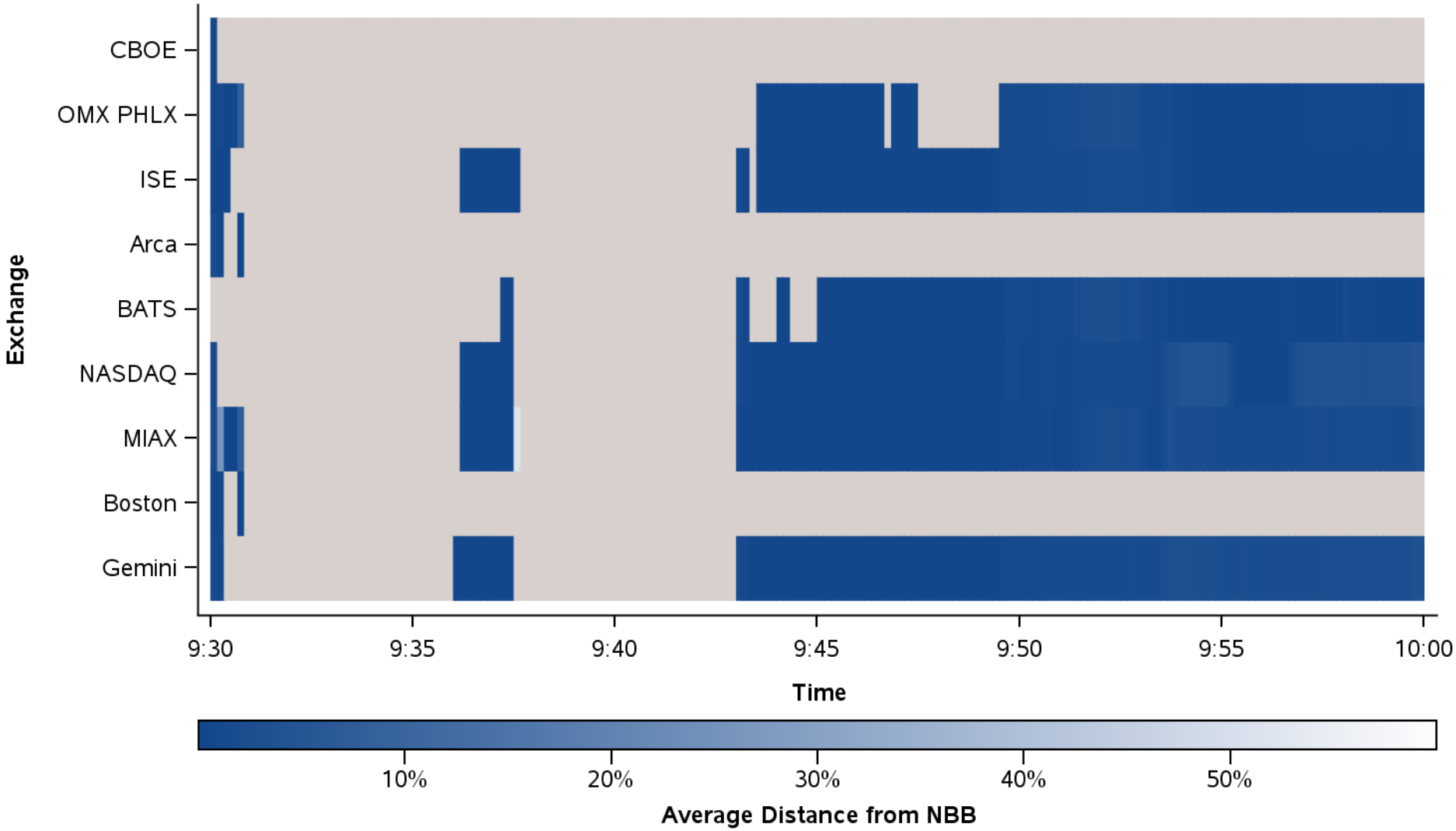
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: IVV Option

8/24/15



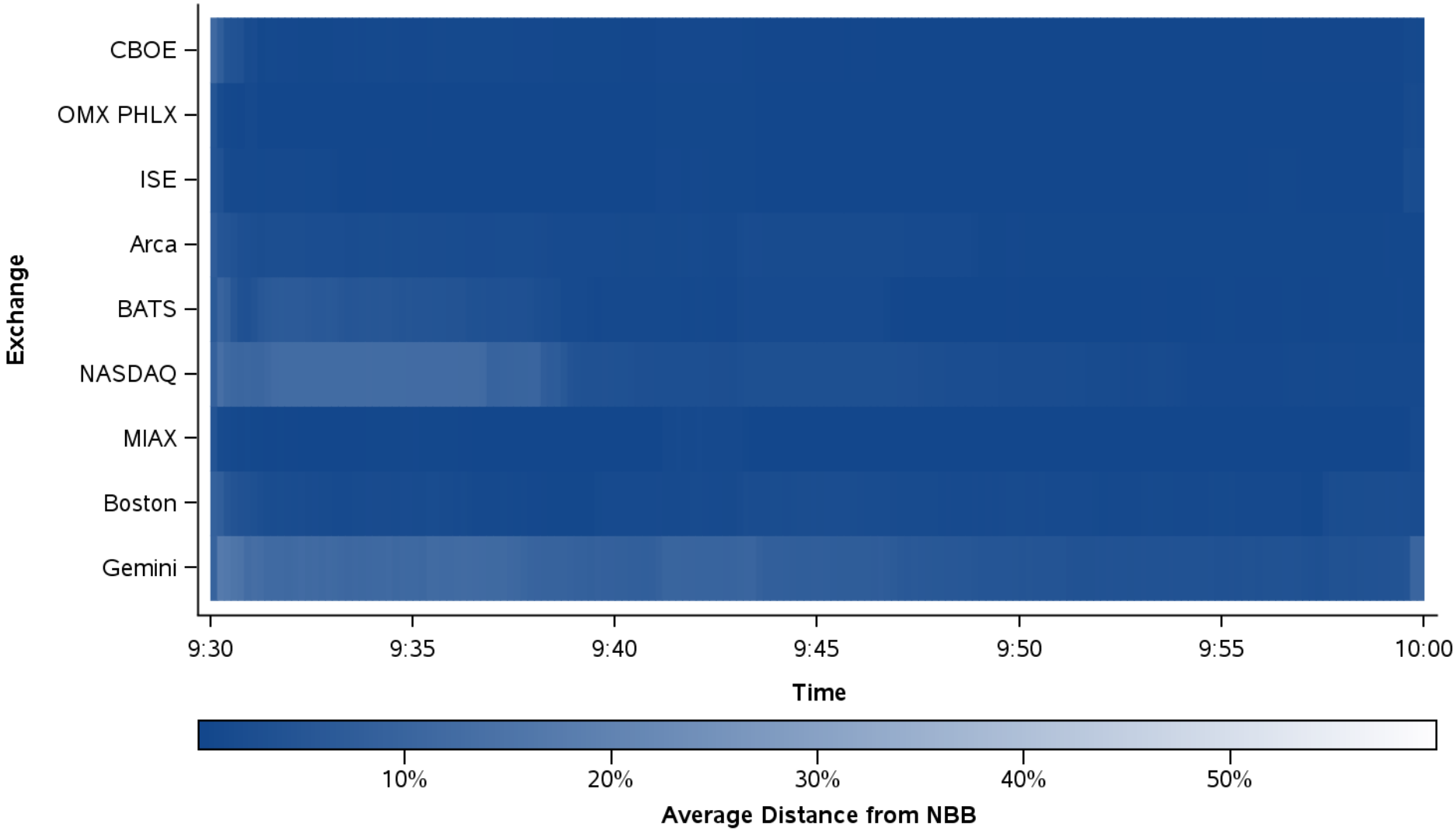
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: IVV Option

8/25/15 - 8/31/15



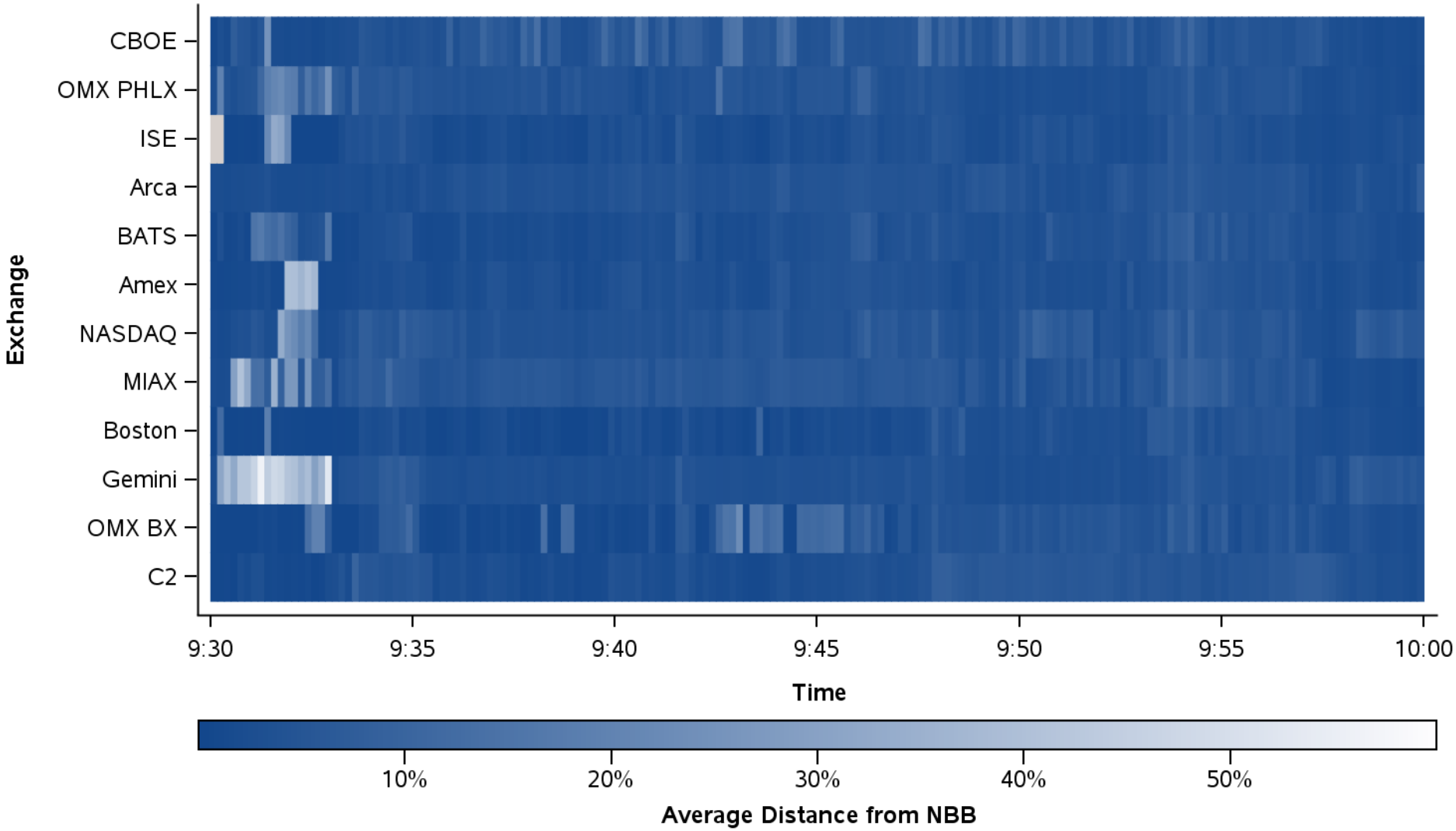
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: SPY Option

8/24/15



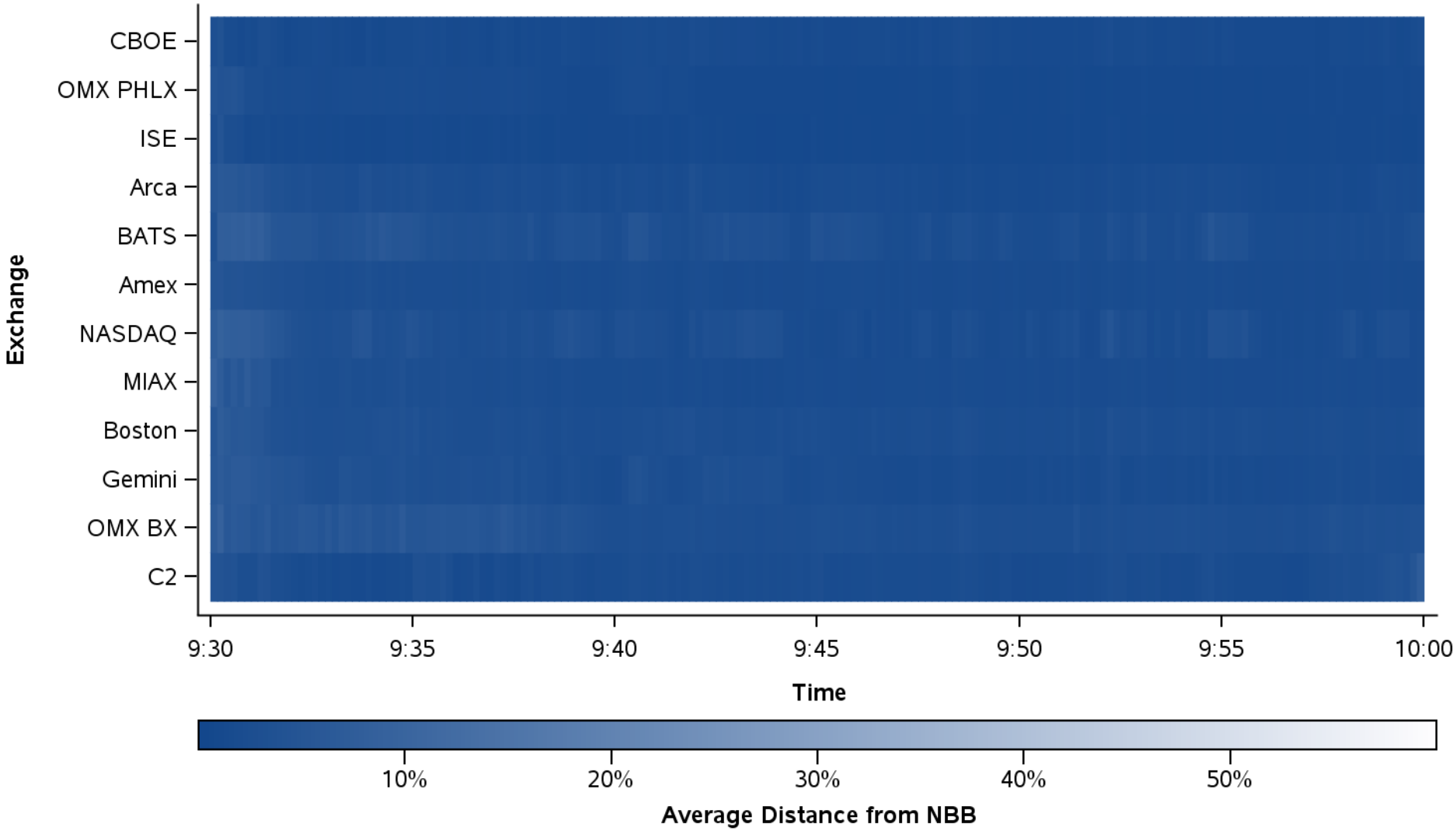
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: SPY Option

8/25/15 - 8/31/15



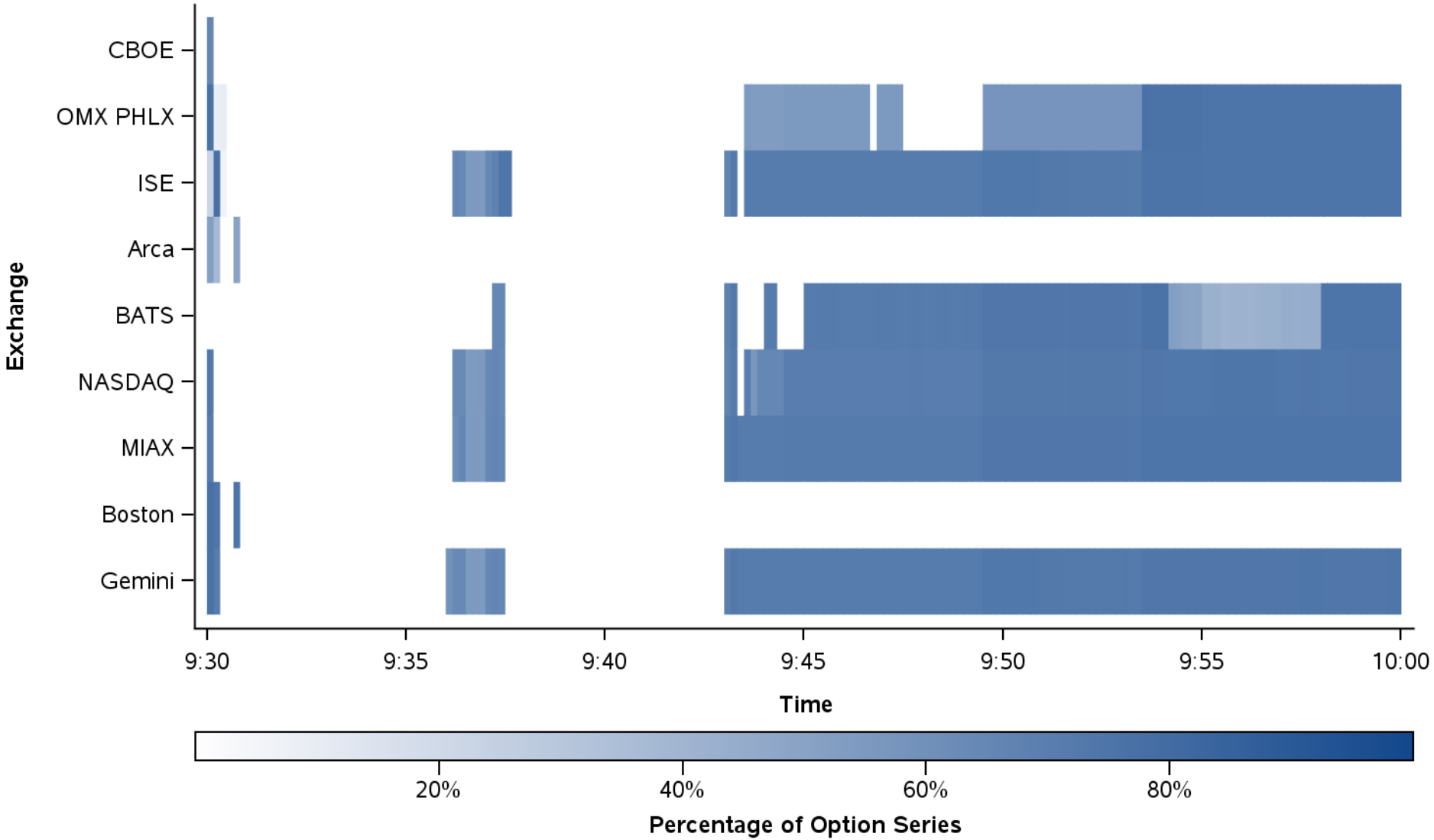
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Percentage of Option Series with a Firm Bid by Exchange

S&P 500: IVV Option

8/24/15



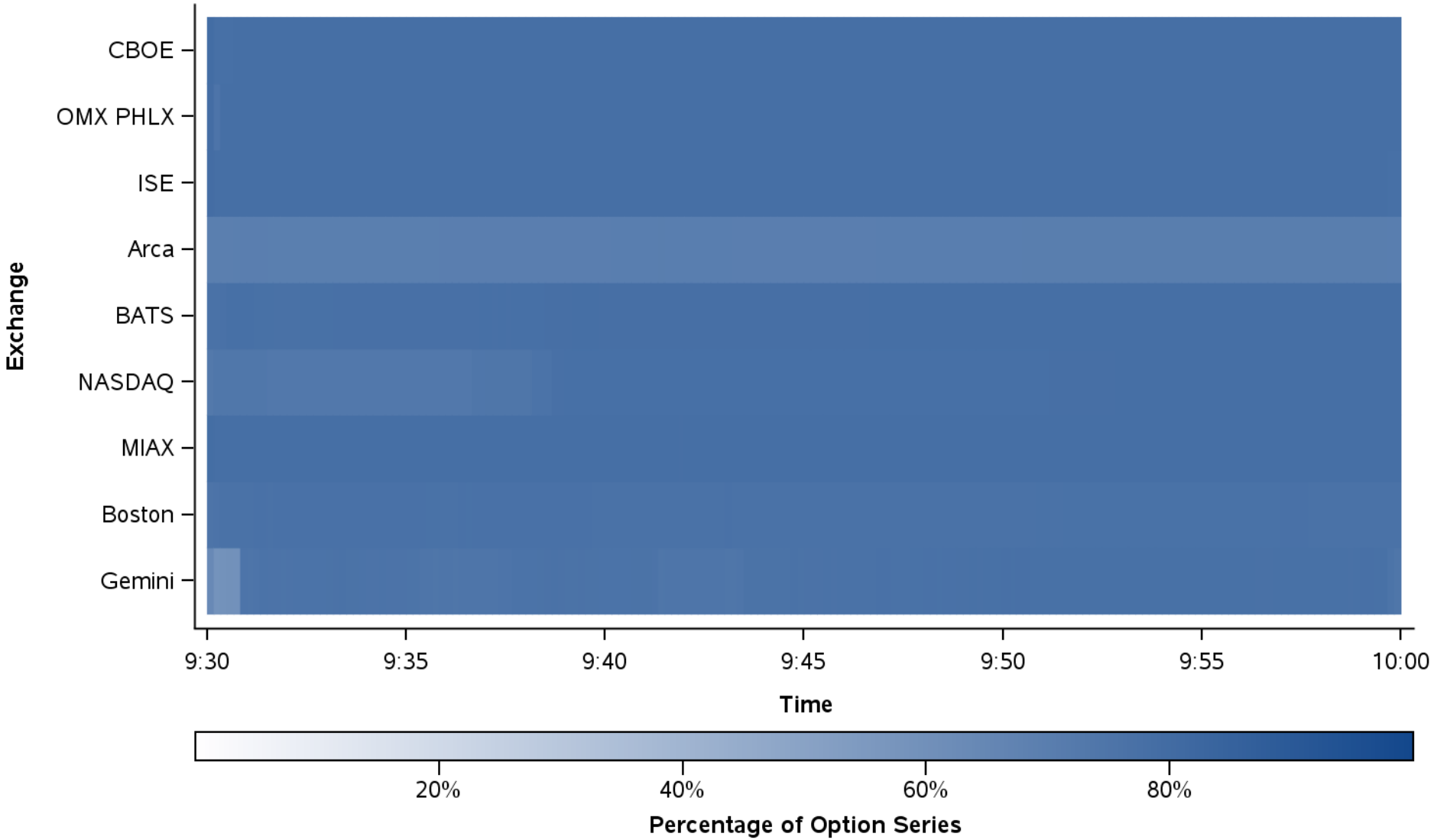
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a bid quote at any point during the ten second interval, the exchange is considered to have reported a bid quote for that ten second interval.

Percentage of Option Series with a Firm Bid by Exchange

S&P 500: IVV Option

8/25/15 - 8/31/15



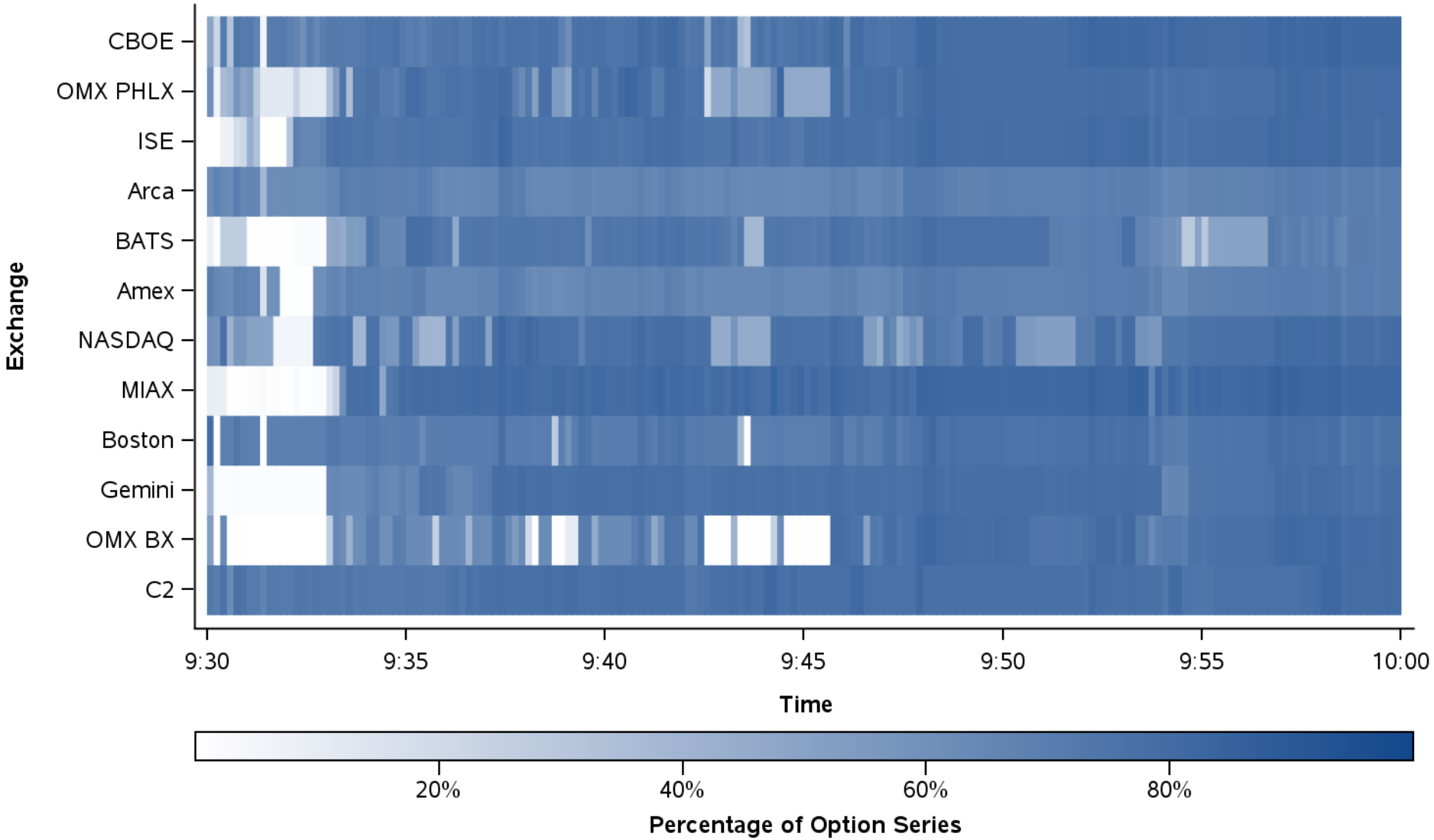
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a bid quote at any point during the ten second interval, the exchange is considered to have reported a bid quote for that ten second interval.

Percentage of Option Series with a Firm Bid by Exchange

S&P 500: SPY Option

8/24/15



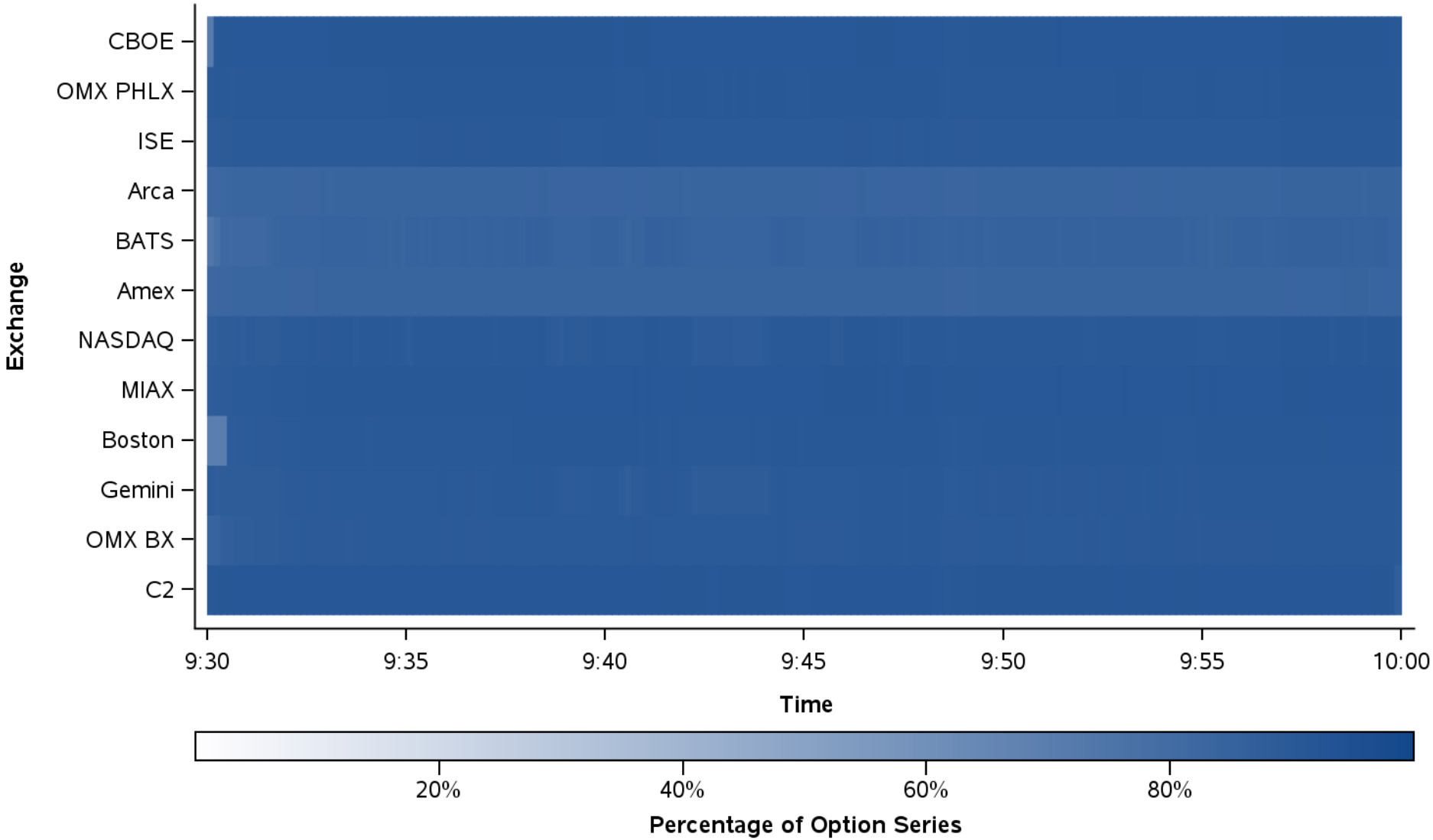
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a bid quote at any point during the ten second interval, the exchange is considered to have reported a bid quote for that ten second interval.

Percentage of Option Series with a Firm Bid by Exchange

S&P 500: SPY Option

8/25/15 - 8/31/15



Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a bid quote at any point during the ten second interval, the exchange is considered to have reported a bid quote for that ten second interval.

Appendix A
Additional Liquidity Metrics

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Summary Statistics

9:30 AM – 10:00 AM

Average Daily Trading Volume[2]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Number of Observations				
SPY	1	–	–	1
High Volume	46	1	–	47
Medium Volume	104	10	13	127
Low Volume	221	29	37	287
All	372	40	50	462
ETF YTD Average Daily Trading Volume				
SPY	115,981,416	–	–	115,981,416
High Volume	13,856,799	5,068,900	–	13,669,822
Medium Volume	1,772,718	1,782,057	958,216	1,690,079
Low Volume	157,352	140,993	207,643	162,182
All	2,614,332	674,456	402,792	2,207,033
Option YTD Average Daily Trading Volume				
SPY	2,417,177	–	–	2,417,177
High Volume	58,686	1,010	–	57,459
Medium Volume	2,148	1,562	107	1,893
Low Volume	76	36	22	65
All	14,400	442	44	11,638

Source: iVolatility; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which volume data are available from CRSP.
[2] Average daily trading volume is calculated from 1/2/15 to 8/21/15. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Volume[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Volume on 8/24/15				
SPY	46,948,449	–	–	46,948,449
High Volume	5,248,691	3,261,217	–	5,206,405
Medium Volume	883,066	1,488,303	1,053,047	948,122
Low Volume	101,535	143,020	260,233	126,186
All	1,082,436	557,296	466,365	970,295
Average Volume from 8/25/15 – 8/31/15				
SPY	27,318,234	–	–	27,318,234
High Volume	2,973,175	902,495	–	2,929,118
Medium Volume	440,337	423,258	195,722	413,953
Low Volume	38,460	32,270	43,428	38,475
All	587,041	151,773	83,024	494,808
Ratio of Average Volume on 8/24/15 to 8/25/15 – 8/31/15				
SPY	1.719	–	–	1.719
High Volume	1.765	3.614	–	1.777
Medium Volume	2.005	3.516	5.380	2.290
Low Volume	2.640	4.432	5.992	3.280
All	1.844	3.672	5.617	1.961

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which volume data are available from CRSP.
[2] Canceled trades corresponding to correction indicators 8, 10, and 12 are excluded.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Trade Count[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Trade Count on 8/24/15				
SPY	181,224	–	–	181,224
High Volume	14,596	4,597	–	14,383
Medium Volume	2,748	5,366	3,064	2,987
Low Volume	403	581	1,130	515
All	3,300	1,878	1,633	2,996
Average Trade Count from 8/25/15 – 8/31/15				
SPY	138,894	–	–	138,894
High Volume	8,742	1,715	–	8,593
Medium Volume	1,511	1,577	501	1,413
Low Volume	136	93	174	136
All	1,957	505	259	1,648
Ratio of Average Trade Count on 8/24/15 to 8/25/15 – 8/31/15				
SPY	1.305	–	–	1.305
High Volume	1.670	2.680	–	1.674
Medium Volume	1.819	3.402	6.116	2.114
Low Volume	2.976	6.234	6.487	3.780
All	1.686	3.720	6.300	1.818

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which volume data are available from CRSP.
[2] Canceled trades corresponding to correction indicators 8, 10, and 12 are excluded.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Volume[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Volume on 8/24/15				
SPY	93,914,200	–	–	93,914,200
High Volume	1,477,424	41,700	–	1,446,877
Medium Volume	117,895	72,440	8,746	103,143
Low Volume	3,152	910	808	2,623
All	469,982	19,813	2,872	380,453
Average Volume from 8/25/15 – 8/31/15				
SPY	54,949,160	–	–	54,949,160
High Volume	1,118,504	43,500	–	1,095,632
Medium Volume	44,081	33,378	2,474	38,979
Low Volume	1,624	380	309	1,329
All	299,311	9,708	872	241,938
Ratio of Average Volume on 8/24/15 to 8/25/15 – 8/31/15				
SPY	1.709	–	–	1.709
High Volume	1.321	0.959	–	1.321
Medium Volume	2.675	2.170	3.535	2.646
Low Volume	1.941	2.396	2.614	1.975
All	1.570	2.041	3.294	1.573

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 options on ETFs, for which intraday data are available from TickData.
[2] Canceled trades corresponding to condition codes A, C, E, G, and O are excluded. Values are show in number of shares.
[3] Options for which the average daily trading volume for the underlying ETF is (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Trade Count[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Trade Count on 8/24/15				
SPY	22,485	–	–	22,485
High Volume	638	49	–	626
Medium Volume	77	110	19	74
Low Volume	5	2	3	4
All	164	30	7	135
Average Trade Count from 8/25/15 – 8/31/15				
SPY	19,792	–	–	19,792
High Volume	457	9	–	447
Medium Volume	33	50	2	31
Low Volume	2	1	1	2
All	120	13	1	98
Ratio of Average Trade Count on 8/24/15 to 8/25/15 – 8/31/15				
SPY	1.136	–	–	1.136
High Volume	1.398	5.326	–	1.400
Medium Volume	2.345	2.186	7.975	2.370
Low Volume	2.434	2.767	4.717	2.545
All	1.365	2.263	6.667	1.382

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 options on ETFs, for which intraday data are available from TickData.
[2] Canceled trades corresponding to condition codes A, C, E, G, and O are excluded.
[3] Options for which the average daily trading volume for the underlying ETF is (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average NBB Size[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average NBB Size on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	2,667	–	–	2,667
High Volume	13,064	2,620	–	12,880
Medium Volume	7,030	4,421	5,135	6,851
Low Volume	2,297	1,867	4,026	2,310
All	4,953	2,513	4,274	4,783
Average NBB Size from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	3,969	–	–	3,969
High Volume	44,072	10,019	–	43,348
Medium Volume	11,878	12,275	14,488	12,177
Low Volume	3,825	3,179	4,749	3,879
All	11,054	5,624	7,281	10,175
Ratio of Average NBB Size on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.672	–	–	0.672
High Volume	0.296	0.262	–	0.297
Medium Volume	0.592	0.360	0.354	0.563
Low Volume	0.601	0.587	0.848	0.595
All	0.448	0.447	0.587	0.470

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average NBB size is calculated by finding the total number of shares at the NBB across all exchanges at each millisecond. Intervals during a trading halt and non-firm quotes are excluded from the calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average NBO Size[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average NBO Size on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	2,705	–	–	2,705
High Volume	12,745	19,672	–	12,867
Medium Volume	9,548	4,641	10,454	9,287
Low Volume	2,106	909	3,090	2,040
All	5,504	2,414	4,734	5,291
Average NBO Size from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	6,424	–	–	6,424
High Volume	45,483	27,818	–	45,107
Medium Volume	16,187	15,880	14,686	16,009
Low Volume	4,003	3,722	4,044	3,980
All	12,545	7,364	6,811	11,476
Ratio of Average NBO Size on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.421	–	–	0.421
High Volume	0.280	0.707	–	0.285
Medium Volume	0.590	0.292	0.712	0.580
Low Volume	0.526	0.244	0.764	0.513
All	0.439	0.328	0.695	0.461

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average NBO size is calculated by finding the total number of shares offered at the NBO across all exchanges at each millisecond. Intervals during a trading halt and non-firm quotes are excluded from the calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Exchanges at the NBB[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Exchanges at the NBB on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	1.892	–	–	1.892
High Volume	3.727	2.991	–	3.714
Medium Volume	3.060	2.277	2.387	3.004
Low Volume	2.451	1.841	1.759	2.386
All	2.777	1.984	1.900	2.709
Average Number of Exchanges at the NBB from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	3.947	–	–	3.947
High Volume	5.005	4.340	–	4.991
Medium Volume	3.949	3.888	3.226	3.870
Low Volume	2.831	2.322	2.898	2.788
All	3.415	2.764	2.983	3.312
Ratio of Average Number of Exchanges at the NBB on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.479	–	–	0.479
High Volume	0.745	0.689	–	0.744
Medium Volume	0.775	0.586	0.740	0.776
Low Volume	0.866	0.793	0.607	0.856
All	0.813	0.718	0.637	0.818

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average number of exchanges at the NBB is calculated by finding number of exchanges with their best bid equal to the NBB at each millisecond. Intervals during a trading halt and non-firm quotes are excluded from the calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Exchanges at the NBO[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Exchanges at the NBO on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	1.892	–	–	1.892
High Volume	3.806	3.057	–	3.792
Medium Volume	2.992	2.351	2.152	2.942
Low Volume	2.367	1.892	1.855	2.318
All	2.719	2.041	1.921	2.659
Average Number of Exchanges at the NBO from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	4.223	–	–	4.223
High Volume	5.099	5.338	–	5.104
Medium Volume	4.036	4.032	3.103	3.940
Low Volume	2.832	2.304	2.708	2.763
All	3.453	2.812	2.811	3.328
Ratio of Average Number of Exchanges at the NBO on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.448	–	–	0.448
High Volume	0.746	0.573	–	0.743
Medium Volume	0.741	0.583	0.694	0.747
Low Volume	0.836	0.821	0.685	0.839
All	0.787	0.726	0.684	0.799

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average number of exchanges at the NBO is calculated by finding number of exchanges with their best offer equal to the NBO at each millisecond. Intervals during a trading halt and non-firm quotes are excluded from the calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Firm Bids[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Firm Bids on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	8.605	–	–	8.605
High Volume	8.298	7.999	–	8.293
Medium Volume	8.068	7.996	7.950	8.062
Low Volume	7.201	7.027	7.488	7.196
All	7.583	7.294	7.591	7.565
Average Number of Firm Bids from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	8.996	–	–	8.996
High Volume	8.426	7.999	–	8.417
Medium Volume	8.173	8.088	7.995	8.148
Low Volume	7.301	7.141	7.821	7.352
All	7.688	7.399	7.867	7.683
Ratio of Average Number of Firm Bids on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.957	–	–	0.957
High Volume	0.985	1.000	–	0.985
Medium Volume	0.987	0.989	0.994	0.989
Low Volume	0.986	0.984	0.957	0.979
All	0.986	0.986	0.965	0.985

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average number of firm bids is calculated as the number of exchanges with a firm bid at each millisecond. Intervals during a trading halt and non-firm quotes are excluded from the calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

ETF Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Firm Offers[2]

9:30 AM – 10:00 AM

Average Daily Trading Volume[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Firm Offers on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	8.549	–	–	8.549
High Volume	8.312	7.999	–	8.306
Medium Volume	8.066	7.996	7.970	8.060
Low Volume	7.219	6.980	7.447	7.207
All	7.594	7.260	7.564	7.572
Average Number of Firm Offers from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	8.997	–	–	8.997
High Volume	8.432	7.999	–	8.423
Medium Volume	8.176	8.092	7.995	8.151
Low Volume	7.294	7.145	7.824	7.347
All	7.686	7.403	7.868	7.681
Ratio of Average Number of Firm Offers on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.950	–	–	0.950
High Volume	0.986	1.000	–	0.986
Medium Volume	0.986	0.988	0.997	0.989
Low Volume	0.990	0.977	0.952	0.981
All	0.988	0.981	0.961	0.986

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 ETFs with listed options, for which intraday data are available from TickData.
[2] Average number of firm offers is calculated as the number of exchanges with a firm offer at each millisecond. Intervals during a trading halt and non-firm quotes are excluded from the calculation.
[3] ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average NBB Size[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average NBB Size on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	21,843	–	–	21,843
High Volume	126,767	8,335	–	126,539
Medium Volume	46,951	3,130	123	38,870
Low Volume	10,372	1,313	29	7,934
All	59,255	2,105	55	50,493
Average NBB Size from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	259,791	–	–	259,791
High Volume	310,668	282,839	–	310,614
Medium Volume	125,797	109,257	31,199	115,582
Low Volume	20,224	8,736	9,307	17,225
All	153,839	48,872	15,049	133,477
Ratio of Average NBB Size on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.084	–	–	0.084
High Volume	0.408	0.029	–	0.407
Medium Volume	0.373	0.029	0.004	0.336
Low Volume	0.513	0.150	0.003	0.461
All	0.385	0.043	0.004	0.378

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Average NBB size is calculated by finding the total number of shares at the NBB across all exchanges. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are no firm bids are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average NBO Size[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average NBO Size on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	30,694	–	–	30,694
High Volume	94,631	10,937	–	94,469
Medium Volume	35,261	2,897	173	29,249
Low Volume	6,948	945	58	5,327
All	44,599	1,817	90	38,023
Average NBO Size from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	270,483	–	–	270,483
High Volume	350,066	281,429	–	349,932
Medium Volume	136,637	124,238	35,942	126,245
Low Volume	23,225	10,132	11,206	19,879
All	171,228	55,371	17,695	148,722
Ratio of Average NBO Size on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.113	–	–	0.113
High Volume	0.270	0.039	–	0.270
Medium Volume	0.258	0.023	0.005	0.232
Low Volume	0.299	0.093	0.005	0.268
All	0.260	0.033	0.005	0.256

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Average NBO size is calculated by finding the total number of shares offered at the NBO across all exchanges. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are no firm offers are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Exchanges at the NBB[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Exchanges at the NBB on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	2.763	–	–	2.763
High Volume	7.149	1.133	–	7.138
Medium Volume	4.995	1.259	0.102	4.228
Low Volume	2.456	0.341	0.029	1.885
All	4.707	0.717	0.049	4.050
Average Number of Exchanges at the NBB from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	7.392	–	–	7.392
High Volume	9.564	9.458	–	9.563
Medium Volume	7.076	6.369	4.411	6.766
Low Volume	3.440	1.903	1.896	3.024
All	6.589	3.649	2.555	6.005
Ratio of Average Number of Exchanges at the NBB on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.374	–	–	0.374
High Volume	0.748	0.120	–	0.746
Medium Volume	0.706	0.198	0.023	0.625
Low Volume	0.714	0.179	0.015	0.623
All	0.714	0.197	0.019	0.674

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Calculated by finding the number of exchanges with their best bid equal to the NBB. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are no firm bids are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Exchanges at the NBO[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Exchanges at the NBO on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	3.164	–	–	3.164
High Volume	7.639	2.973	–	7.630
Medium Volume	5.687	1.778	0.165	4.850
Low Volume	3.000	0.538	0.058	2.317
All	5.267	1.058	0.088	4.551
Average Number of Exchanges at the NBO from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	7.791	–	–	7.791
High Volume	9.952	9.827	–	9.952
Medium Volume	7.551	7.230	5.051	7.292
Low Volume	3.845	2.390	2.247	3.429
All	7.007	4.276	2.983	6.437
Ratio of Average Number of Exchanges at the NBO on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.406	–	–	0.406
High Volume	0.768	0.302	–	0.767
Medium Volume	0.753	0.246	0.033	0.665
Low Volume	0.780	0.225	0.026	0.676
All	0.752	0.247	0.029	0.707

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Calculated by finding the number of exchanges with their best offer equal to the NBO at each millisecond. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are firm offers are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Firm Bids[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Firm Bids on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	6.785	–	–	6.785
High Volume	9.540	1.674	–	9.525
Medium Volume	6.883	2.331	0.152	5.883
Low Volume	3.297	0.478	0.037	2.532
All	6.474	1.235	0.069	5.586
Average Number of Firm Bids from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	11.826	–	–	11.826
High Volume	11.165	9.952	–	11.162
Medium Volume	8.135	7.501	5.184	7.805
Low Volume	3.941	2.073	2.031	3.430
All	7.762	4.184	2.858	7.052
Ratio of Average Number of Firm Bids on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.574	–	–	0.574
High Volume	0.854	0.168	–	0.853
Medium Volume	0.846	0.311	0.029	0.754
Low Volume	0.837	0.231	0.018	0.738
All	0.834	0.295	0.024	0.792

Source: TickData; CRSP; SEC Halts Data.

Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Average number of firm bids is calculated as the number of exchanges with a firm bid at each millisecond. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are no firm bids are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Option Summary Statistics Grouped by Average Daily Trading Volume and Number of Halts on 8/24/15[1]

Average Number of Firm Offers[2]

9:30 AM – 10:00 AM

Underlying ETF ADTV[3]	Number of Halts on 8/24/15			All
	0	1–3	4+	
Average Number of Firm Offers on 8/24/15 (9:30 AM – 10:00 AM)				
SPY	7.738	–	–	7.738
High Volume	10.847	5.119	–	10.836
Medium Volume	8.235	3.310	0.237	7.091
Low Volume	4.221	0.758	0.073	3.259
All	7.642	1.823	0.118	6.620
Average Number of Firm Offers from 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	11.938	–	–	11.938
High Volume	11.628	10.936	–	11.627
Medium Volume	8.800	8.419	5.977	8.505
Low Volume	4.457	2.575	2.459	3.930
All	8.284	4.847	3.381	7.583
Ratio of Average Number of Firm Offers on 8/24/15 to 8/25/15 – 8/31/15 (9:30 AM – 10:00 AM)				
SPY	0.648	–	–	0.648
High Volume	0.933	0.468	–	0.932
Medium Volume	0.936	0.393	0.040	0.834
Low Volume	0.947	0.294	0.030	0.829
All	0.922	0.376	0.035	0.873

Source: TickData; CRSP; SEC Halts Data.

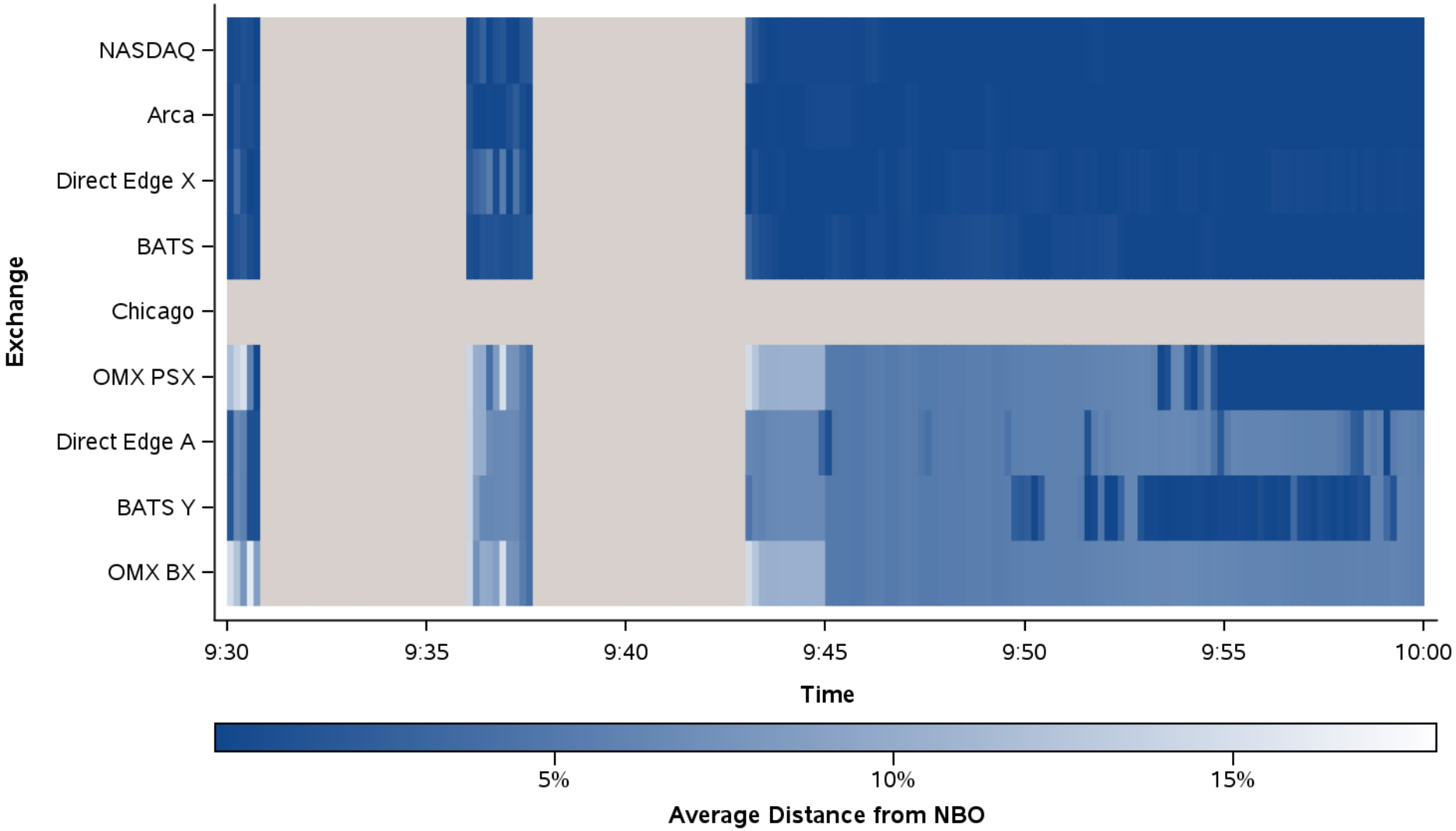
Note:
[1] Based on a sample of 462 option classes on ETFs, for which intraday data are available from TickData.
[2] Average number of firm offers is calculated as the number of exchanges with a firm offer at each millisecond. Only option series with a strike price within 10% of the 8/21/15 closing price and an expiration date after 8/28/15 are included. Intervals during trading halts and intervals in which there are no firm offers are excluded.
[3] Option classes are grouped based on the average daily trading volume in the underlying ETF. ETFs with average daily trading volume of (i) 500,000 shares or less are grouped as "Low"; (ii) between 500,000 and 5,000,000 shares are grouped as "Medium"; and (iii) greater than 5,000,000 shares are grouped as "High."

Appendix B
Additional Exchange-Specific Response Charts

Average Distance from NBO by Exchange

S&P 500: IVV ETF

8/24/15



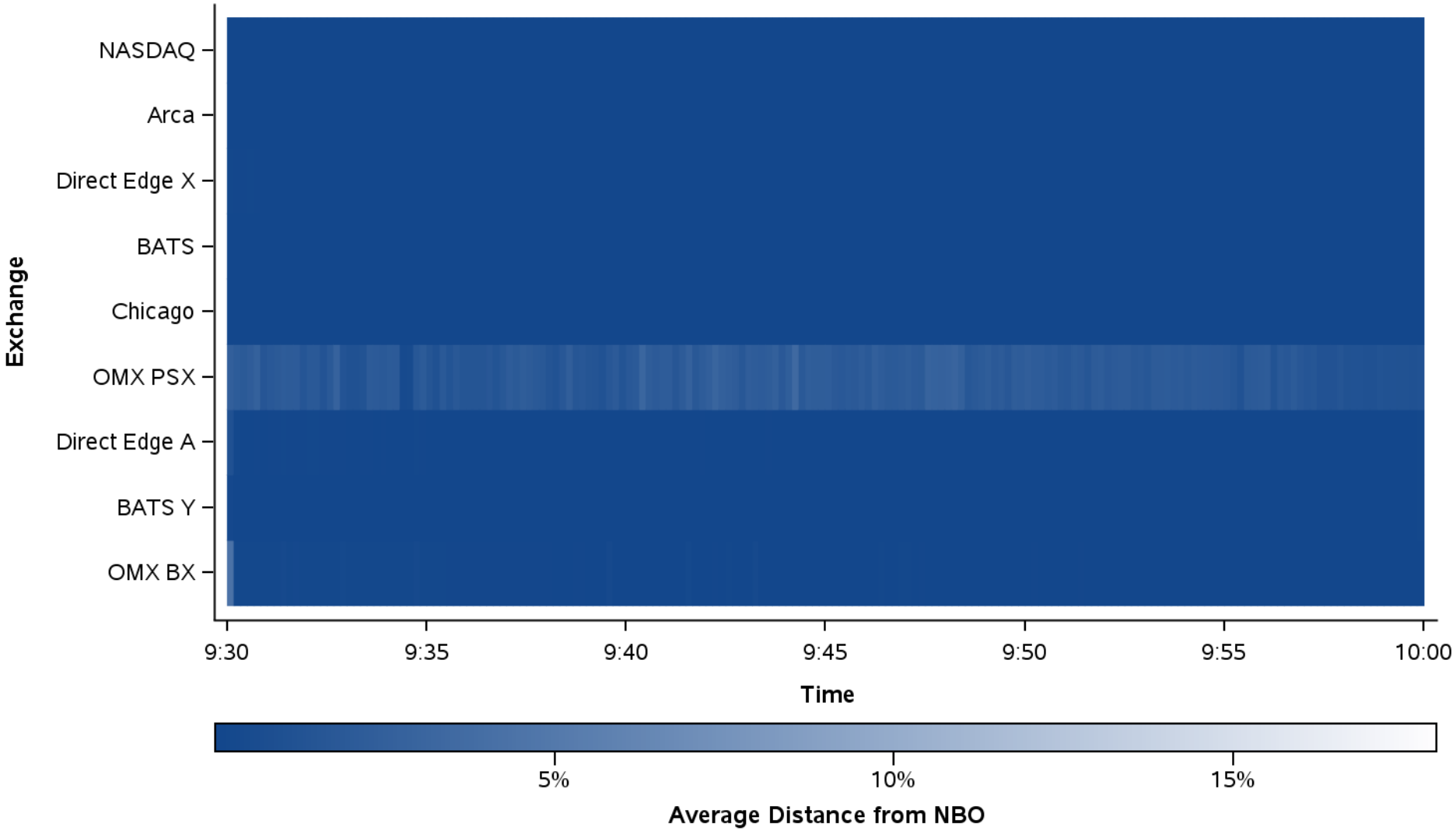
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: IVV ETF

8/25/15 - 8/31/15



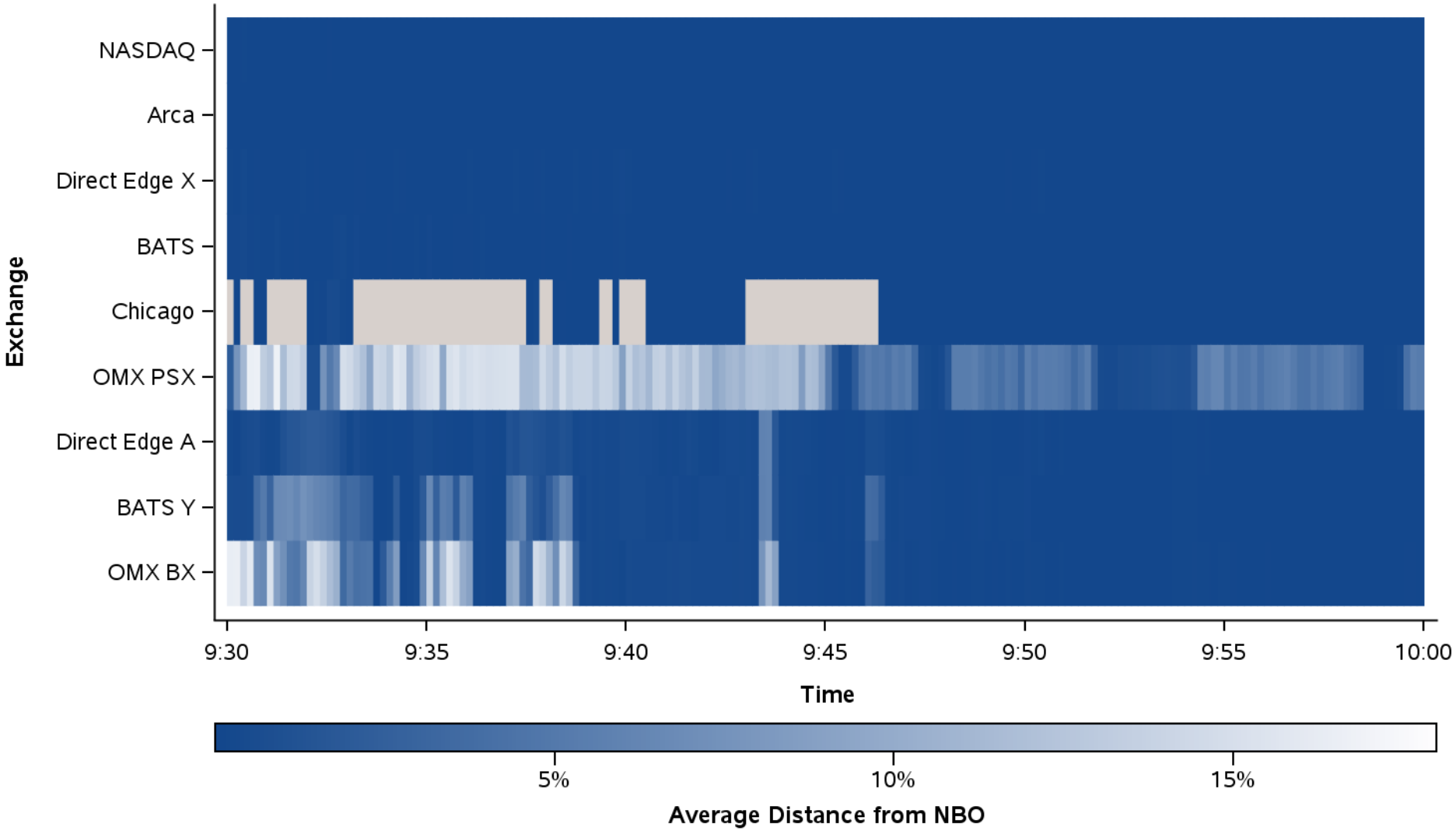
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: SPY ETF

8/24/15



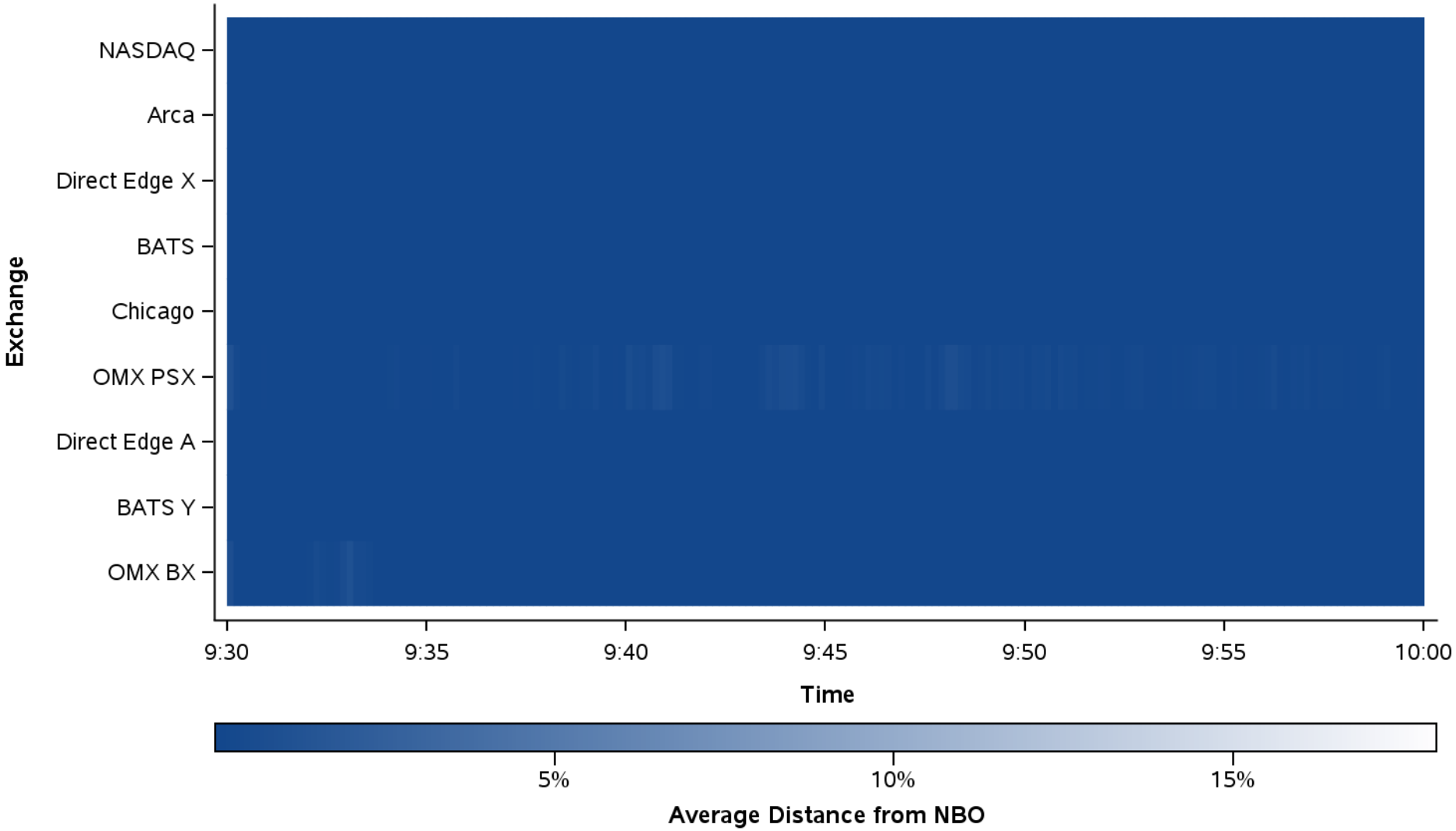
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: SPY ETF

8/25/15 - 8/31/15



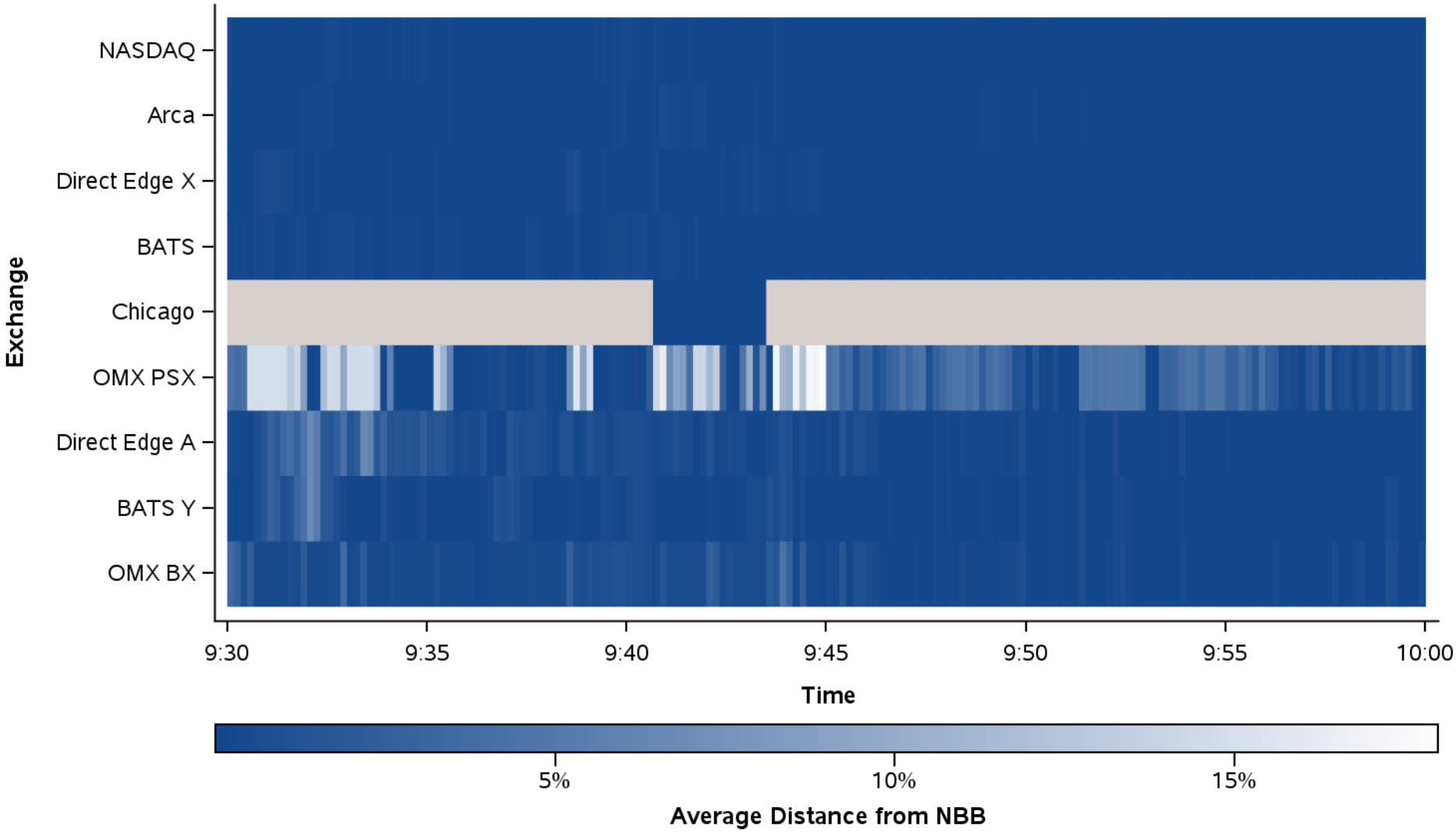
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: VOO ETF

8/24/15



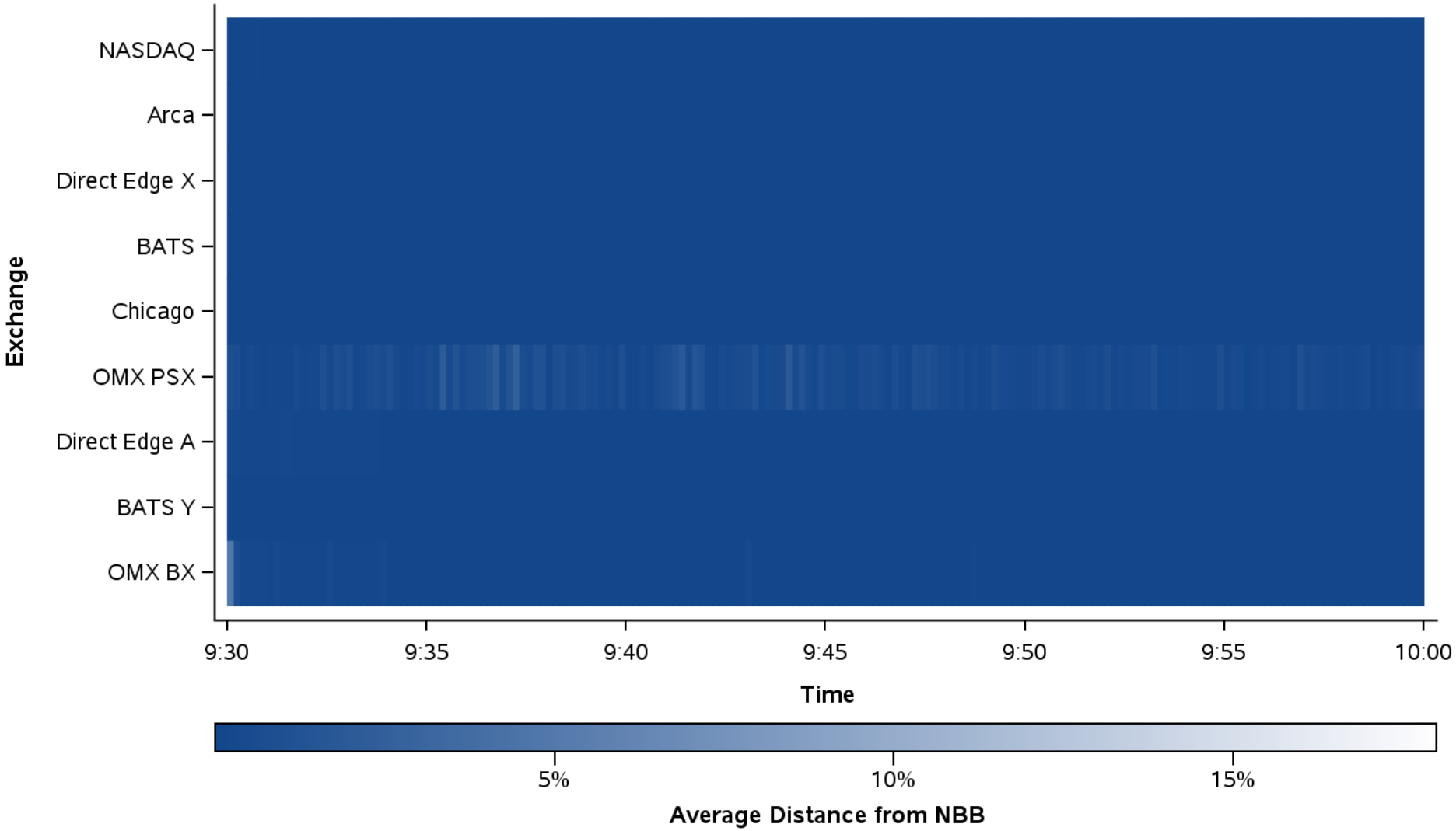
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: VOO ETF

8/25/15 - 8/31/15



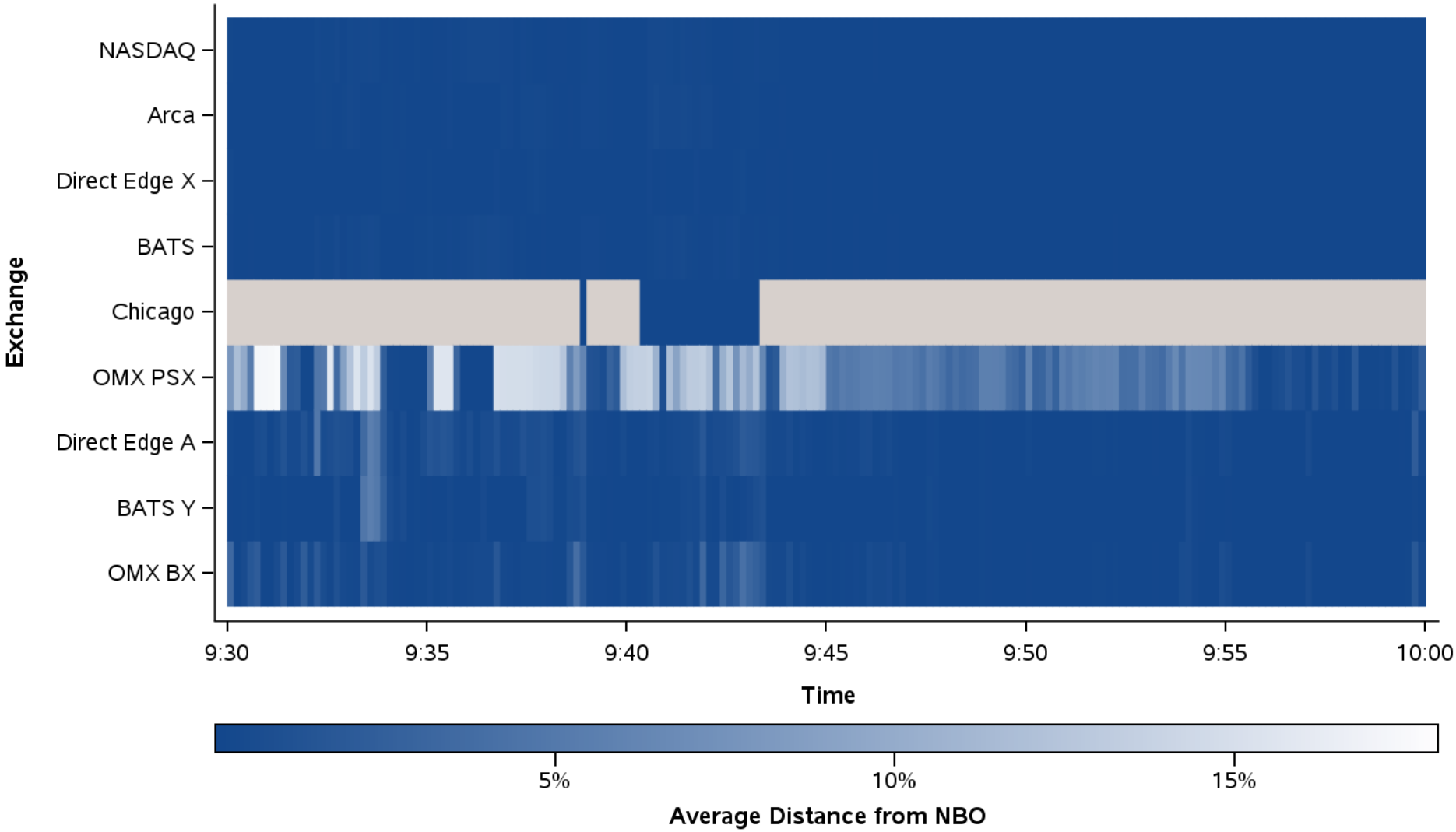
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: VOO ETF

8/24/15



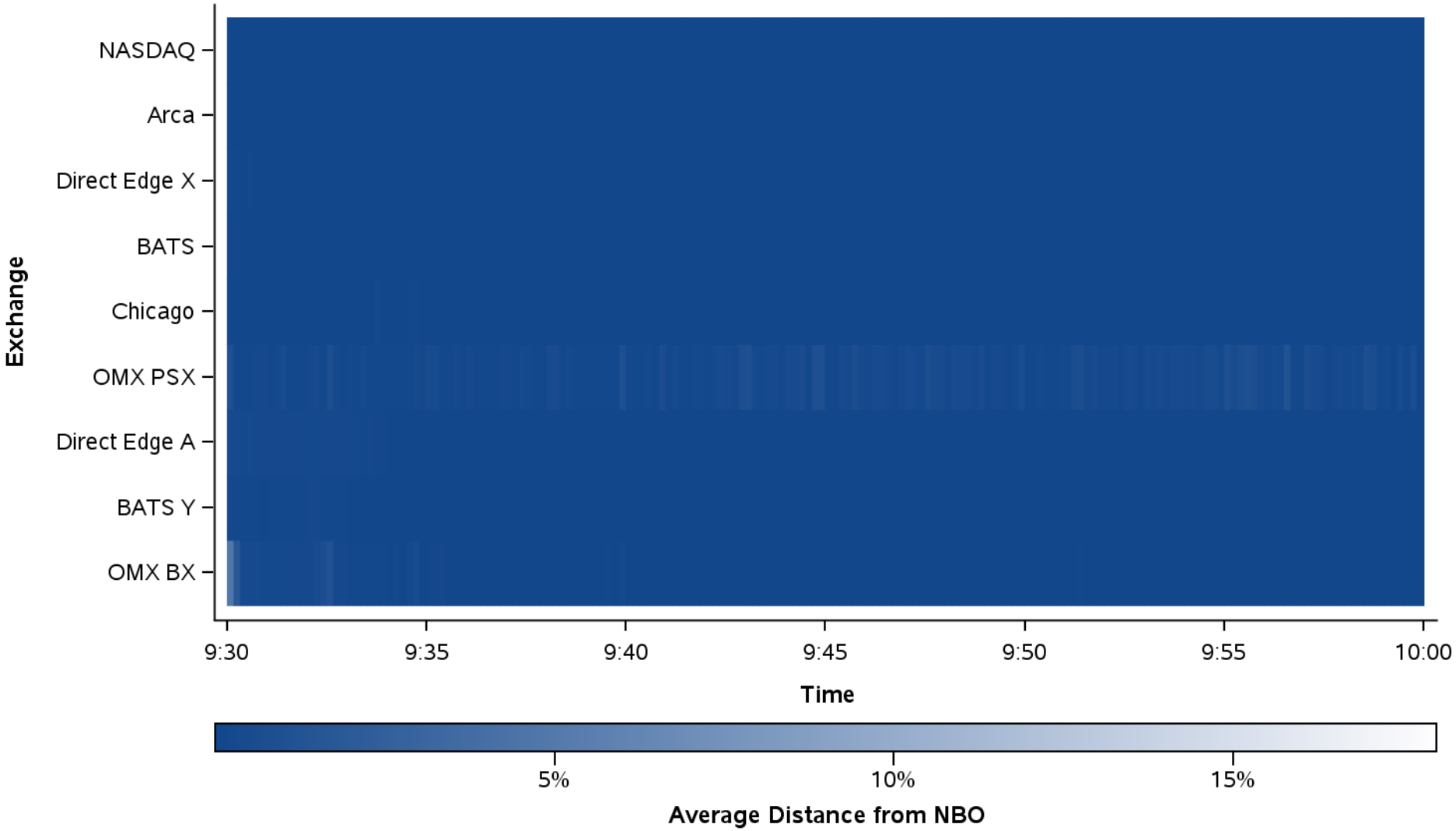
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: VOO ETF

8/25/15 - 8/31/15



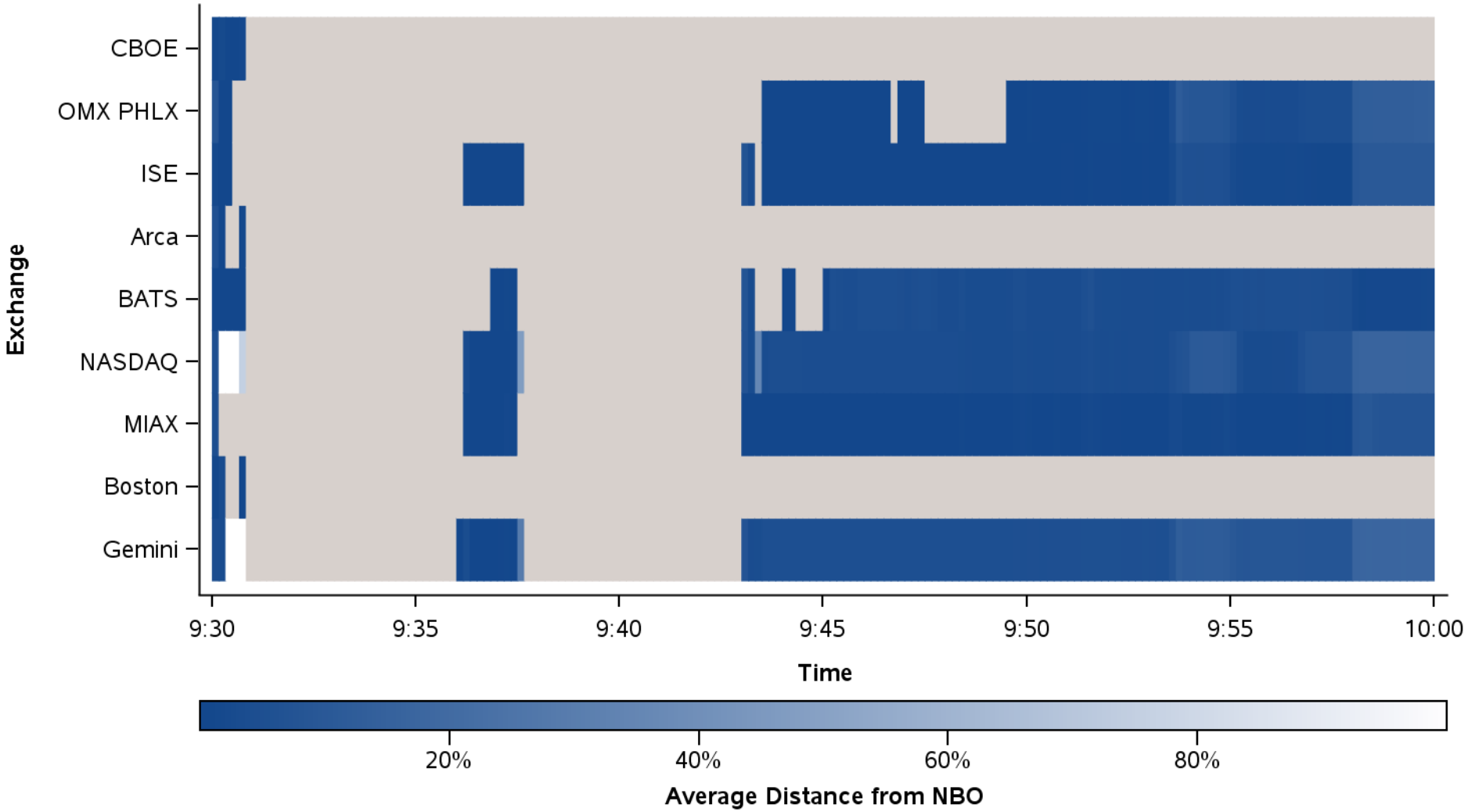
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: IVV Option

8/24/15



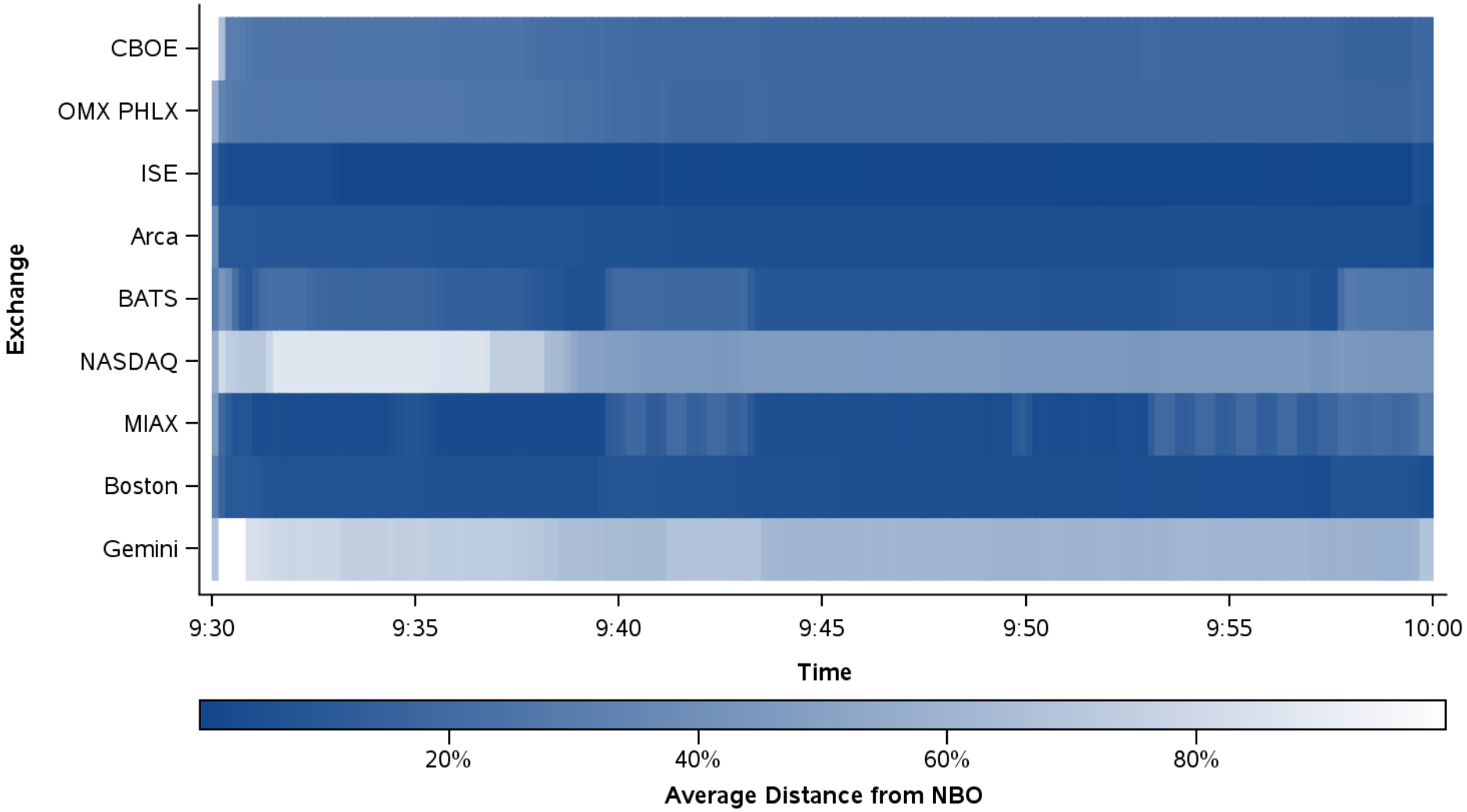
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval. Instances in which the average distance from the NBO is greater than 100% are displayed in white.

Average Distance from NBO by Exchange

S&P 500: IVV Option

8/25/15 - 8/31/15



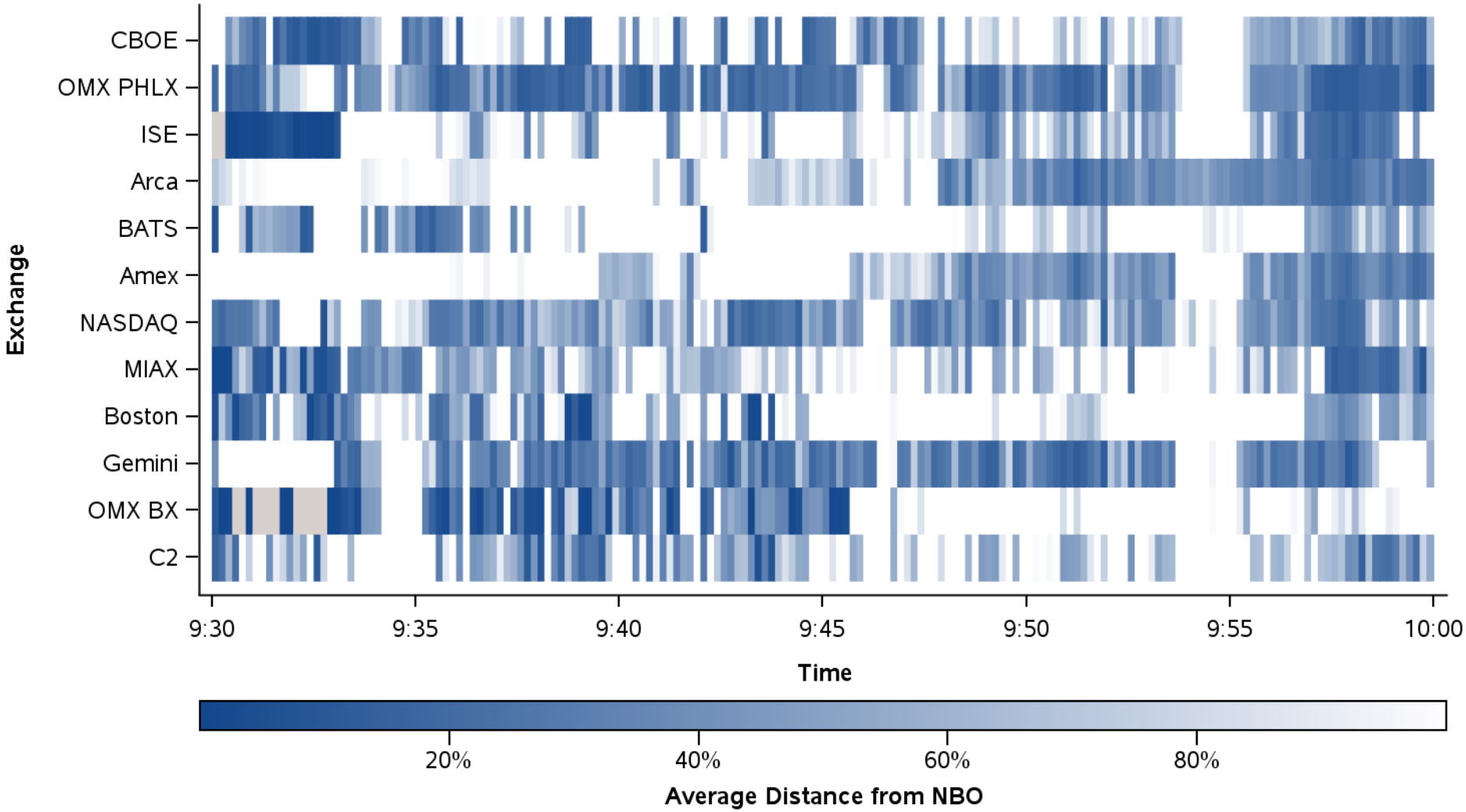
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval. Instances in which the average distance from the NBO is greater than 100% are displayed in white.

Average Distance from NBO by Exchange

S&P 500: SPY Option

8/24/15



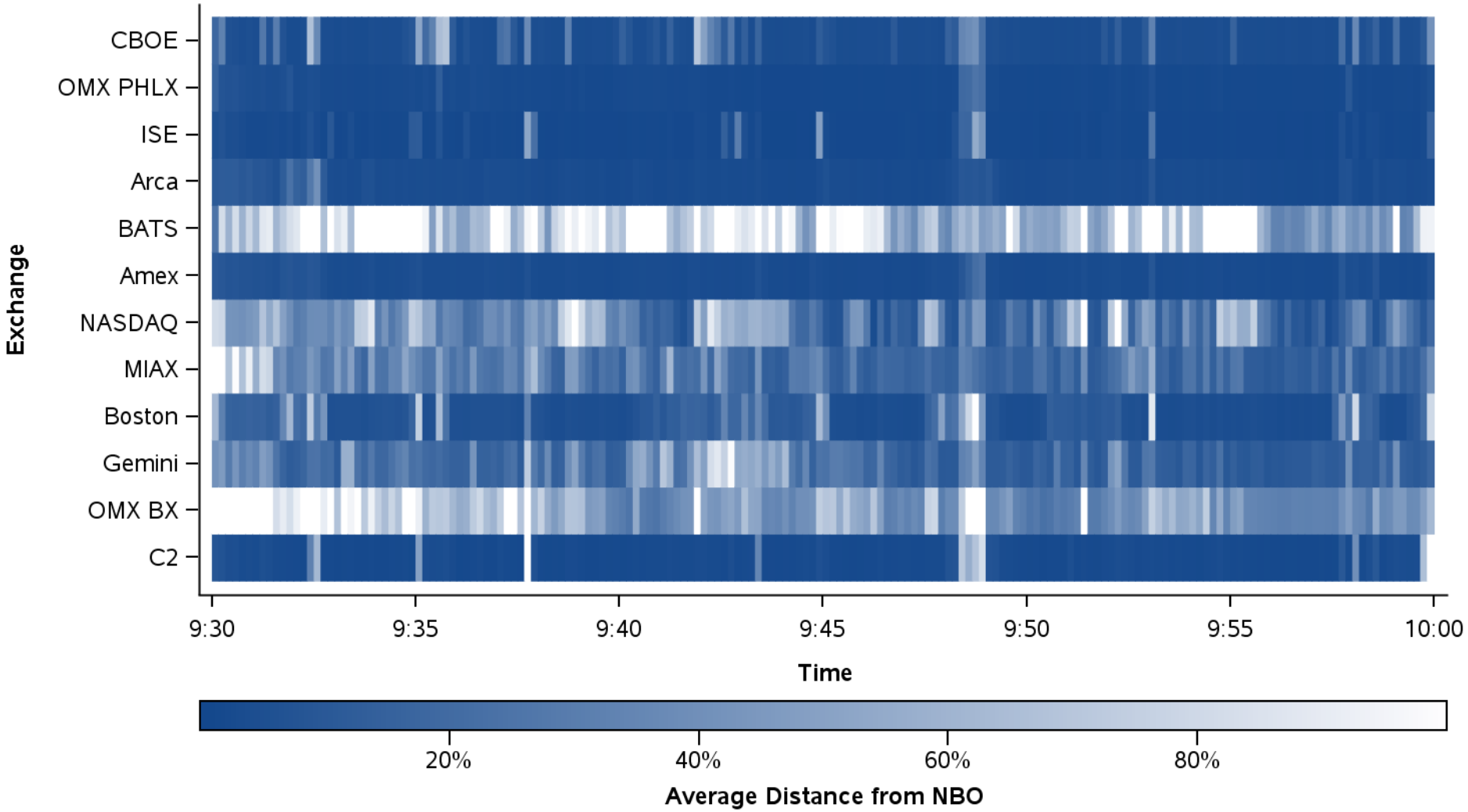
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval. Instances in which the average distance from the NBO is greater than 100% are displayed in white.

Average Distance from NBO by Exchange

S&P 500: SPY Option

8/25/15 - 8/31/15



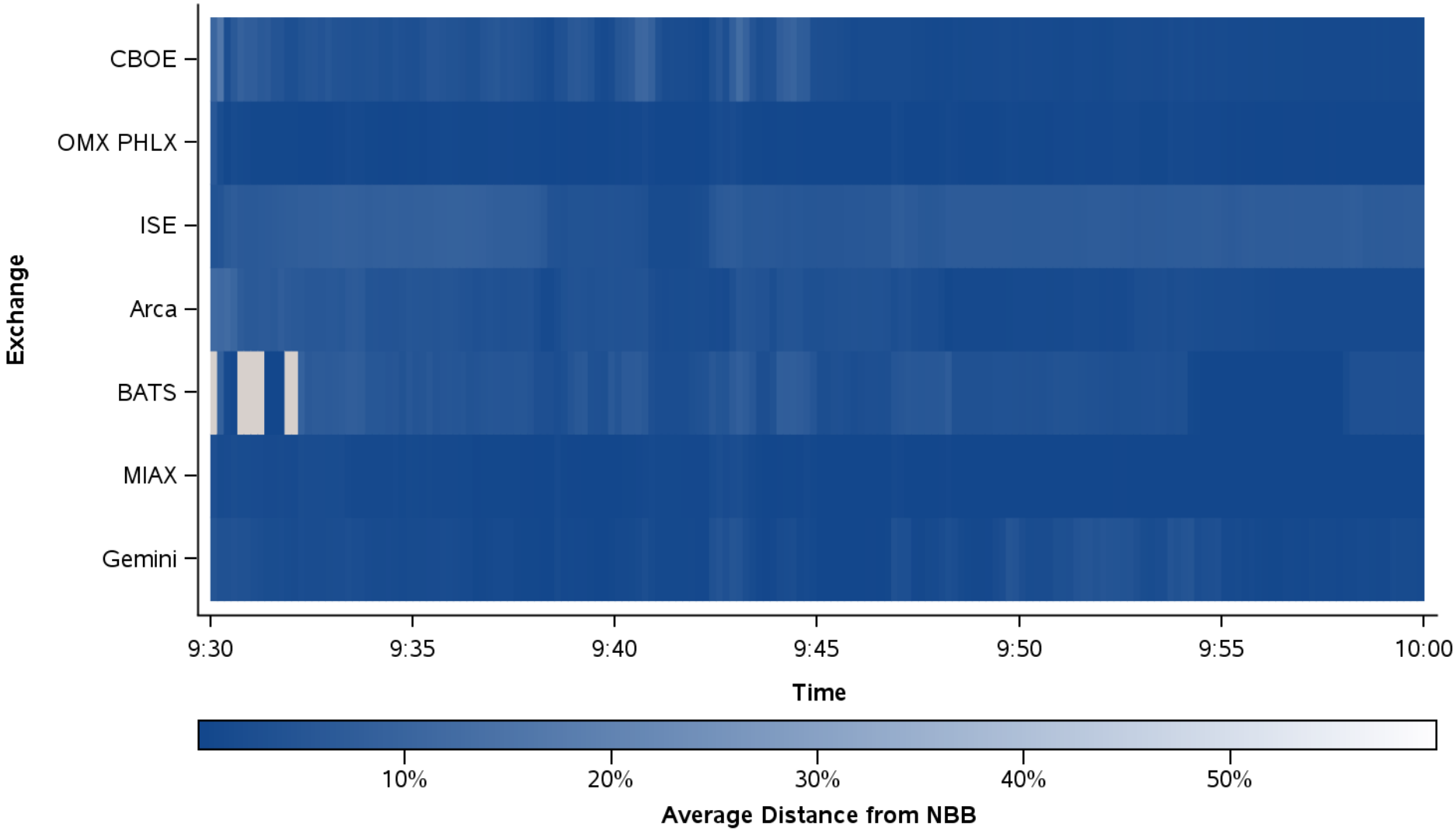
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval. Instances in which the average distance from the NBO is greater than 100% are displayed in white.

Average Distance from NBB by Exchange

S&P 500: VOO Option

8/24/15



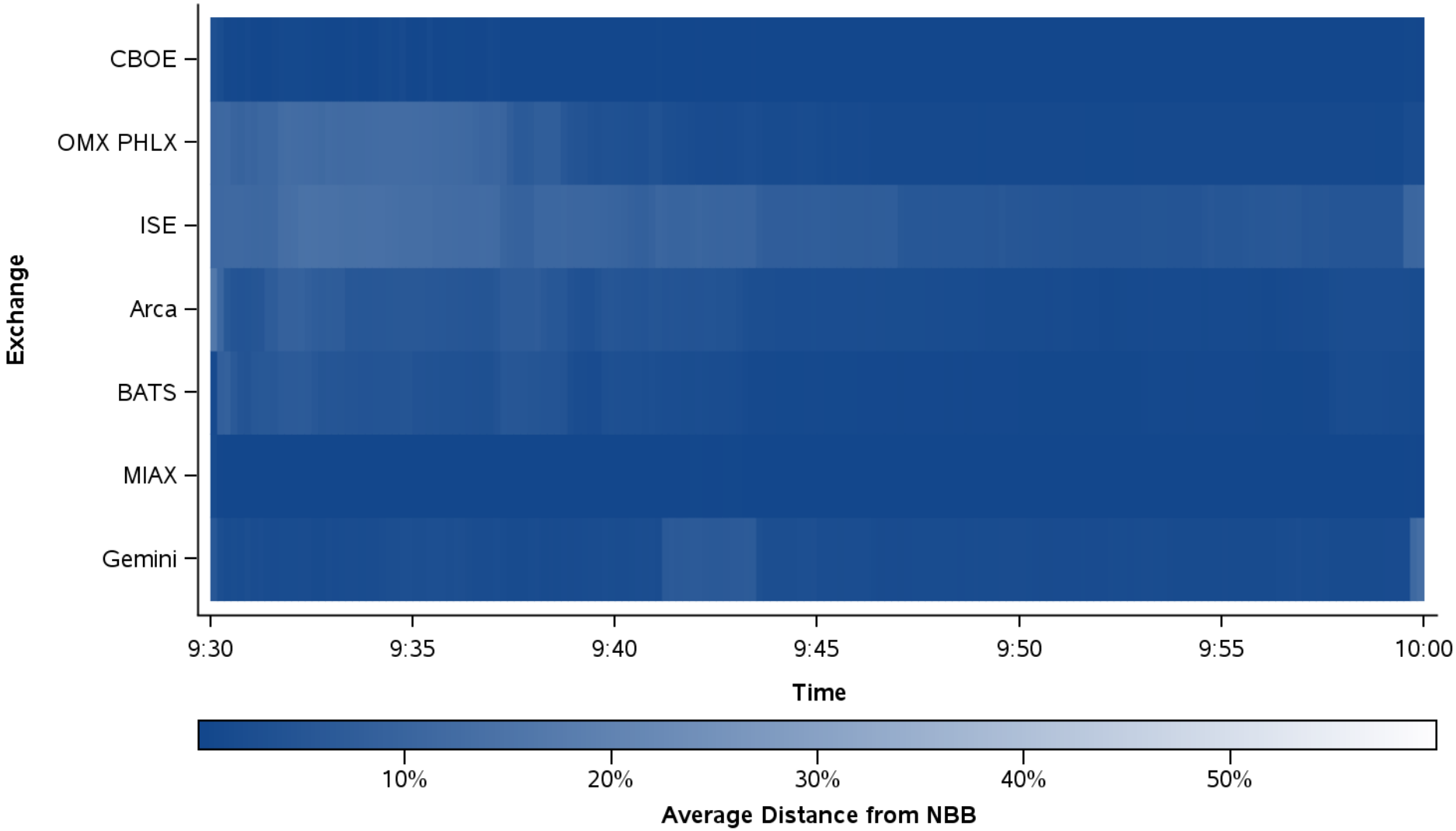
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBB by Exchange

S&P 500: VOO Option

8/25/15 - 8/31/15



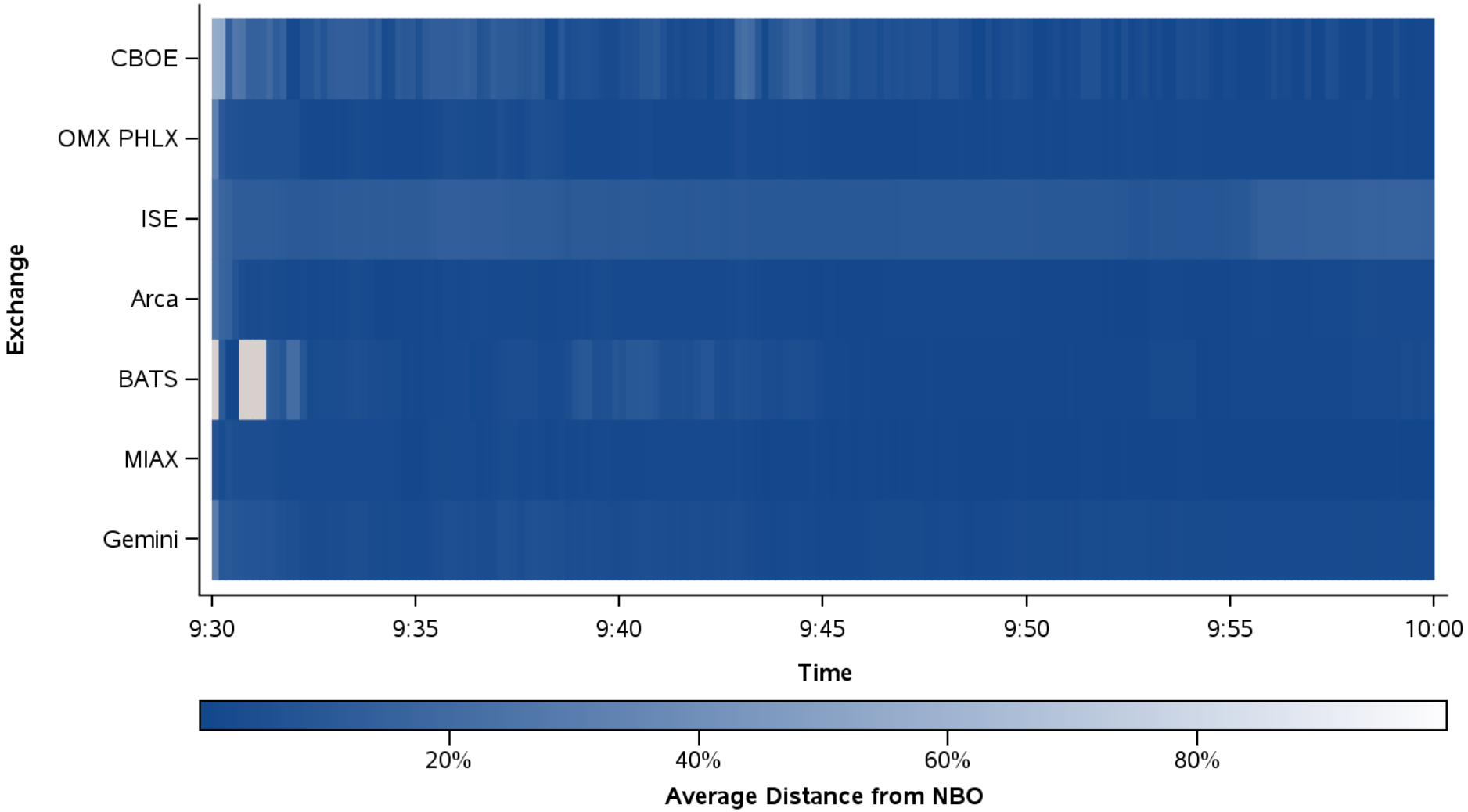
Source: TickData

Note: Average distance from the NBB is calculated over ten second intervals. Only firm bids are included. Intervals in which an exchange does not have a firm bid are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBB for 5 seconds and does not have a firm bid for the other 5 seconds, the average distance from the NBB is 1% for that interval.

Average Distance from NBO by Exchange

S&P 500: VOO Option

8/24/15



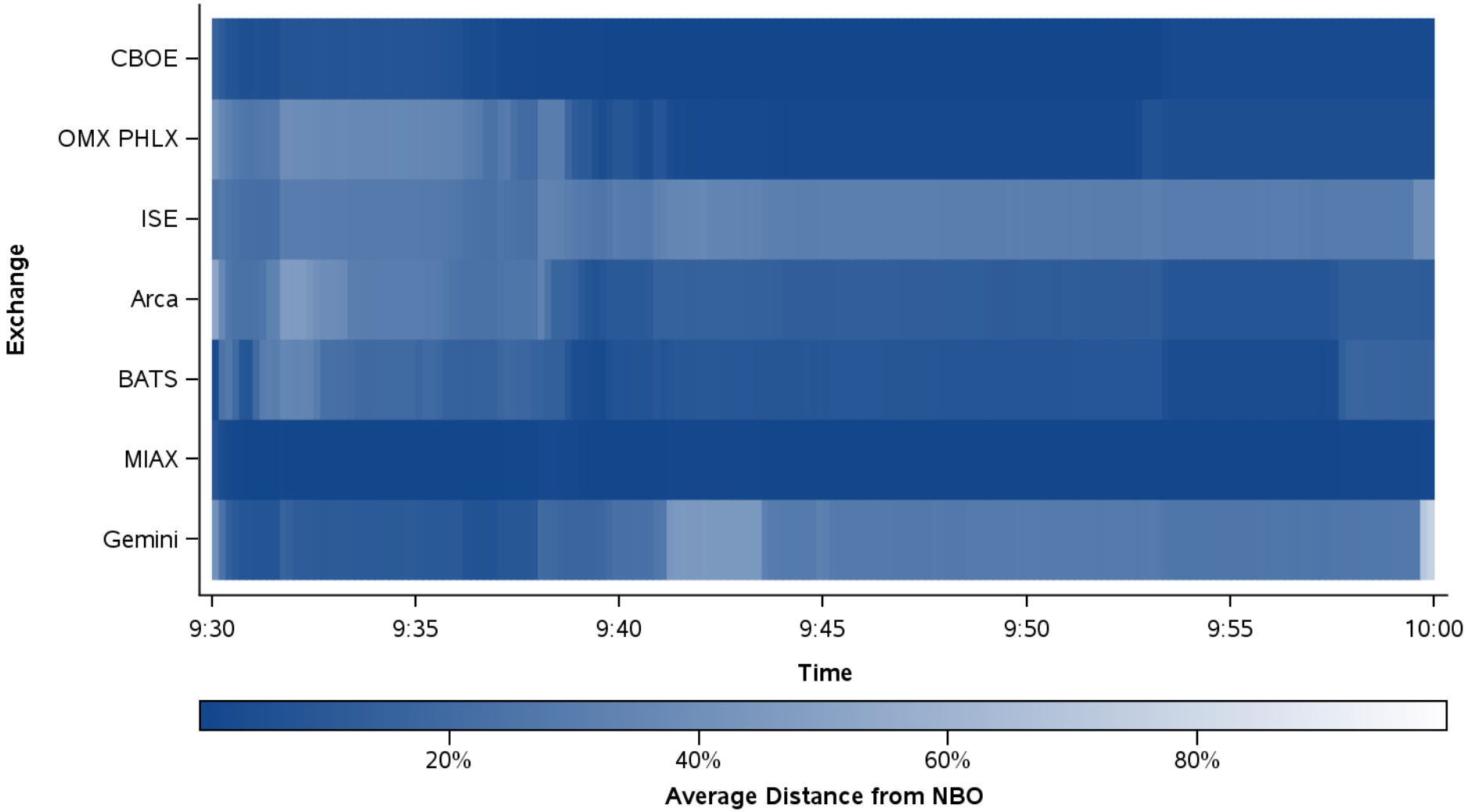
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval. Instances in which the average distance from the NBO is greater than 100% are displayed in white.

Average Distance from NBO by Exchange

S&P 500: VOO Option

8/25/15 - 8/31/15



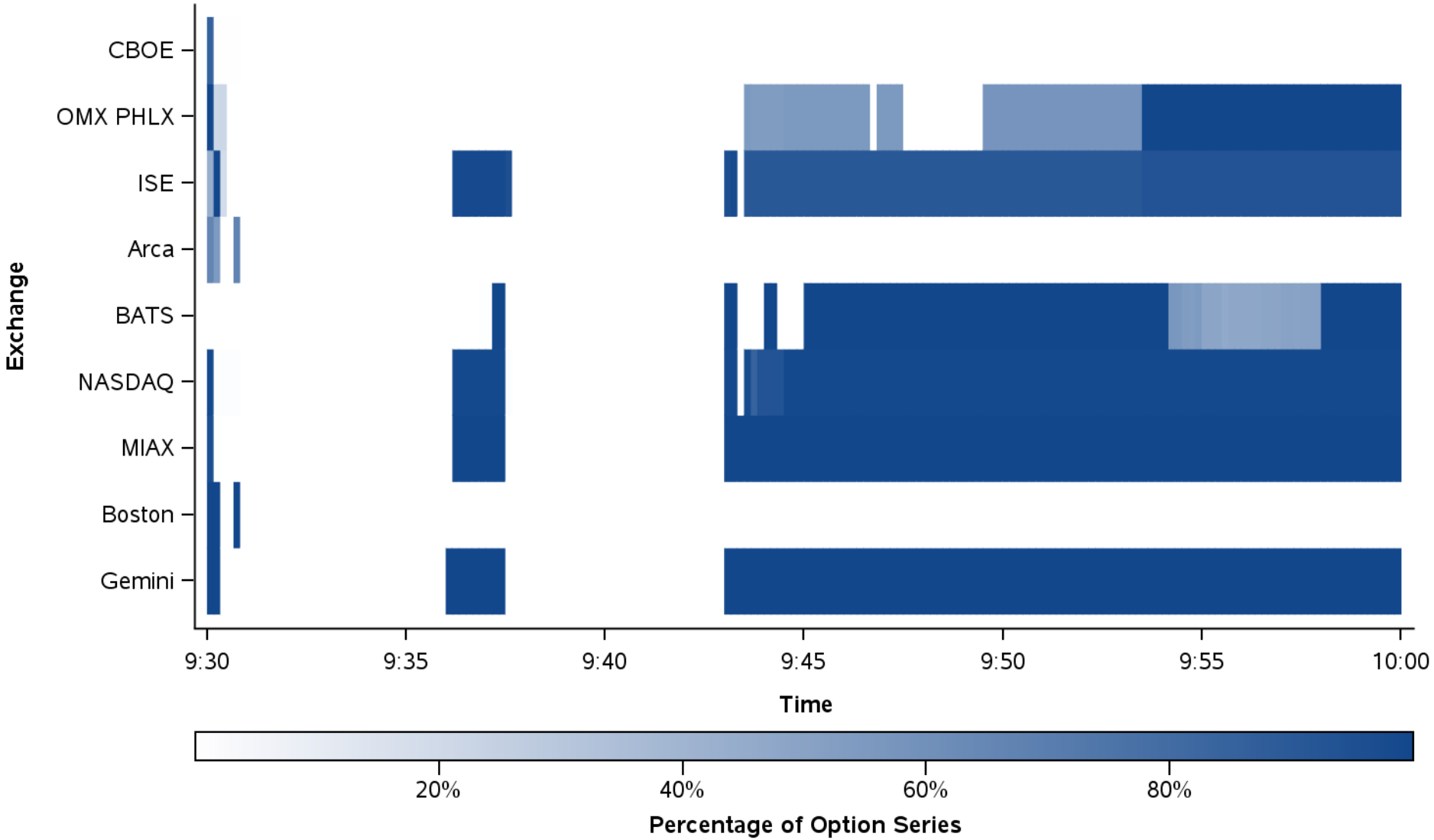
Source: TickData

Note: Average distance from the NBO is calculated over ten second intervals. Only firm offers are included. Intervals in which an exchange does not have a firm offer are excluded from the average distance calculation. Thus, if an exchange is 1% from the NBO for 5 seconds and does not have a firm offer for the other 5 seconds, the average distance from the NBO is 1% for that interval. Instances in which the average distance from the NBO is greater than 100% are displayed in white.

Percentage of Option Series with a Firm Offer by Exchange

S&P 500: IVV Option

8/24/15



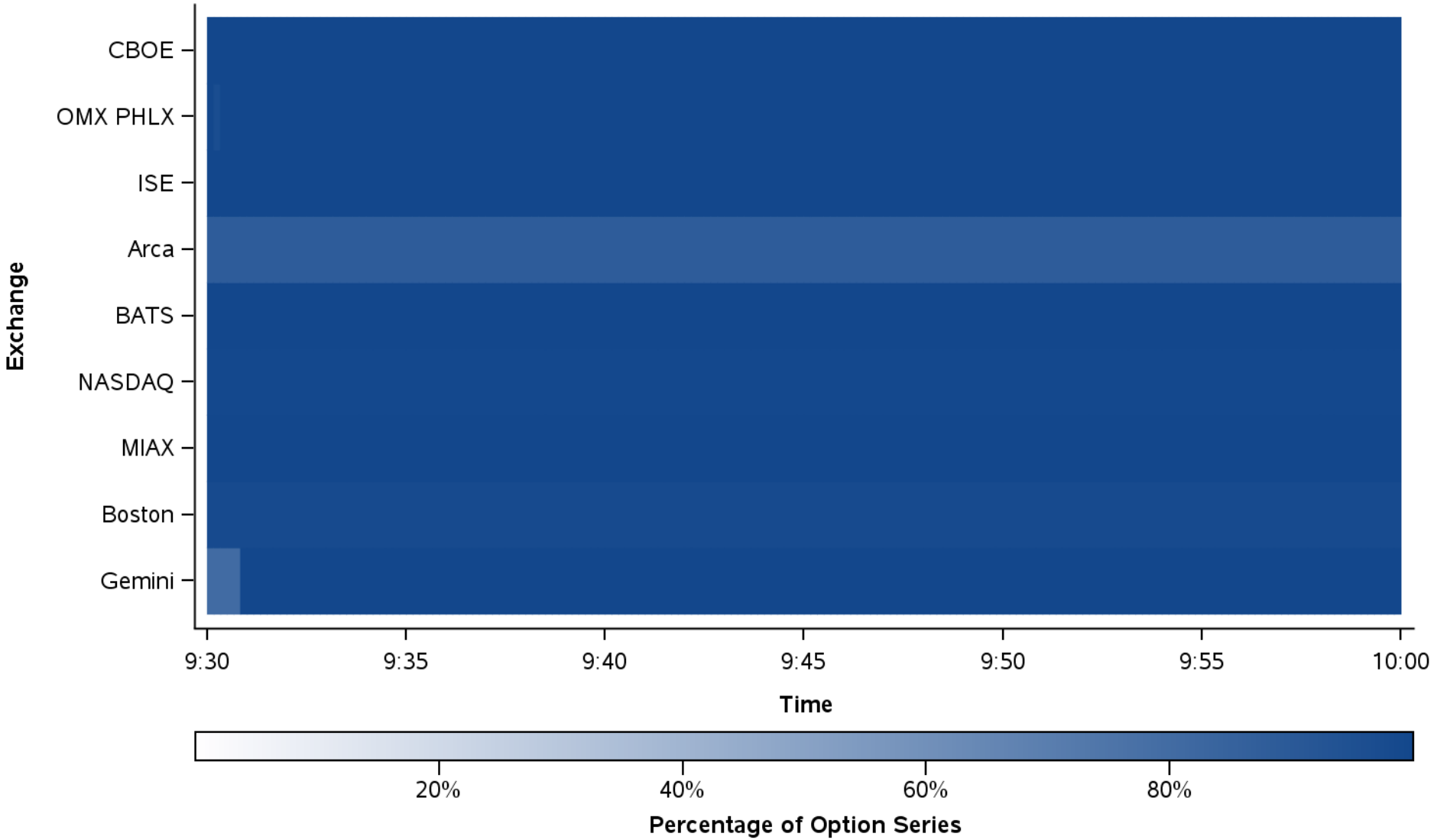
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a ask quote at any point during the ten second interval, the exchange is considered to have reported a ask quote for that ten second interval.

Percentage of Option Series with a Firm Offer by Exchange

S&P 500: IVV Option

8/25/15 - 8/31/15



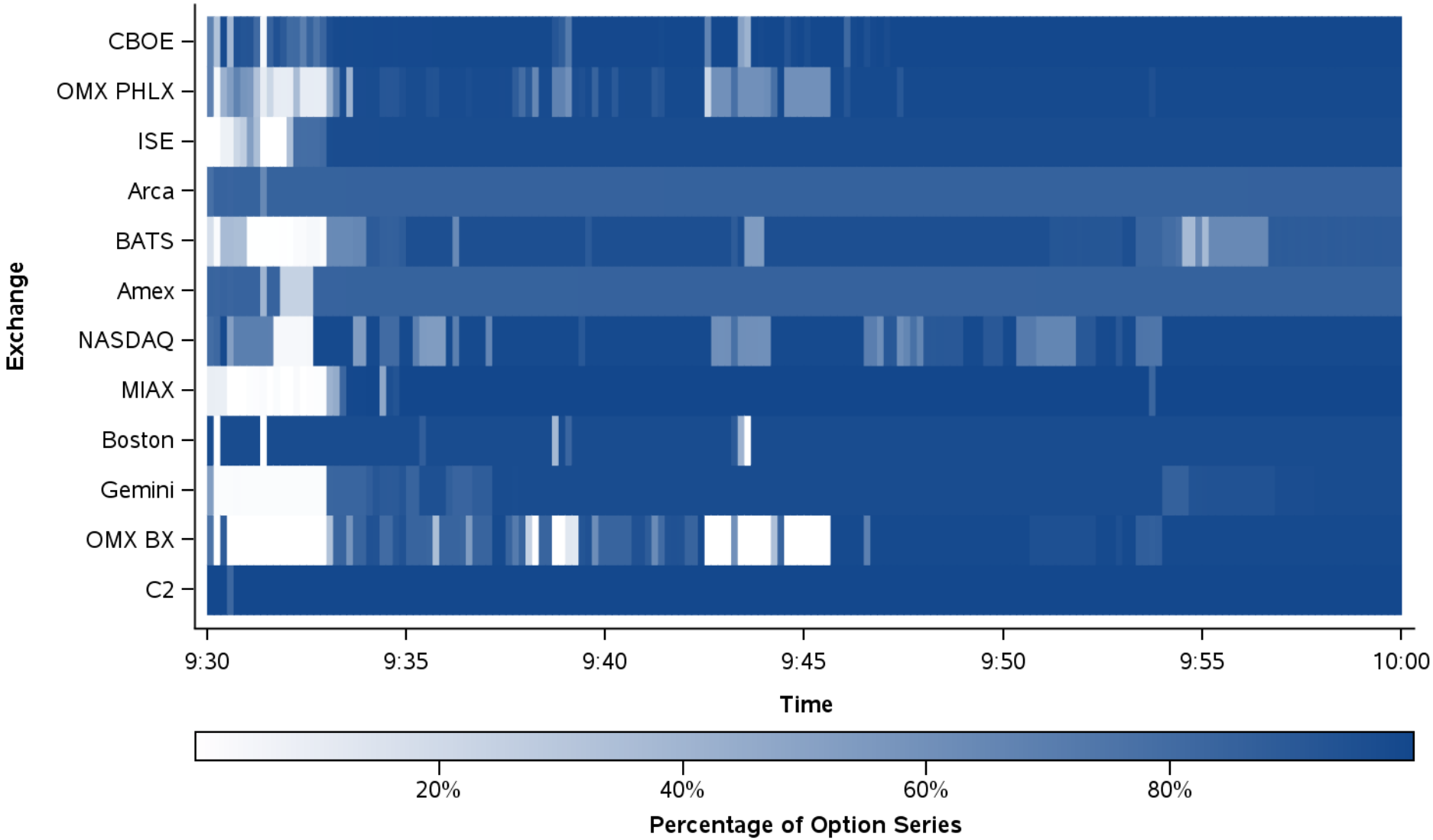
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a ask quote at any point during the ten second interval, the exchange is considered to have reported a ask quote for that ten second interval.

Percentage of Option Series with a Firm Offer by Exchange

S&P 500: SPY Option

8/24/15



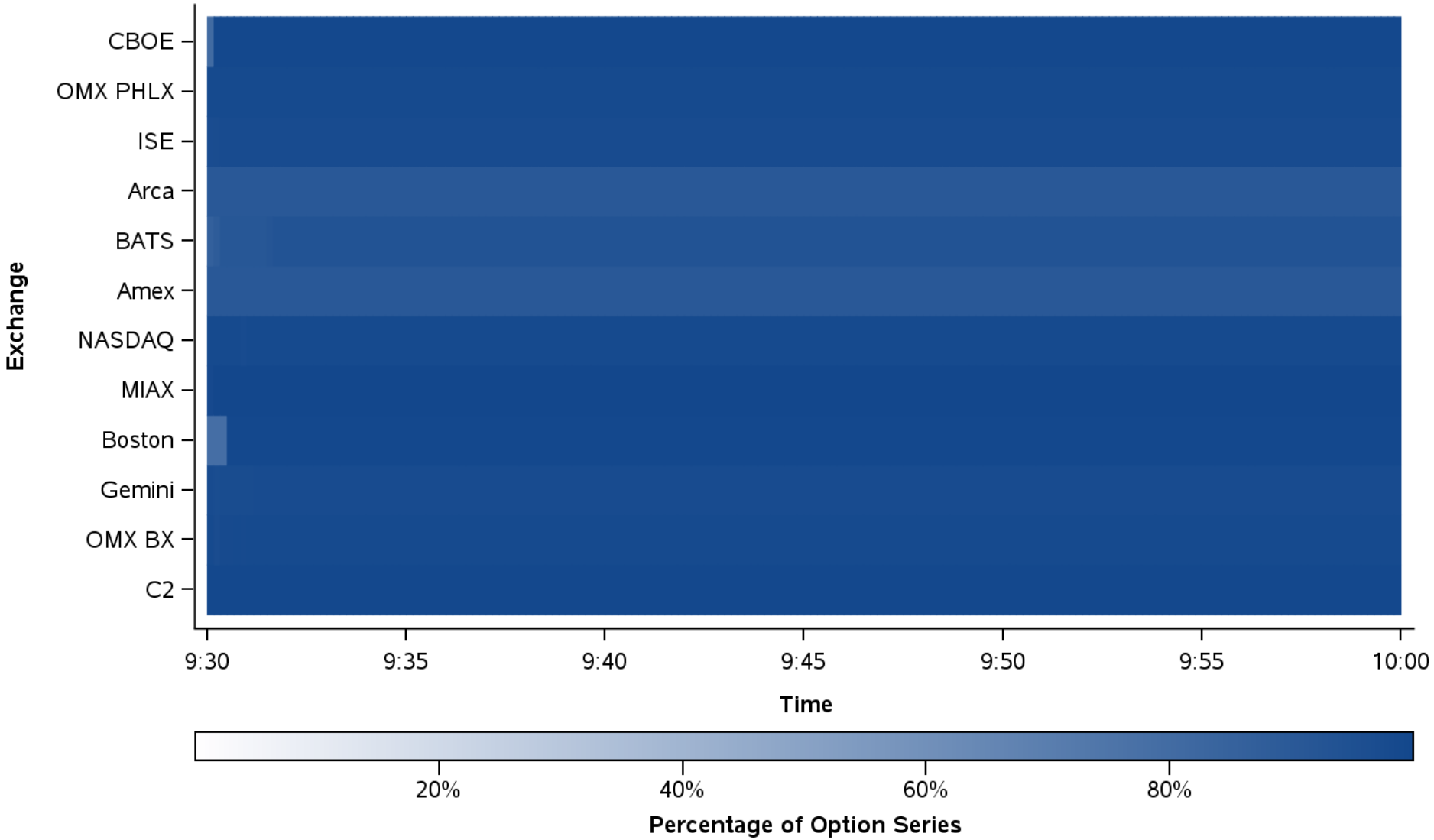
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a ask quote at any point during the ten second interval, the exchange is considered to have reported a ask quote for that ten second interval.

Percentage of Option Series with a Firm Offer by Exchange

S&P 500: SPY Option

8/25/15 - 8/31/15



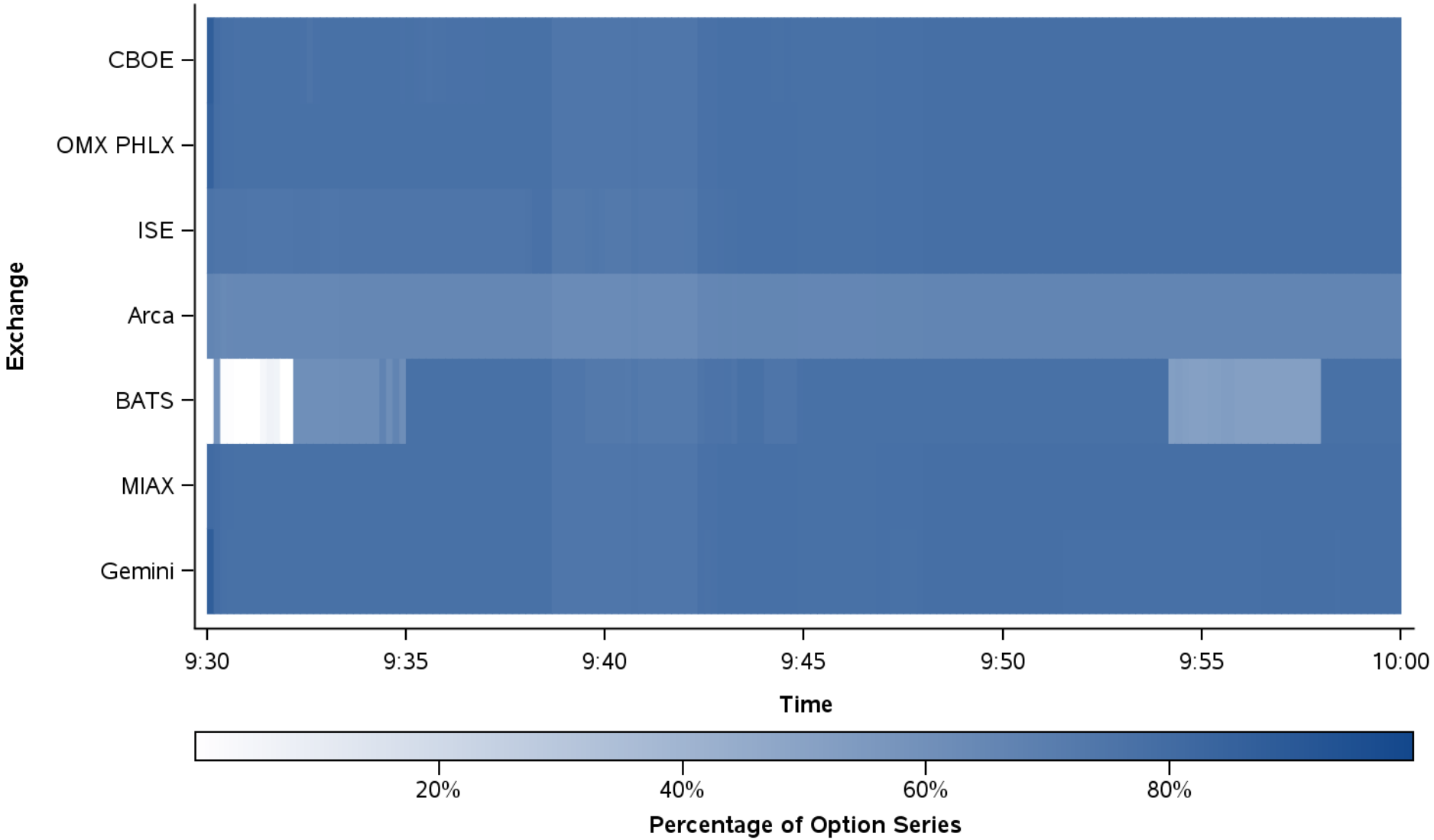
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a ask quote at any point during the ten second interval, the exchange is considered to have reported a ask quote for that ten second interval.

Percentage of Option Series with a Firm Bid by Exchange

S&P 500: VOO Option

8/24/15



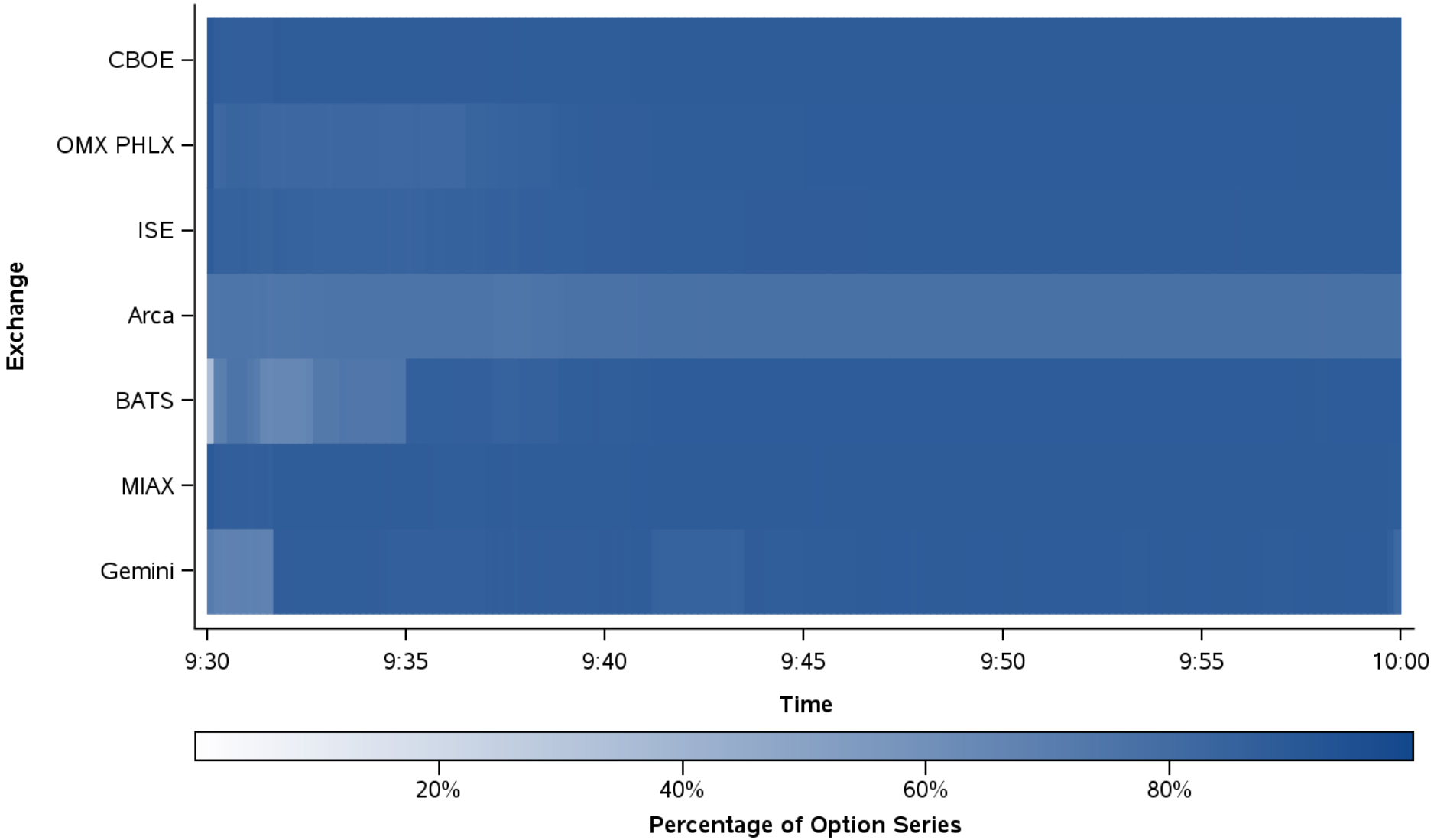
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a bid quote at any point during the ten second interval, the exchange is considered to have reported a bid quote for that ten second interval.

Percentage of Option Series with a Firm Bid by Exchange

S&P 500: VOO Option

8/25/15 - 8/31/15



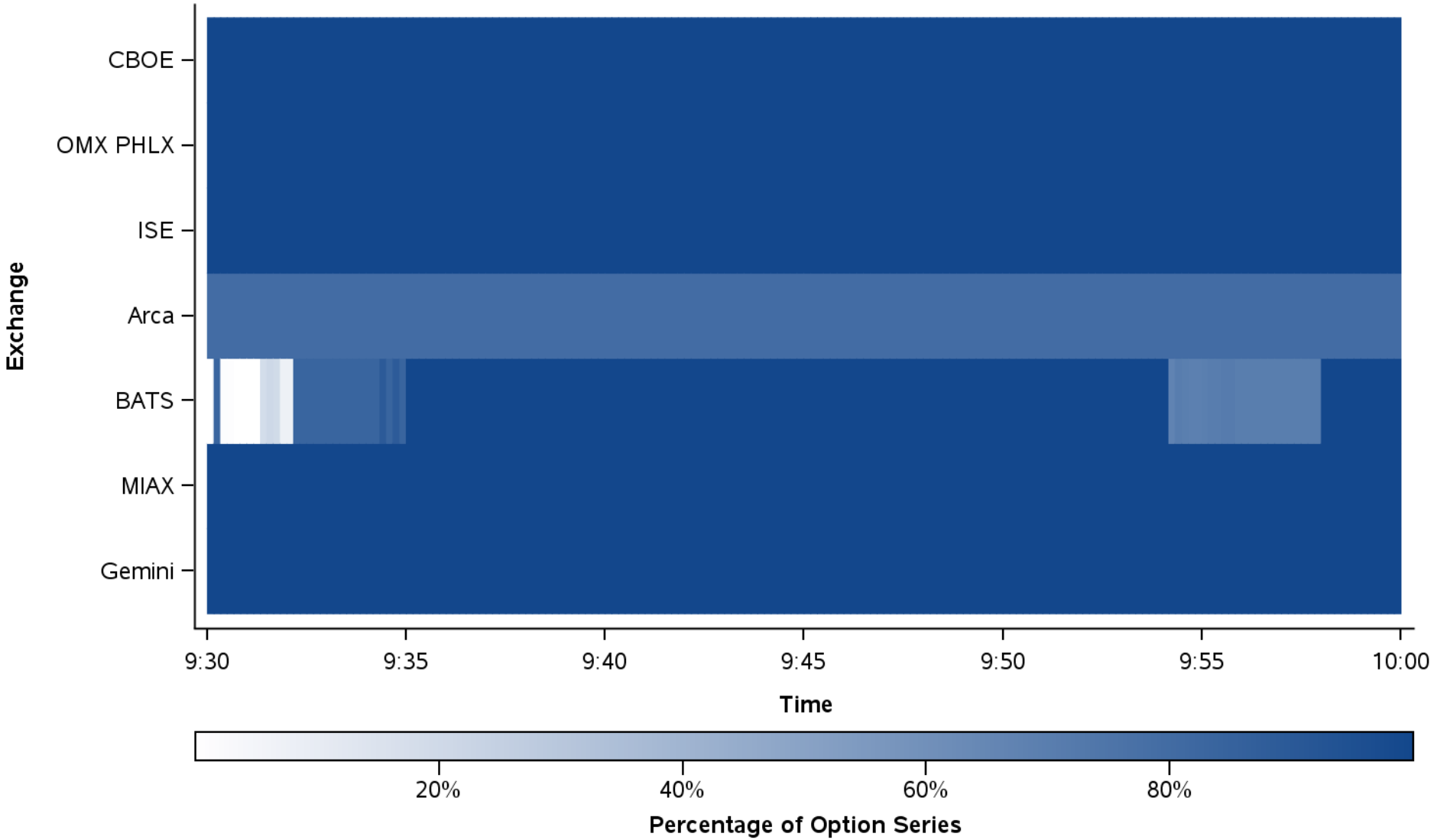
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a bid quote at any point during the ten second interval, the exchange is considered to have reported a bid quote for that ten second interval.

Percentage of Option Series with a Firm Offer by Exchange

S&P 500: VOO Option

8/24/15



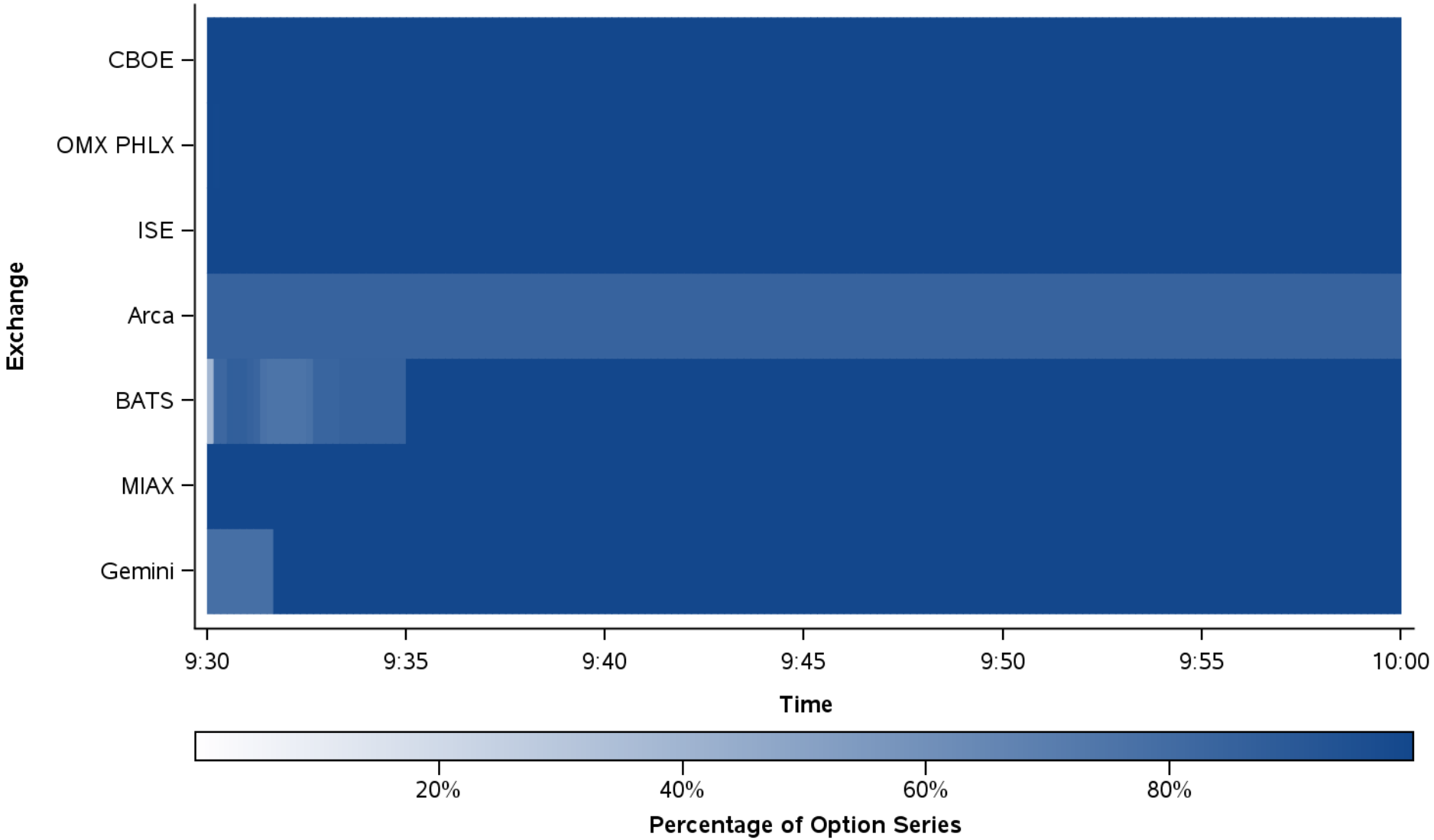
Source: TickData

Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a ask quote at any point during the ten second interval, the exchange is considered to have reported a ask quote for that ten second interval.

Percentage of Option Series with a Firm Offer by Exchange

S&P 500: VOO Option

8/25/15 - 8/31/15



Source: TickData

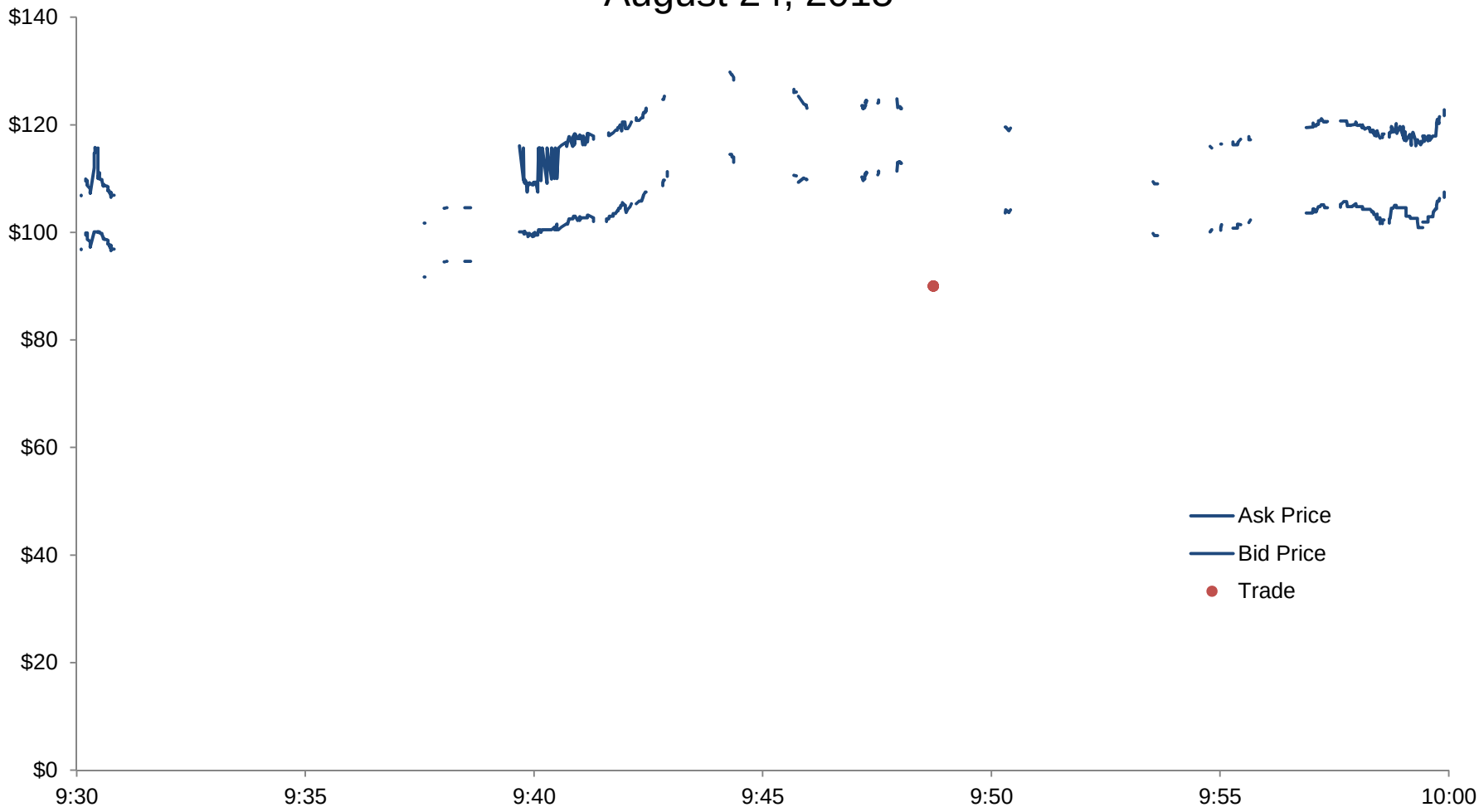
Note: The percentage of option series is calculated over ten second intervals. If an exchange reports a ask quote at any point during the ten second interval, the exchange is considered to have reported a ask quote for that ten second interval.

Appendix C
Sample Charts: SPX Quotes and Trades

SPX September 2015 Call Option Quotes and Trades

Strike Price: $1840

August 24, 2015



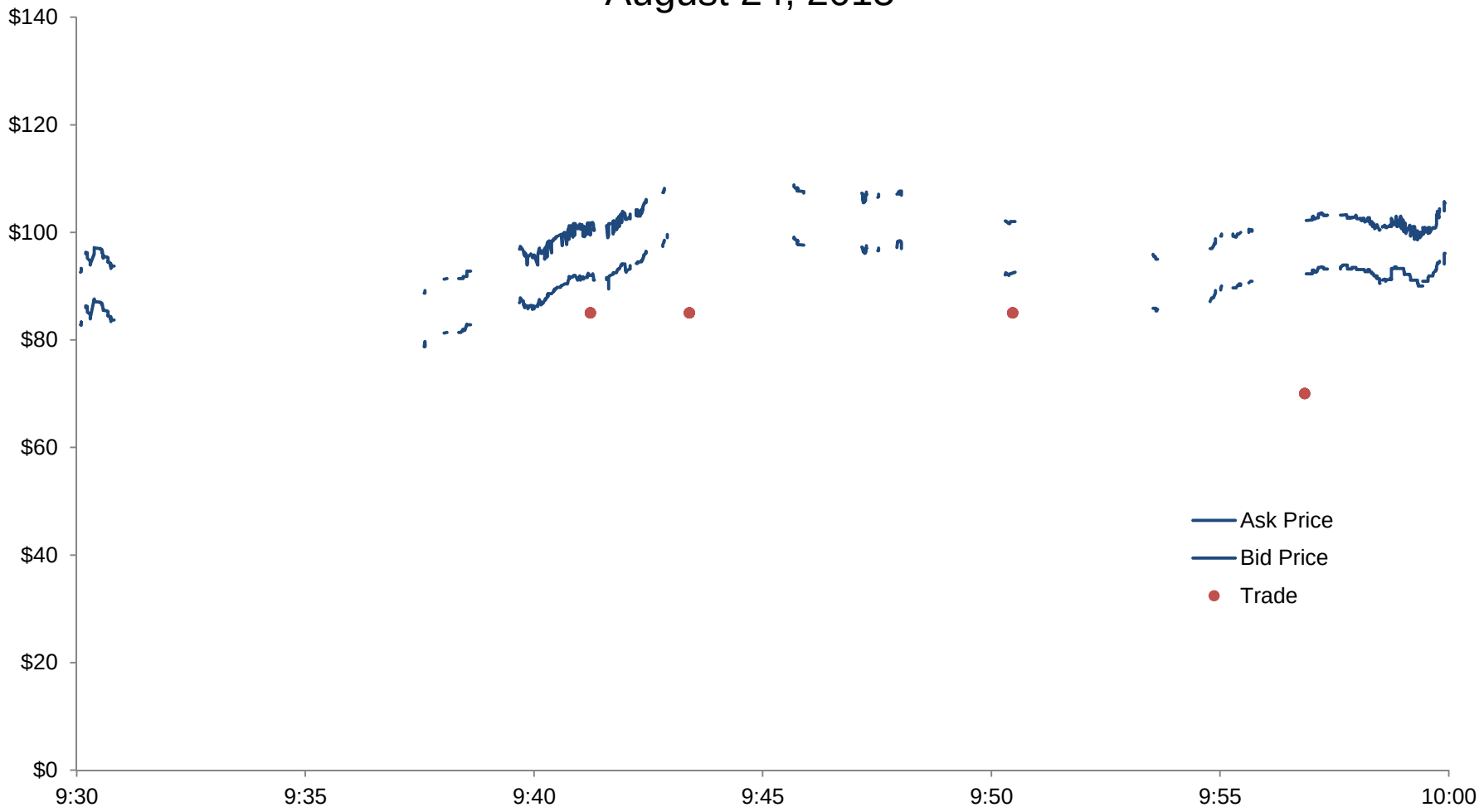
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Call Option Quotes and Trades

Strike Price: $1860

August 24, 2015



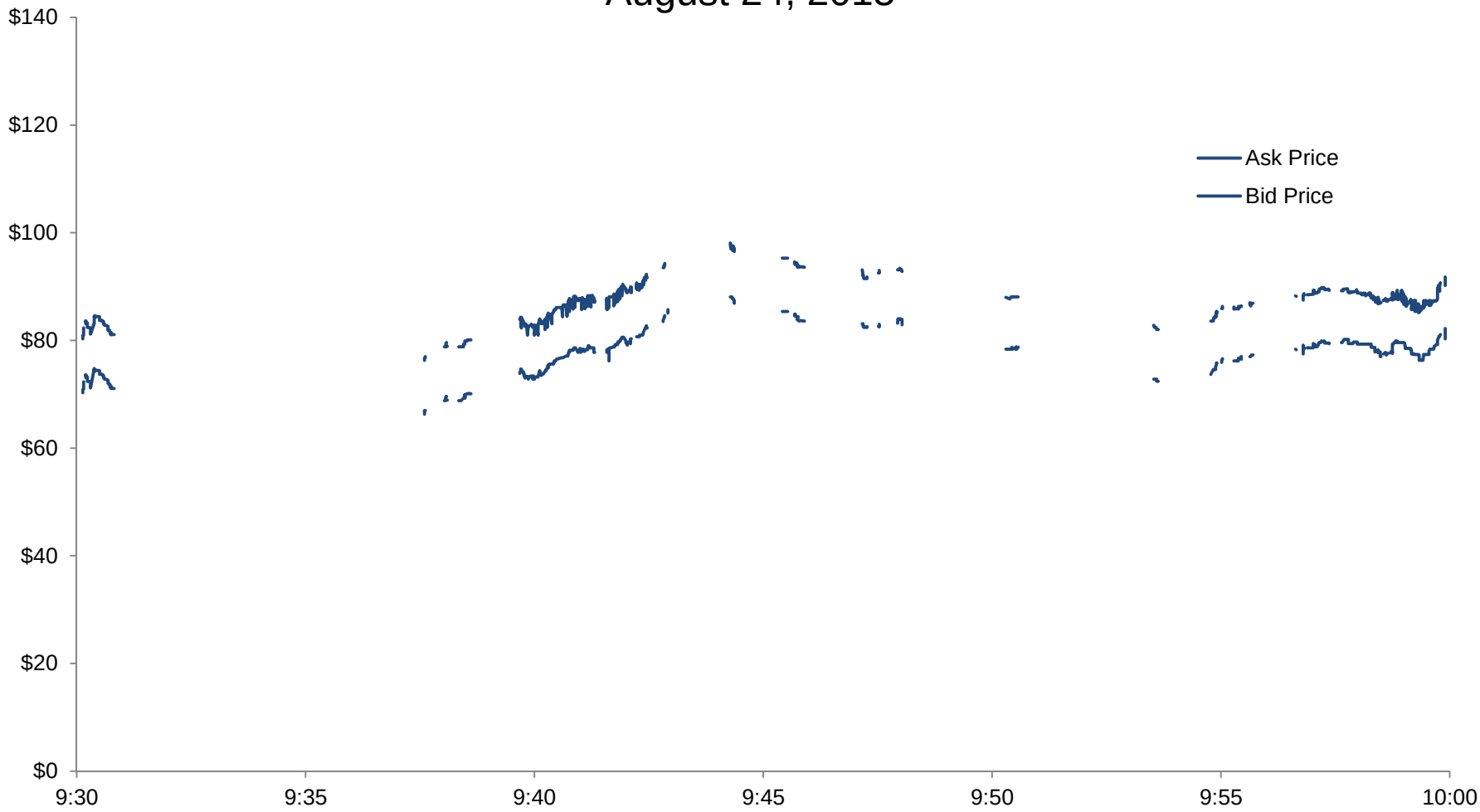
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Call Option Quotes and Trades

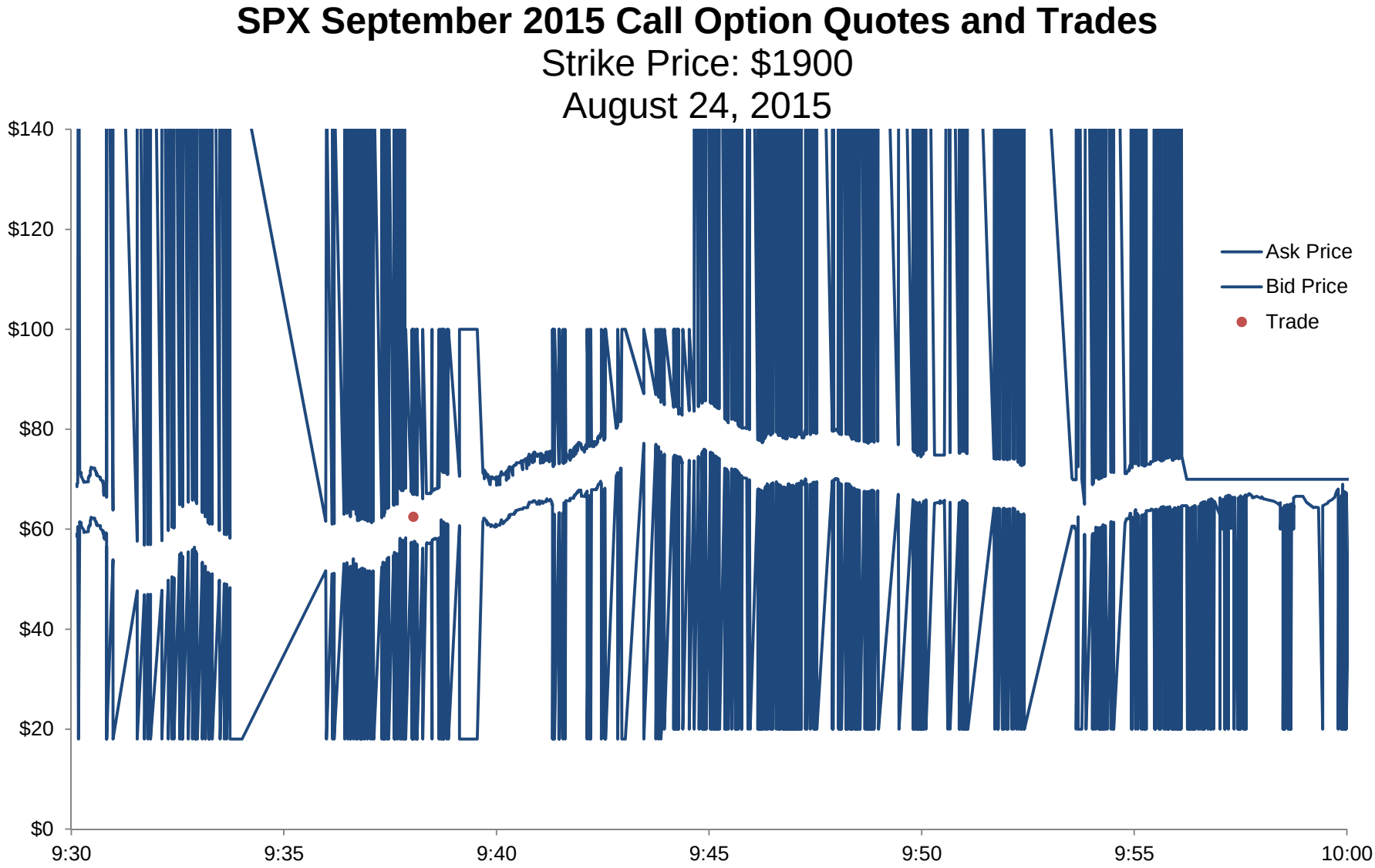
Strike Price: $1880

August 24, 2015



Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.



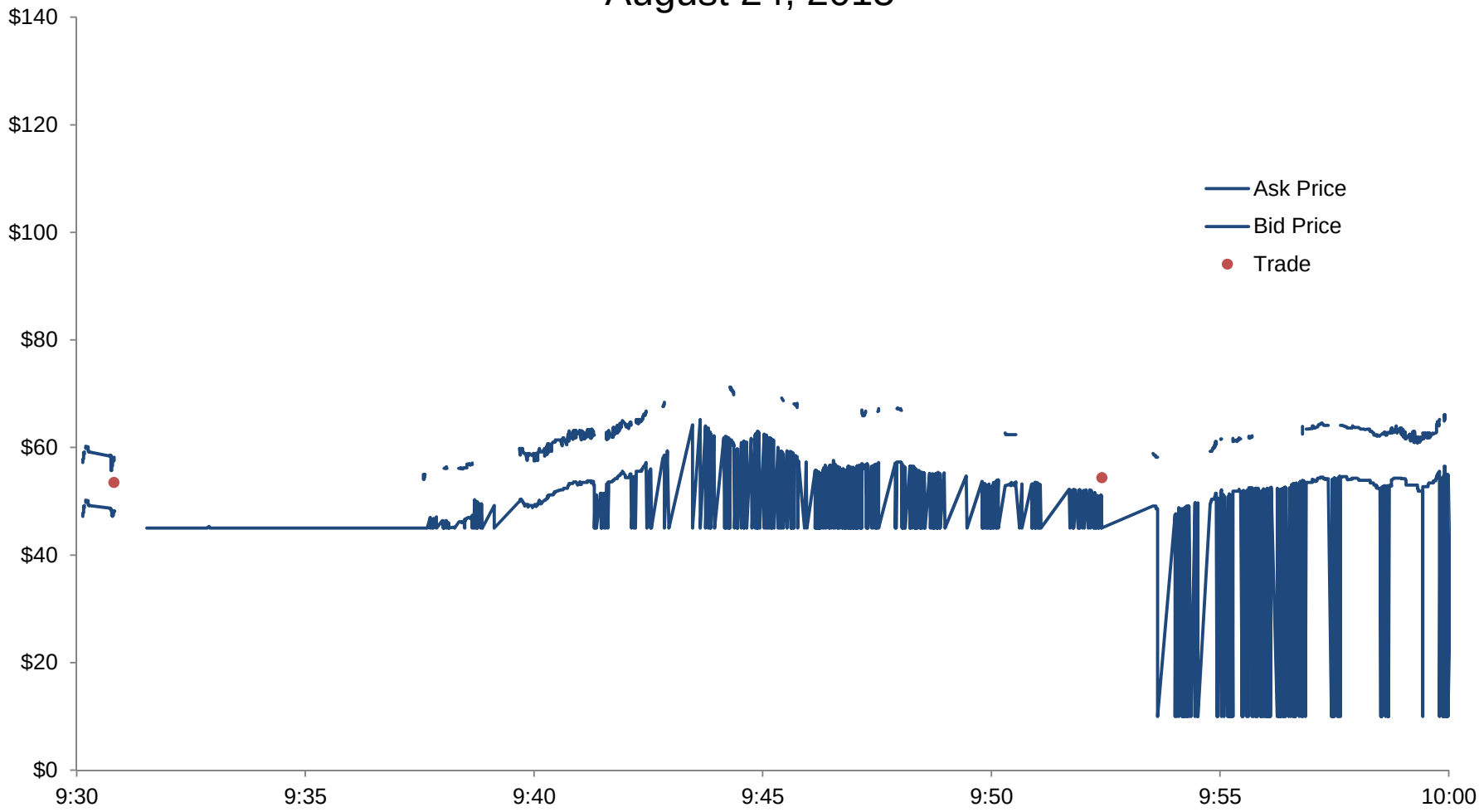
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Call Option Quotes and Trades

Strike Price: $1920

August 24, 2015



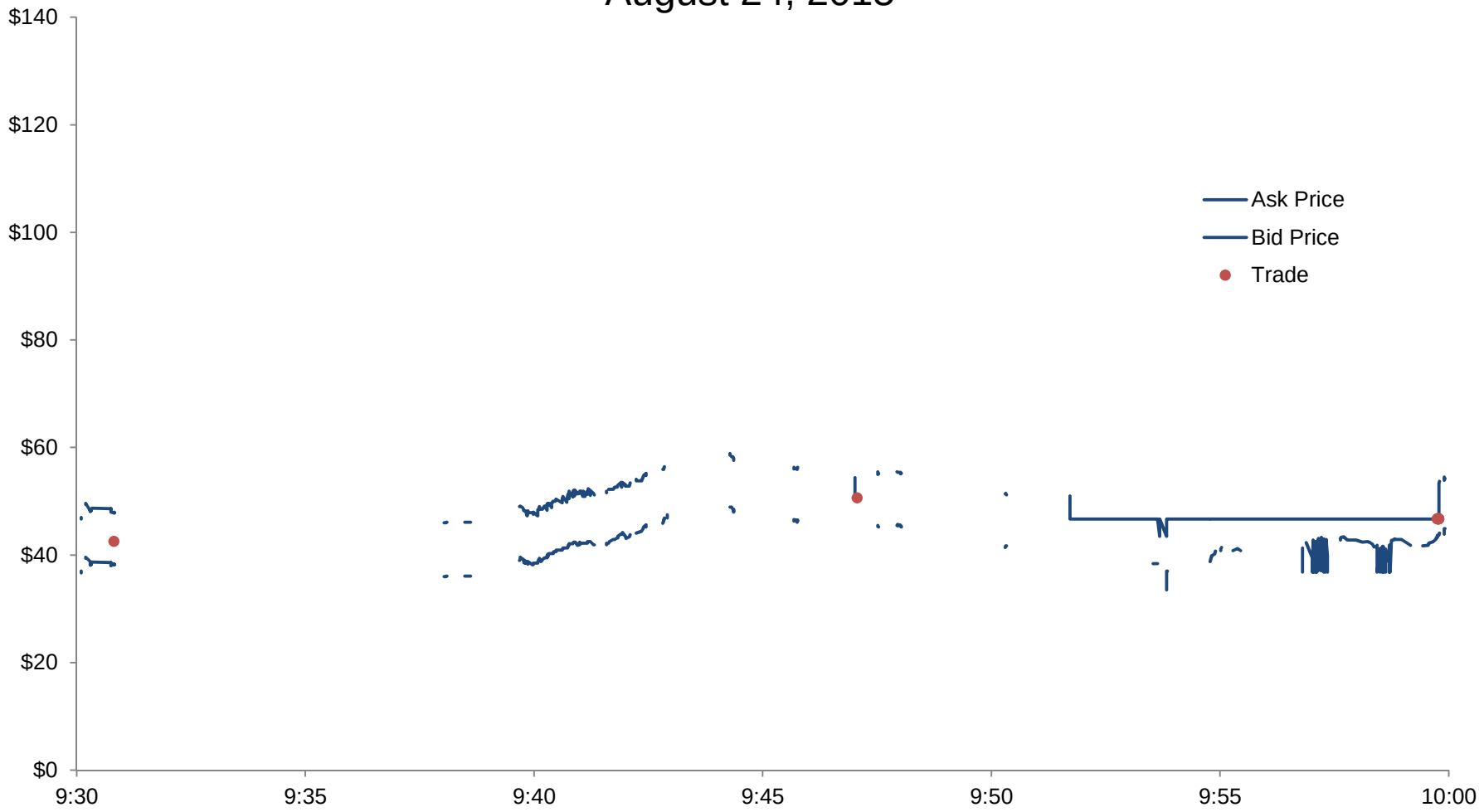
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Call Option Quotes and Trades

Strike Price: $1940

August 24, 2015



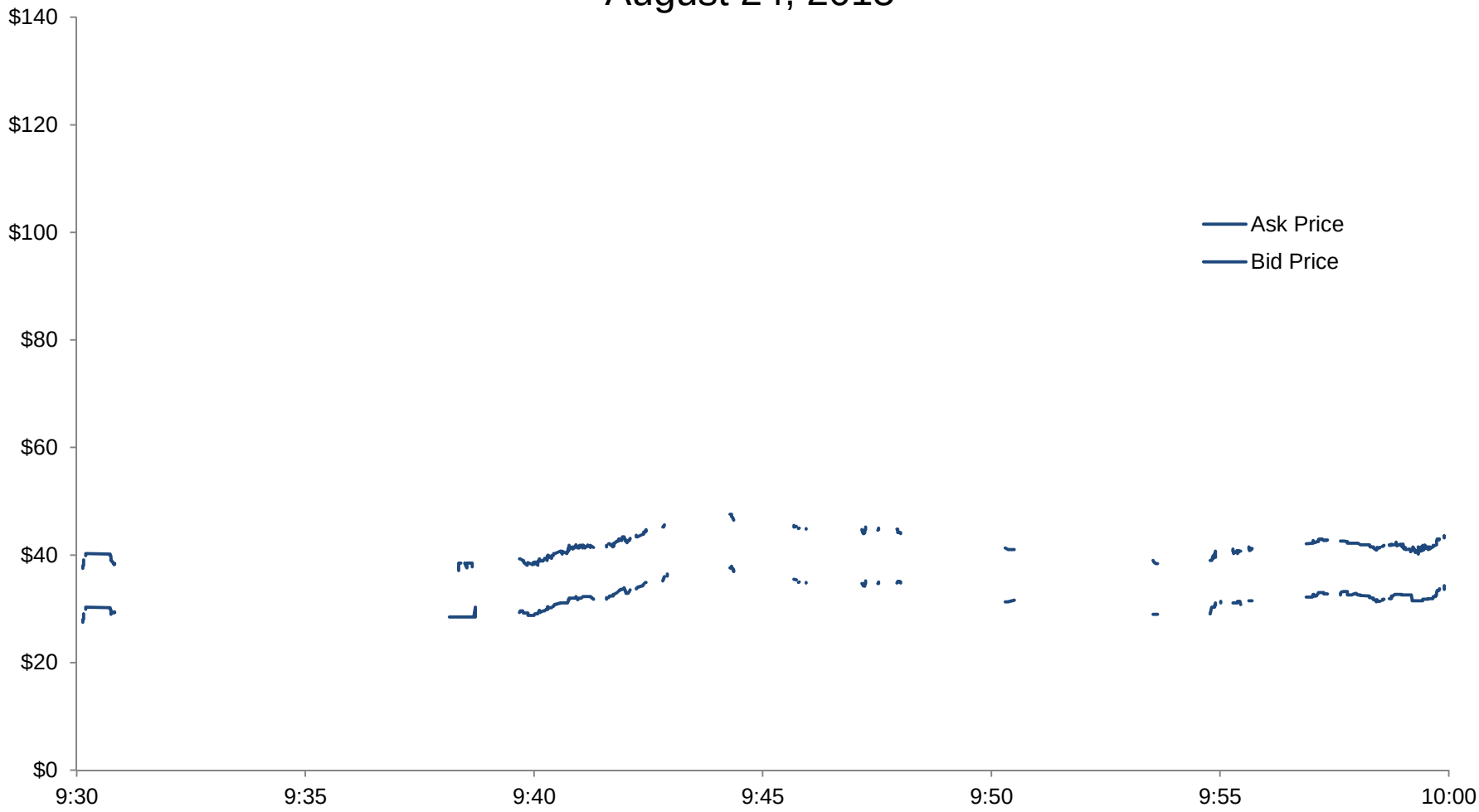
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Call Option Quotes and Trades

Strike Price: $1960

August 24, 2015



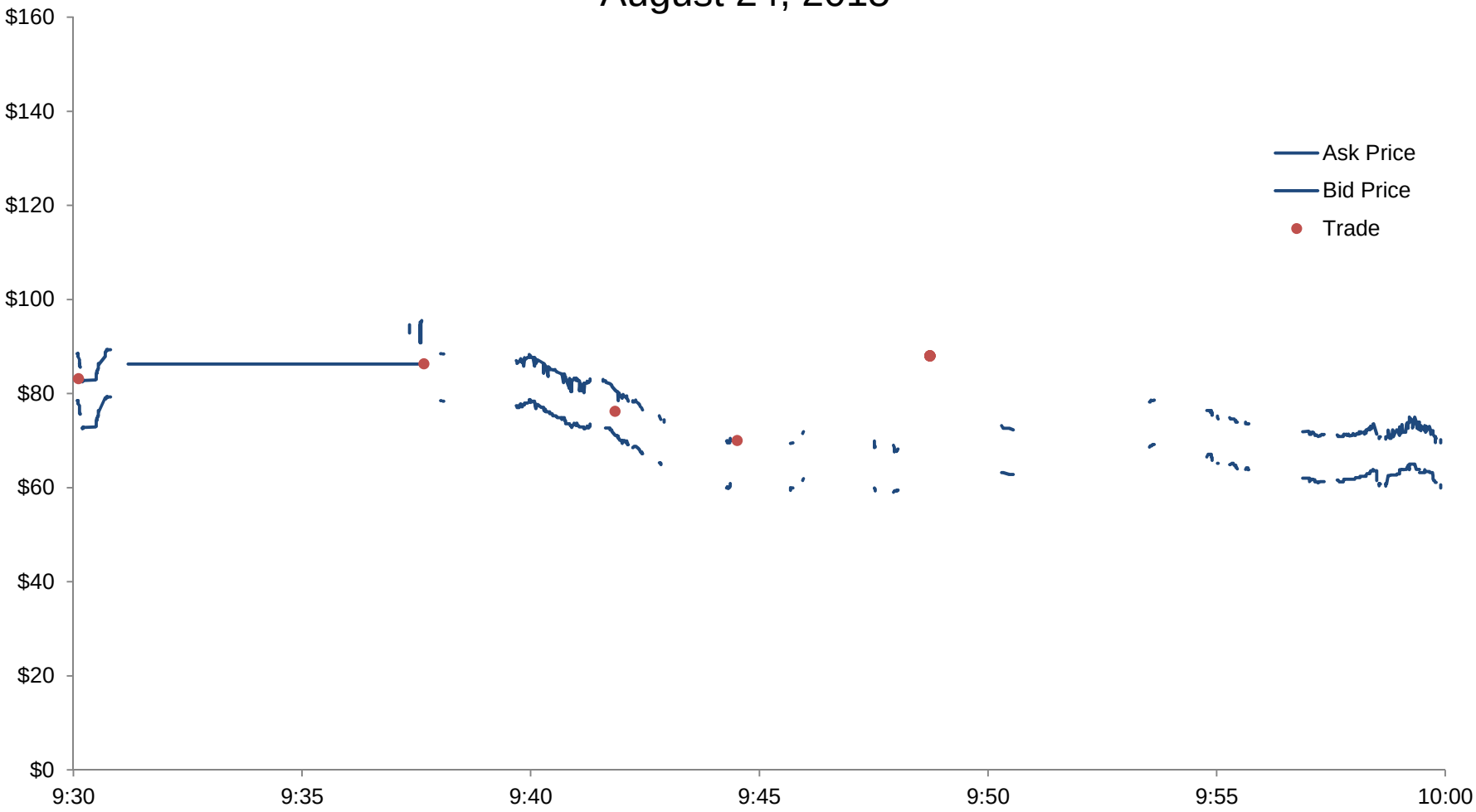
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1840

August 24, 2015



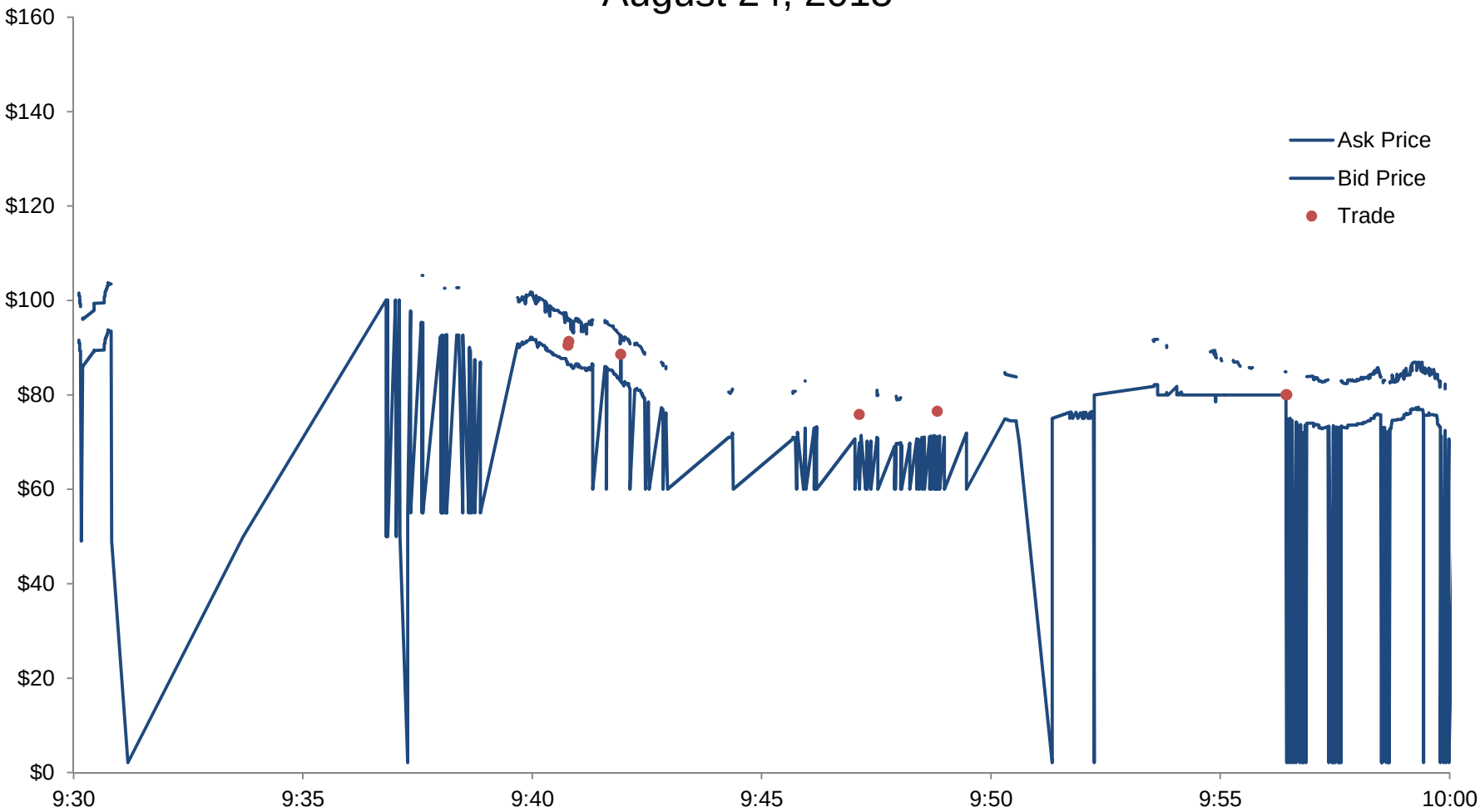
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1880

August 24, 2015



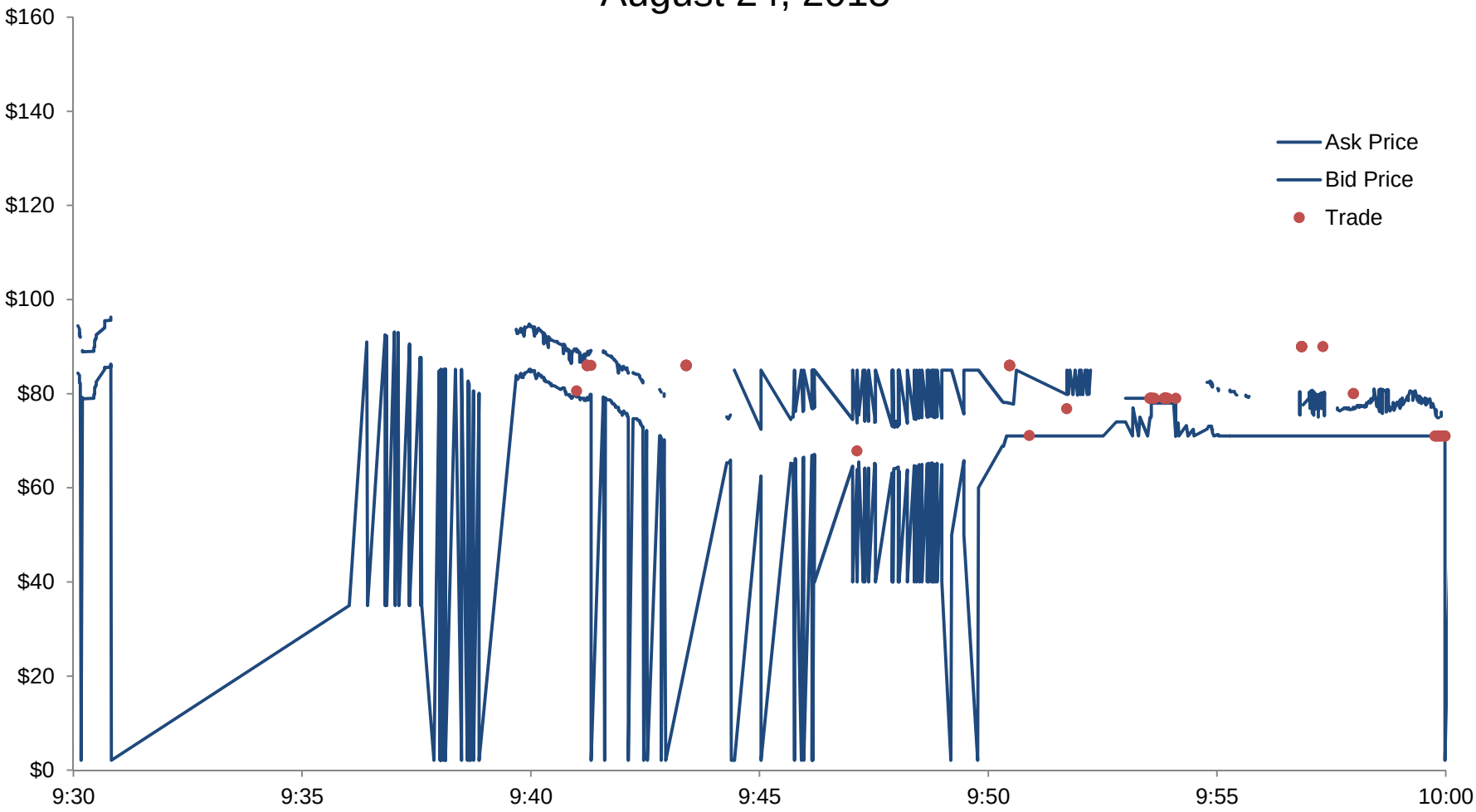
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1860

August 24, 2015



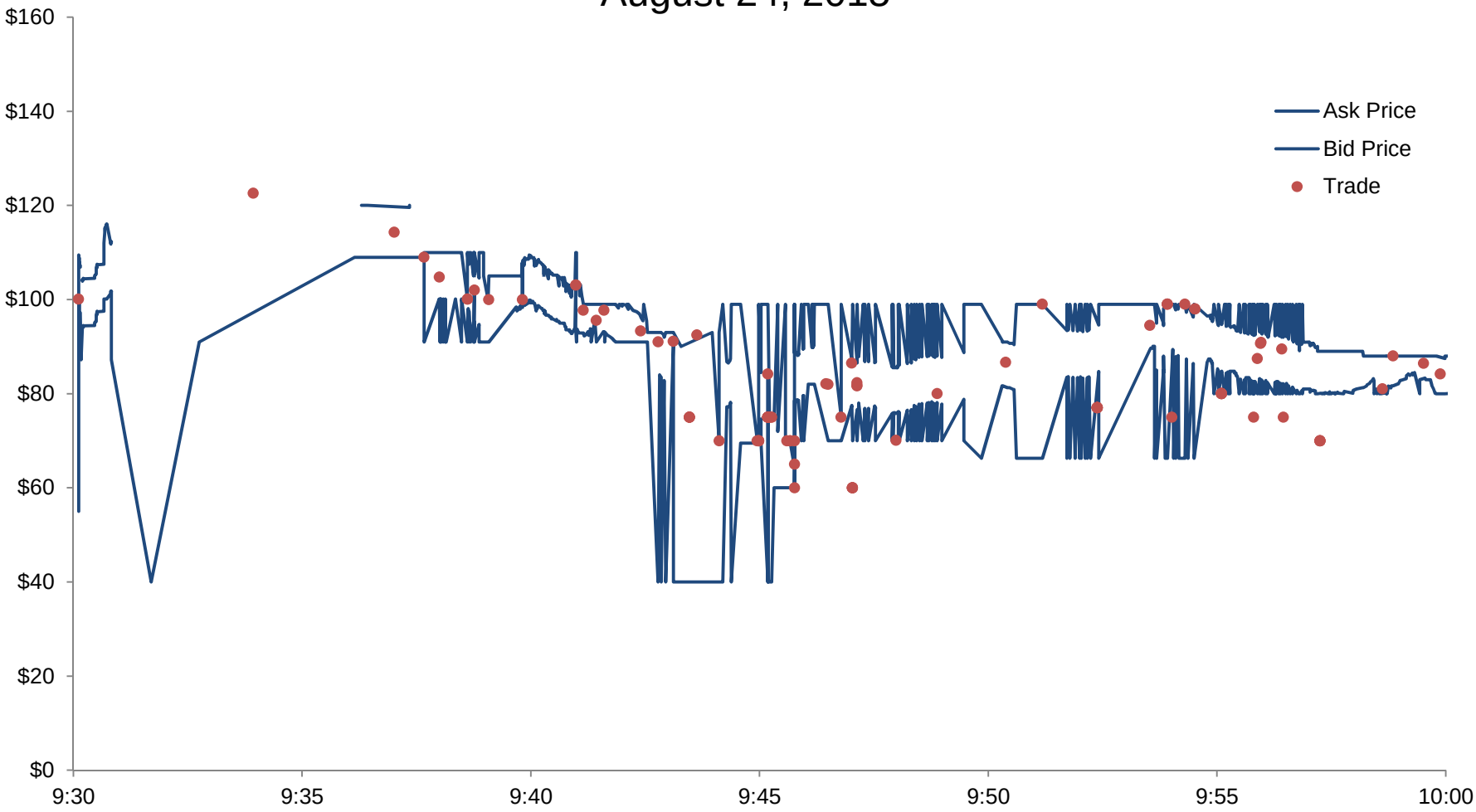
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1900

August 24, 2015



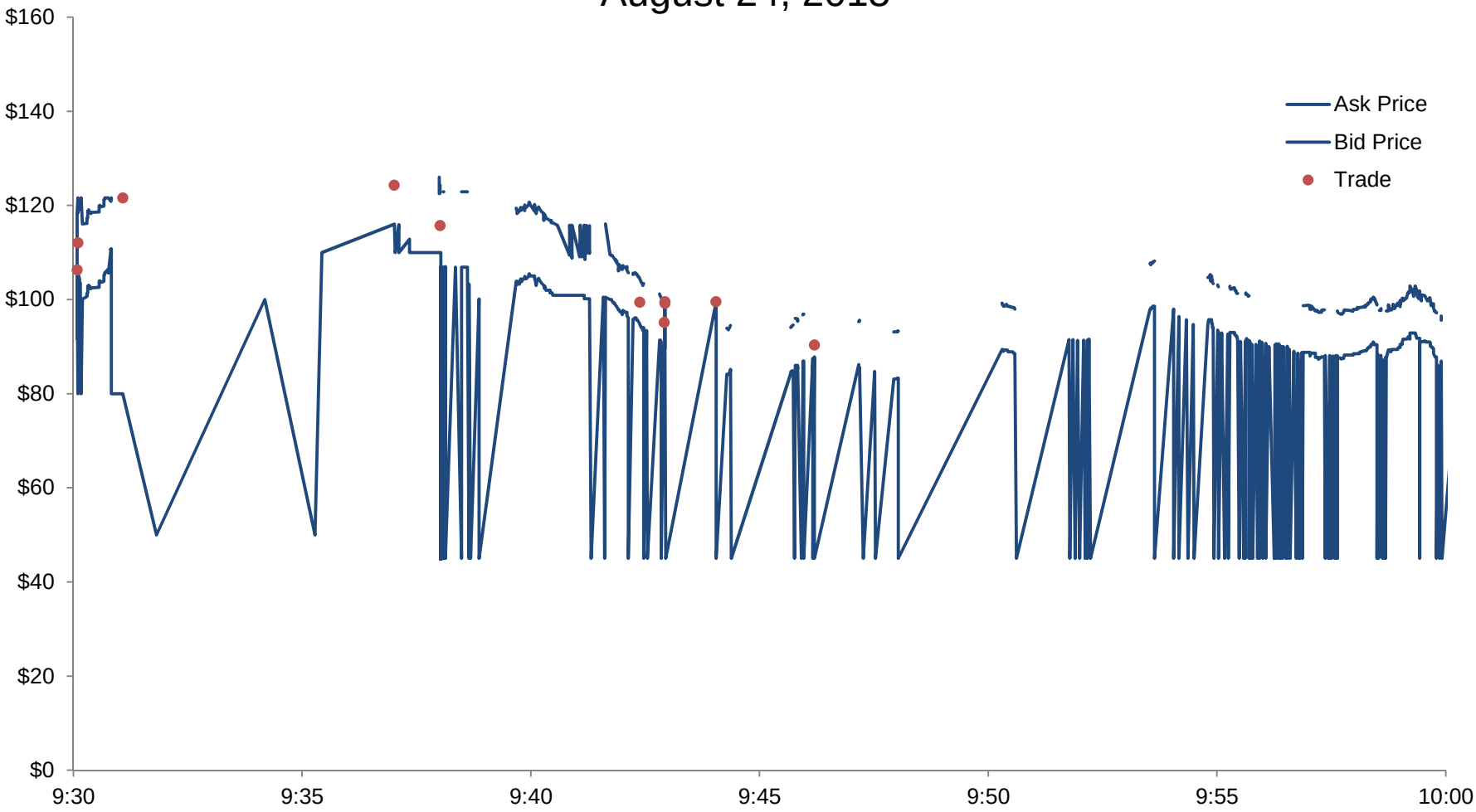
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1920

August 24, 2015



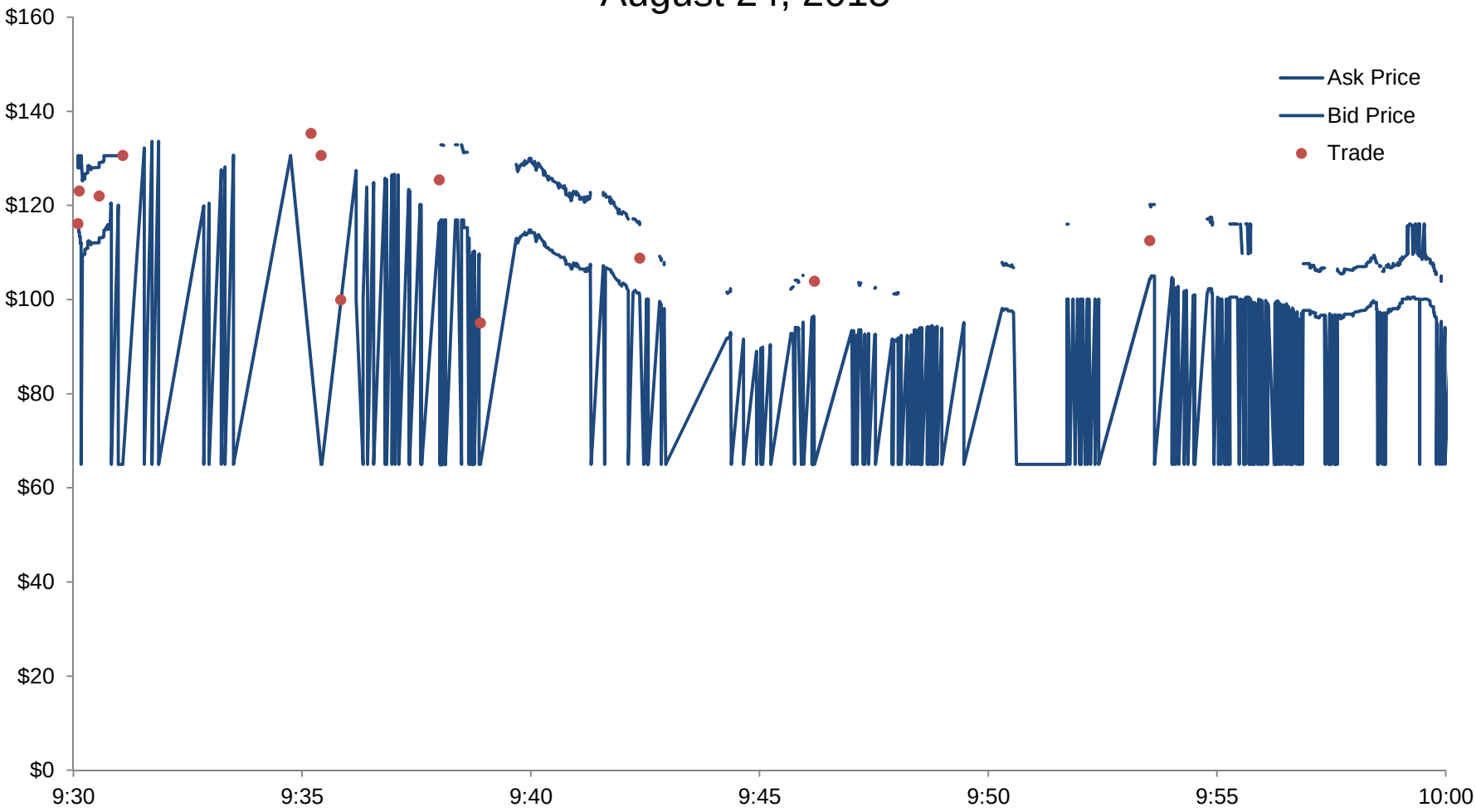
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1940

August 24, 2015



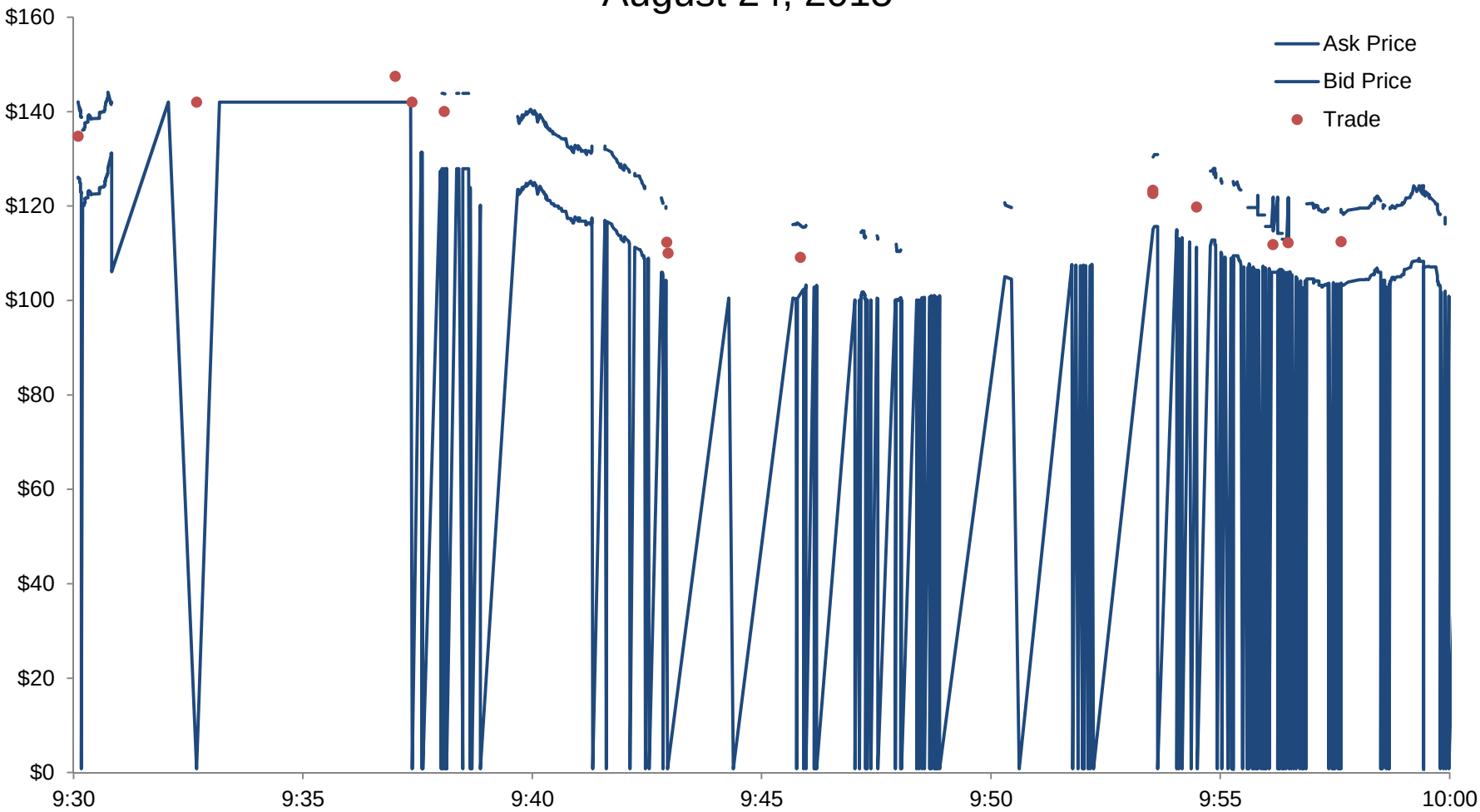
Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.

SPX September 2015 Put Option Quotes and Trades

Strike Price: $1960

August 24, 2015



Source: TickData.

Note: All trades and quotes are included. The strike prices of interest were selected based on the closing price of the S&P 500 Cash Index on 8/24/15, which was 1893.