MEMORANDUM

TO: FILE

FROM: DIVISION OF ECONOMIC AND RISK ANALYSIS[1]

SUBJECT: CORNERSTONE ANALYIS OF THE IMPACT OF THE OPTION PENNY PILOT PROGRAM ON MARKET QUALITY

DATE: DECEMBER 18, 2017

The Division of Economic and Risk Analysis contracted with Cornerstone Research ("Cornerstone"), an economic and financial consulting firm, to conduct analyses related to investigating the effects on market quality of the continuing pilot program that allows certain exchange-traded options to be quoted in reduced price increments[2] ("Option Penny Pilot" or "Pilot"). Cornerstone's analysis uses quoted and effective spreads as measures of market quality.[3] Effective and quoted spreads are frequently used as measures of trading costs and are especially useful in assessing overall market quality for retail investors.[4] The Division believes that the methodology employed by Cornerstone in the analysis is appropriate to address the questions presented and agrees with the conclusions drawn by Cornerstone based on that analysis.

Main Finding:

The Cornerstone analysis finds that inclusion in the Pilot is associated with a statistically significant decrease in effective and quoted spreads for the most liquid options - those with trading volume in the top five percent of the universe of all listed option classes.[5] However, for less liquid options, the results do not suggest that inclusion in the Pilot has a significant effect on

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[1] This is a memorandum 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] More specifically, the Pilot specifies that options trading at less than $3.00 have trading increments of one cent, while those trading at $3.00 or more have trading increments of five cents. Options not in the Pilot have corresponding minimum price increments of $0.05 for options trading below $3.00 and $0.10 for options above $3.00. The Pilot makes an exception for options on the QQQQ, IMW and SPY which trade at or above one cent increments, regardless of price level.

[3] In Cornerstone's analysis, spreads are volume-weighted across different trades in an option series, and then equally weighted across option series, in order to obtain spreads for the option-class day. Those spreads are then equally weighted across different days in the pre-event month and the post-event month, respectively, in order to obtain option-class month observations.

[4] "Decimal Pricing Has Contributed to Lower Trading Costs and a More Challenging Trading Environment," GAO report, May 2005, at 3 (available at http://www.gao.gov/new.items/d05535.pdf).

[5] Note that Cornerstone's analysis on option classes on common stock incorporates data on 3,833 option classes and 1,331,185 class-day observations.

market quality. Cornerstone reports that the option classes added to the Pilot were mostly chosen from the most liquid and heavily traded option classes.[6]

Comparison to Analyses of Self-Regulatory Organizations:
Several Self-Regulatory Organizations (SROs) conducted analyses of the effects of the Options Penny Pilot. The SROs made these analyses available on their websites.[7] The reports of the SROs focus on the activity on their own exchanges; none of the reports takes a holistic view of the Pilot on all exchanges. Also, their analyses typically did not use control samples. Finally, the most recent of the publicly available reports from an SRO dates from 2013, and thus the Cornerstone analysis covers more recent time periods.[8] However, the SRO analyses generally agree with the conclusions drawn from Cornerstone's analysis that the Pilot was associated with a narrowing of spreads.

Analysis:
Cornerstone's analysis uses quoted and effective spreads as a measure of market quality, and it employs two methodologies.

The first methodology uses a univariate "difference-in-differences" approach, in which the changes in quoted and effective spreads during the Pilot for options classes included in the Pilot are compared to contemporaneous changes in spreads for a control sample of option classes that were not included in the pilot. Options classes included in the control sample were matched on option class volume and underlying market capitalization. This sample was referred to as the "matched sample".

The second methodology uses multivariate regression models to explain variation in the quoted and effective spreads before and after option classes were added to the Pilot. These models include independent variables to control for other factors that can impact spreads, including option volume, underlying stock volume, and underlying stock volatility.

Using data on options on common stocks added to the Pilot between January 26, 2007 and January 5, 2016,[9] both methodologies have similar findings. The "difference-in-differences"

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[6] Although some of the original thirteen options were not among the most liquid, most heavily traded options, the order approving the commencement of the penny pilot program describes the selection of the initial option classes as follows; "The Commission believes that the thirteen options classes to be included in the penny pilot program represent a diverse group of options classes with varied trading characteristics. This diversity should facilitate analyses by the Commission, the options exchanges and others." See Securities Exchange Act Release No. 55156 (January 23, 2007), 72 FR 4759, 4760 (February 1, 2007) (SR-NYSEArca-2006-73) (Order approving a penny pilot program on NYSE Arca).

[7] These data and analyses are available online at https://www.nyse.com/markets/amex-options/reports , http://www.ise.com/options-penny-pilot , https://www.cboe.org/general-info/pdfframed?content=/hybrid/cboepennypilotreport03042008.pdf&section=SEC_HYBRID_HOME&title=CBOE%20Penny%20Pilot%20Report and http://boxoptions.com/regulatory/pilot-reports/

[8] http://www.ise.com/assets/files/investors/Topaz_Penny_Pilot_Report_15.pdf

[9] Results for 693 option classes on ETFs were generally similar to option classes on common equity.

tests find that, compared to the control sample, inclusion in the Pilot is associated with a decrease in effective spreads of 3.5 cents and a decrease in quoted spreads of 5.1 cents. Similarly, using the same matched sample, the regression model finds that the Pilot is associated with a decrease in effective spreads of 3.6 cents and a decrease in quoted spreads of 5.2 cents. These results are statistically significant.

Cornerstone reports results separately for sub-periods 2007-2009, 2010-2011, and 2012-2015. The results are generally weaker in both statistical significance and in economic magnitude for the period 2012-2015. One potential explanation advanced by Cornerstone for the smaller decrease in spreads for later additions to the Pilot is that the benefits of the Pilot are most pronounced for options on larger stocks or for option classes with the highest trading volume, and to the extent that the later additions to the Pilot tend to be smaller stocks with lower-volume options, there would be smaller declines in spreads for the later additions. Also, the 2012–2015 results are based on a relatively small sample of options.

One caveat to the results of the analysis that Cornerstone emphasizes is that the option exchanges have a different fee structure for classes within and outside the Pilot. Cornerstone's analysis does not try to examine whether the improvements in market quality could be attributed only to the Pilot, or also to the differing fee structures. However, Cornerstone also notes that the average declines in execution costs for the most liquid option classes appear to be substantially higher than the potential impact of any fee adjustments.

As option classes added to the Pilot were mostly the most liquid and heavily traded, Cornerstone also includes analysis specifically aimed at testing whether the Pilot contributed to improved market quality for less liquid option classes. The analysis uses more recent data, from February 2016, in order to allow the testing of the impact of the Pilot on option classes that may have been more liquid when they were originally added to the Pilot, but that over time became less liquid. Due to the low liquidity of these option classes, had the inclusion decision been made in February 2016, they may have not been selected for inclusion in the Pilot.

However, Cornerstone's analysis is neither consistent nor inconsistent with the proposition that additional low volume option classes would benefit from pilot inclusion.[10] Compared to samples of non-Pilot options matched on option class volume, underlying market capitalization, and underlying price, the results indicate evidence of statistically significant reductions in quoted and effective spreads for the top two quartiles, by trading volume, of option classes included in the Pilot. These option classes have trading volume in the top 5% of the universe of all listed option classes. While Cornerstone also finds reductions in spreads for the bottom two

[10] Also, there exist some option classes with liquidity equal to that of those in the Pilot, but they are not in the Pilot because they did not meet the Pilot requirements at the time a replacement class was being added to the Pilot. Some of these are included in the controls used for the Third and Fourth Quartile in Table 22 of Cornerstone's research, described as "Number of Clusters for Matching with Replacement".

quartiles of option classes included in the pilot, these reductions are generally not statistically significant.

Conclusion:
The evidence Cornerstone presents suggests that the existing Pilot program has resulted in improvements in market quality (as measured by quoted and effective spreads) for the Pilot option classes. Cornerstone's research does not provide any clear evidence that expanding the Pilot to include lower-volume options would result in similar benefits. While noting that the analysis does not control for different fee structures that apply to option classes included and excluded from the Pilot, Cornerstone asserts that the estimated reduction in execution costs for option classes within the pilot appear to be substantially larger than the potential impact of fee differentials.

MEMORANDUM

DATE: July 3, 2017

TO: Division of Economic and Risk Analysis

FROM: Stewart Mayhew, Cornerstone Research

RE: Analysis of the Impact of the Option Penny Pilot Program on Market Quality

Executive Summary

This memo summarizes research requested by the staff of the Commission's Division of Economic and Risk Analysis (DERA) under the terms of contract SECHQ1-16-C0024 with Cornerstone Research.[1] This research relates to an ongoing pilot program that, since 2007, has allowed certain exchange-traded options to be quoted in reduced price increments ("Option Penny Pilot" or "Pilot"). DERA staff requested an analysis of the impact of the Option Penny Pilot on market quality, as part of an effort to evaluate the efficacy of the program. The current memo summarizes our research investigating the extent to which inclusion in the Pilot impacts measures of market quality. The results of this research should aid the staff of the Commission as it seeks to evaluate the overall impact of the Pilot, and as it makes decisions regarding whether

[1] The analysis summarized in this memo was undertaken by a team of researchers under the direction of Dr. Stewart Mayhew at Cornerstone Research. The team also included Dr. Amber Anand of Syracuse University, Dr. D. Timothy McCormick, and the staff of Cornerstone Research. The findings presented herein are results of analysis performed by the research team in response to specific requests and questions from DERA staff. This memo does not seek to offer any policy recommendations, and should not be construed as an endorsement by the authors or by Cornerstone Research of any particular policy alternative. Any views and interpretations expressed in this memo are solely those of Dr. Mayhew, Dr. Anand, and Dr. McCormick, who are responsible for the content, and do not necessarily represent the views of Cornerstone Research.

the program should be made permanent and/or whether the program covers the appropriate number of option classes.

The research summarized herein encompasses the addition of option classes to the Pilot over an eight-year period between January 26, 2007 and January 5, 2016. It analyzes the impact of addition to the Pilot on quoted and effective spreads, while attempting to control for other factors that influence spreads and for any selection bias that may influence the addition of certain option classes to the program.

Section I of this memo provides a brief overview of the background of the Pilot, including the timing of when new option classes were added. Section II describes the data used for the analysis.

Section III reports summary statistics for option class volume, underlying stock volume, and underlying market capitalization for option classes already in the Pilot, new classes selected for inclusion in the Pilot, and option classes not in the Pilot, as of each addition date ("event date"). The option classes in the Pilot and those selected for inclusion tend to have significantly higher trading volume and tend to be on underlying stocks with higher market capitalization compared to classes not participating in the Pilot.

Section IV provides additional detail regarding the construction of control samples and reports summary statistics for the control samples.

Section V presents results of univariate "difference-in-differences" tests, which compare changes in quoted and effective spreads after option classes are added to the Pilot to contemporaneous changes in spreads for a control sample of non-switching option classes (matched on option class volume and underlying market capitalization). The difference-in-differences results (presented in Table 5) indicate that inclusion in the Pilot is associated with a

decrease in dollar effective spreads of 3.5 cents and a decrease in dollar quoted spreads of 5.1 cents. These decreases were found to be statistically significant at the 1% confidence level, and similar results were found for relative spreads. Results are also reported separately for subperiods 2007–2009, 2010–2011, and 2012–2015. The average decline in spreads was smaller for the most recent additions to the Pilot in 2012–2015, although this group has relatively few observations. The decline in spreads is found to be robust for option classes with different levels of underlying market capitalization (Table 6) and option class trading volume (Table 7).

Section VI analyzes additions to the Pilot using a multivariate regression approach designed to control for other factors that can impact spreads, including option volume, underlying stock volume, and stock volatility. This analysis confirms that inclusion in the Pilot is associated with a statistically significant decline in effective spreads and quoted spreads, although the estimated magnitude of the effect varies somewhat, depending on how the model is implemented. When the regression model is estimated on the entire universe of listed options, the results indicate that inclusion in the Pilot is associated with a decrease in effective spreads of 8.8 cents (Table 13) and a decrease in quoted spreads of 16.1 cents (Table 14). When the model is estimated only on the matched sample described in Section IV, the Pilot is associated with a decrease in dollar effective spreads of 3.6 cents (Table 15) and a decrease in dollar quoted spreads of 5.2 cents (Table 16). Similar results are found for percentage spreads. The decline in effective spreads is found to be largest in the 2010–2011 subperiod, and smallest for the most recent additions in 2012–2015. In some specifications, the effect of the Pilot program is found to be close to zero and not statistically significant for the 2012–2015 subperiod. We reiterate the caveat for the 2012–2015 results that they are based on a relatively small sample of switching options.

Section VII explores further whether the Pilot is contributing to an improvement in market quality for the least liquid option classes, a question that is significant if the Commission staff wishes to consider whether penny quoting should be expanded to a larger set of option classes or constricted to a smaller set. This question presents empirical challenges because the option classes added to the Pilot are generally the most liquid, thus making it difficult to extrapolate the benefits of the Pilot to less liquid option classes. We address this by examining market quality for Penny Pilot option classes using a more recent period of February 2016. The examination of a recent period allows us to study Penny Pilot option classes that may have been more liquid when they were originally added to the Pilot but with the passage of time became less liquid. The analysis compares spreads between Pilot options and a control sample of (non-Pilot) options, matched on option volume, underlying market capitalization, and underlying price. Results are reported by option volume quartiles to examine whether the benefits of inclusion in the Pilot taper off at a particular threshold (Table 23). The results indicate evidence of significant benefits of inclusion in the Pilot for the top two quartiles, corresponding to the option classes with trading volume in the top 5% of the universe of all listed option classes. For the bottom two quartiles of Pilot options, most of the results are not statistically significant, suggesting that the benefits of the Pilot decline as option liquidity declines.

I. Background: Option Penny Pilot Program

On Friday, January 26, 2007, the options exchanges commenced the Pilot program to quote and trade options on 13 stocks and ETFs in one-cent increments. The Pilot specified that options trading at less than $3.00 would have trading increments of one cent, while those trading

at $3.00 or more would have trading increments of five cents, with the exception of options on the QQQQ which would trade at one cent increments, regardless of price level. The change represents a reduction relative to options not in the Pilot, which have corresponding minimum price increments of five cents for options trading below $3.00 and ten cents for options trading above $3.00.

As summarized in Table 1, the Pilot was subsequently expanded to include additional option classes. Most notably, the Pilot was expanded by an additional 22 option classes on September 28, 2007 and 28 option classes on March 28, 2008. The Pilot was subsequently expanded to include the next 300 most actively traded, multiply-listed options classes that were not yet included in the Pilot, excluding options with high premiums. These option classes were added in groups of 75 on each of November 2, 2009, February 1, 2010, May 3, 2010, and August 2, 2010. Further, SPX and IWM began trading in one-cent increments regardless of the price level on February 1, 2010. Since 2011, additions have occurred at the beginning of January and July each year, when a handful of options (less than 10) have been added to the Pilot to replace options that no longer exist.[2] This analysis encompasses the addition to the Pilot of options on common equity and ETFs, commencing on January 26, 2007 and concluding on January 5, 2016.

II. Data and Sample

Options Price Reporting Authority (OPRA) data were obtained from CBOE LiveVol, which contains options trades, along with contemporaneous quotes from each exchange, as well as the National Best Bid and Offer (NBBO). For each of the event dates listed in Table 1

[2] See https://www.ise.com/options/regulatory-and-fees/options-penny-pilot/.

beginning in January 2007 and ending with the addition in January 2016, OPRA data were obtained for the full calendar month prior to the event date ("pre-event month") and for the full calendar month subsequent to the event date ("post-event month"). For example, for the event date on January 26, 2007, data were obtained for the calendar months of December 2006 and February 2007.

The OPRA data were supplemented with data from the Center for Research in Security Prices (CRSP) and OptionMetrics. CRSP data were used to obtain characteristics of the underlying equity instrument, including market capitalization, average daily trading volume, and prices. Daily OptionMetrics data were used to obtain additional characteristics of the traded option series and to provide a mapping between the OPRA and CRSP data.

The analysis is focused on options on common stock and ETFs, with results reported separately for common stock and ETFs.[3] Option classes for which the underlying stock or ETF traded below $1 or above $1,000 on any day during the pre-event month or the post-event month of any addition date are excluded, as are option series with non-standard settlements. Outlier spreads (effective or quoted) which are greater than $5 when the option price is less than $100, or are greater than $10, are excluded from the analysis. The sample for option classes on common stock incorporates data on 3,833 option classes and 1,331,185 class-day observations. The sample for option classes on ETFs incorporates data on 693 option classes and 194,694 class-day observations.

[3] The analyses reported in the body of this memo are based on a database of regular option trades (trades involving only one leg). An analysis of complex trades shows similar results and is reported in the Appendix.

III. Characteristics of Options Added to the Pilot

Table 2 contains summary statistics for option class volume, underlying volume, and underlying market capitalization for option classes not in the Pilot, classes being added to the Pilot, and classes already in the Pilot, computed during the pre-event month. Switching option classes generally have a higher average daily option volume, higher average daily underlying stock volume, and higher underlying market capitalization vis-à-vis option classes outside the Pilot. This is not surprising and simply reflects the fact that more actively traded options on more actively traded and larger stocks tend to be selected for inclusion in the Pilot. Note that the volume and market cap metrics for switching options decreased substantially between 2007 and 2010, indicating that option classes with higher volume and market cap were added to the Pilot prior to option classes with lower volume and market cap.

Since the large number of illiquid options may unduly influence the average for volume and underlying market capitalization for options outside the Pilot, it is worth examining the distribution of these characteristics across all option classes. Figure 1 shows a scatterplot of option classes on common stock based on average daily option volume and underlying market capitalization, while Figure 2 plots option classes on common stock based on average daily underlying volume and underlying market capitalization. Figures 3 and 4 show analogous plots for option classes on ETFs. All figures plot the data as of February 2016. The distributions confirm that options in the Pilot have higher trading volume and larger underlying market capitalizations vis-à-vis the overall population of traded options.

IV. Control Sample

The primary goal of this research is to assess the degree to which including an option class in the Pilot resulted in narrower quoted and effective spreads. Quoted and effective spreads are frequently used as measures of trading costs and, more generally, to assess market quality. Even though the analysis focuses on relatively short windows of one month before and one month after each addition date, it is possible that other market-wide factors influencing option spreads might have changed systematically between the pre-event and post-event months. The difference-in-differences methodology recognizes this possibility and controls for any such market-wide factors by comparing changes in market quality for the added option classes with contemporaneous changes in a control sample of option classes that were not added.

Control samples are constructed by matching switching options with non-switching options on the basis of option class volume and underlying market capitalization. Specifically, each switching option was matched with a control option by rank ordering the entire universe of traded options on option class volume and underlying market capitalization in the pre-event month, and then minimizing the difference in ranks between the switching option and the control option. Matching was completed without replacement, that is, each control option class is matched with exactly one switching option class for each event date. The results are similar across two different sets of matched controls: an "unconstrained" set, where the matched option is any non-switching option regardless of whether it is in the Pilot, and a "constrained" set, where the control option must be outside the Pilot. In later years, when most of the highest option volume options are in the Pilot, the unconstrained sample is likely to provide a closer match for the volume of the switching option. Table 3 contains summary statistics for the

control samples for option classes on common stock during the pre-event month. Table 4 contains the same summary statistics for option classes on ETFs.

V. Impact of the Pilot on Quoted and Effective Spreads

Figures 5–8 graphically illustrate the impact on spreads for the switching options after being added to the Pilot vis-à-vis the control sample. Figure 5 depicts the average dollar effective spreads during the pre-event month and the post-event month across the different addition dates. As can be seen in Figure 5, dollar effective spreads for switching options are substantially lower in the post-event month as compared to the pre-event month. No corresponding decline in effective spreads occurs for the control sample. A similar pattern is observed for relative effective spreads (Figure 6), dollar quoted spreads (Figure 7), and relative quoted spreads (Figure 8). Figures 9–12 show a similar pattern for option classes on ETFs. These figures suggest that inclusion in the Pilot is associated with substantially lower quoted and effective spreads.[4]

Tables 5–12 present changes in effective and quoted spreads for options that are switching into the Pilot,[5] as compared to a control group of non-switching options. Spreads are volume-weighted across different trades in an option series and then equally weighted across option series, in order to obtain spreads for the option-class day. Those spreads are then equally weighted across different days in the pre-event month and the post-event month, respectively, in

[4] The graphs shown in Figures 5–8 are based on event-time data aggregated across all event dates. Similar graphs could be made for any individual event date. For example, a graph showing the evolution of spreads surrounding August 2, 2010 is provided in the Appendix.

[5] The addition dates in January 2010 and July 2010 are the pre-event months for the additions in February 2010 and August 2010, respectively and, hence, are excluded as addition dates from the analysis to ensure that event windows do not overlap.

order to obtain option-class month observations. A similar methodology is adopted for computing spreads for the control sample, and the results of a difference-in-differences specification are reported. P-values are computed using a paired t-test and the Wilcoxon Signed-Rank test.

As shown in the first panel in Table 5, average dollar effective spreads declined from 10.5 cents in the pre-event month to 6.8 cents in the post-event month for the switching options in the overall sample, a decrease of 3.7 cents, while effective spreads in the control sample decreased by 0.2 cents. Relative to the control sample, effective spreads declined by 3.5 cents, as reported in the column labeled "diff-in-diff." This decline is statistically significant (at the 1% level). Table 5 also reports results for the different subperiods. As indicated in the table, inclusion in the Pilot is associated with a decrease in effective spreads of 3.3 cents for classes added between 2007 and 2009, 3.8 cents for classes added between 2010 and 2011, and 1.4 cents for classes added between 2012 and 2015. The second panel of Table 5 reports analogous results based on percentage effective spreads.

Similarly, as shown in the third panel of Table 5, average dollar quoted spreads declined from 13.9 cents in the pre-event month to 8.7 cents in the post-event month for the switching options in the overall sample, while quoted spreads for the control sample decreased from 12.4 to 12.2 cents. Based on the difference-in-differences, inclusion in the Pilot is associated with a decline in quoted spreads of 5.1 cents, which is statistically significant at the 1% level.

One potential explanation for the smaller decrease in spreads for later additions to the Pilot is that the benefits of the Pilot are most pronounced for options on larger stocks or for option classes with the highest trading volume, and to the extent that recent additions to the Pilot

tend to be smaller stocks with lower-volume options, there would be smaller declines in spreads in recent years.

To examine this, Table 6 decomposes the sample into categories based on the underlying market capitalization, using breakpoints calculated from NYSE stocks. Because most options being added are in the largest market capitalization quartile, they are decomposed into more granular categories. The difference-in-differences spreads are negative and statistically significant for all categories, with the Wilcoxon Signed-Rank test significant at the 1% level. Average dollar effective spreads declined by 3.5 cents for the largest quartile, by 3.6 cents for the third quartile, and by 2.9 cents for options below the 50th percentile, vis-à-vis the changes in the control group. Thus, the spread declines for Pilot stocks are consistent across all market cap categories. In addition, all four spread measures show similar results.

Table 7 decomposes the sample based on the percentile of the option volume in the pre-event month. Because almost the entire population of the switching options is in the top 10% by volume, they are decomposed into more granular categories. The difference-in-differences spreads are negative and statistically significant for all categories, with the Wilcoxon Signed-Rank test significant at the 1% level. Relative effective spreads declined by 4.4% for the top two percentiles, by 6% for the 95th to 97th percentile, by 5.5% for the 90th to 94th percentile, and by 7.2% for options below the 90th percentile, vis-à-vis changes in the control groups. The spread declines for Pilot option classes are consistent across all volume categories for all four spread measures.

Table 8 decomposes the sample based on the quoted price for an option. The difference-in-differences spreads are negative and statistically significant for all categories, with the Wilcoxon Signed-Rank test significant at the 1% level. Average dollar effective spreads

declined by 2.7 cents for options priced below $1.00, by 2.9 cents for options priced between $1.00 and $3.00, by 4.2 cents for options priced between $3.00 and $5.00, and by 4.6 cents for options priced over $5.00, vis-à-vis the changes in the control group. The spread declines for Pilot option classes are consistent across all price categories for all four spread measures.

Table 9 decomposes the sample based on the time to expiration for an option. The difference-in-differences spreads are negative and statistically significant for all categories, with the Wilcoxon Signed-Rank test significant at the 1% level. Average dollar effective spreads declined by 3.4 cents for options expiring within a week, by 3 cents for options expiring between one and four weeks, and by 3.6 cents for options expiring in more than four weeks, vis-à-vis the changes in the control group. The spread declines for Pilot option classes are consistent across all expiration categories for all four spread measures.

Tables 10–12 show results for option classes on ETFs decomposed by addition year, underlying market capitalization (as measured by price multiplied by shares outstanding), and option volume. Overall, average dollar effective spreads declined by 5 cents and average dollar quoted spreads declined by 6.8 cents. When decomposed by the market capitalization of the underlying ETF or by option trading volume, all difference-in-differences spreads are negative and statistically significant at the 1% level for the Wilcoxon Signed-Rank test.

The difference-in-differences analysis described above has focused on examining the impact of the Pilot on effective spreads and quoted spreads. The same technique can also be applied to examine other market characteristics. For example, analysis showing the impact on average daily trading volume, average trade size, and quoted depth at the NBBO is presented in the Appendix.

VI. Regression Analysis

The difference-in-differences analysis reported in the previous section used a control-sample methodology to control for any market-wide difference in factors that might have affected spreads between the pre-event and post-event months. This section presents further results based on a multivariate regression methodology that further controls for changes in other factors that might affect spreads, including option volume, stock volume, and equity volatility.

A. Baseline Regression Specification (Contains All Options)

The baseline multivariate regression approach is estimated at the class-day level for periods covering a calendar month prior to, and a calendar month subsequent to, each date of addition to the Pilot and contains all traded option classes:

$$Spread_{j,t} = \beta_1 PP_{j,t} + \beta_2 EqVol_{j,t} + \beta_3 OpVol_{j,t} + \beta_4 Volatility_{j,t} + SECID_j + Date_t + \varepsilon_{j,t}$$

where $Spread_{j,t}$ is a measure of quoted or effective spreads for a particular option class on a particular day; $PP_{j,t}$ is the binary variable of interest, taking a value of 1 in the post-switch period for options switching to the Pilot; $EqVol_{j,t}$ is the log of underlying stock volume on the day; $OpVol_{j,t}$ is the log of option class volume; $Volatility_{j,t}$ is the underlying stock volatility calculated as the difference between the high and low prices of the day divided by the closing price; $SECID_j$ is an option class fixed effect; and $Date_t$ is a date fixed effect.

The variable of interest $PP_{j,t}$ is the interaction term between indicator variables for the switching options and the post-switch period. The specification does not include individual

(main effect) indicator variables for switching options and the post-switch period because these are subsumed by the option class and date fixed effects. The model is estimated on observations at the class/day level, and the dependent variable is constructed by aggregating spread measures across the option series within the same class. The spreads are first volume-weighted across trades within each option series-day and then equally weighted across option series to obtain option class-day spreads. Hence, this specification incorporates all option series within the option classes with positive trading volume. The model is estimated on a sample including all option class/day measures for the calendar month prior to, and the calendar month after, each date of addition to the Pilot for all options. Standard errors are clustered on option class and date.

B. Matched Sample Regression Specification (Contains Only Matched Sample)

We also estimate an alternative specification, which has three key differences with the baseline specification. First, the alternate specification contains only the matched sample for each event, where an event constitutes a pre-event and post-event month for an addition. Second, the variable of interest is a switching indicator (which takes on a value of 1) only in the post-event month for the switching options. This indicator is zero for the control options, regardless of whether they are in the Pilot or not. Third, the option class fixed effect is replaced with an option class event fixed effect, since the same control option may be outside the Pilot for a particular event and may be in the Pilot for another event.

C. Findings

Table 13 reports results for effective spreads using the baseline specification estimated over the pre-event month and post-event month for the full sample, as well as for the different time periods. The indicator variable of interest is negative and statistically significant (at the 1% level) for effective spreads (for the full sample and for all time periods, except for the most recent additions in 2012–2015), showing a decline in trading costs for options being added to the Pilot. Dollar effective spreads declined by an average of 8.8 cents after addition to the Pilot for the full sample. Comparing the different subperiods separately, the maximum decline in spreads is for the additions in the 2010–2011 period (8 cents). The indicator is not statistically significant for the most recent additions from 2012–2015, with a coefficient close to zero.

Similarly, Table 14 reports results for quoted spreads using the baseline multivariate regression framework. Dollar quoted spreads declined by 16.1 cents for the entire sample, which is statistically significant. Comparing the subperiods individually, the decline is strongest in the 2010–2011 subperiod (12.2 cents), and is not statistically significant for additions made in the 2012–2015 subperiod.

Table 15 reports regression results for effective spreads using the matched sample approach, for the complete time period as well as for different subperiods. Dollar effective spreads declined by 3.6 cents for the full sample, which is statistically significant at the 1% level. The coefficient of interest (i.e., switching indicator) is statistically significant and negative across all specifications, including the 2012–2015 subperiod. Similar results are reported in Table 16 for quoted spreads, with dollar quoted spreads declining by 5.2 cents for the full sample, which is statistically significant at the 1% level.

Table 17 reports regression results for effective spreads using the matched sample approach, decomposed into different market capitalization categories. The coefficient of interest (i.e., switching indicator) is statistically significant and negative across all categories. Similar results are reported in Table 18 for quoted spreads.

Table 19 reports regression results for effective spreads using the matched sample approach, decomposed into different categories based on option volume. The coefficient of interest (i.e., switching indicator) is statistically significant and negative across all categories. Similar results are reported in Table 20 for quoted spreads.

Table 21 reports regression results for option classes on ETFs using the full sample and matched sample approach. Similar to the common stock sample, the results show that switching to the Penny Pilot has a significant (at the 5% level) negative effect on quoted spreads. For effective spreads, we find similar negative effects (significant at the 1% level), with the exception of the effective dollar specification for the full ETF sample.

VII. Impact of Pilot on the Least Liquid Option Classes

Based on the results reported above, we observe a decline in spreads for option classes in the Pilot vis-à-vis the control options, which is robust across different spread measures, as well as different partitions based on market capitalization, option volume, etc. This does not necessarily imply that all option classes would benefit from inclusion in the Pilot because, as noted above, the Pilot option classes are not representative of the overall population of option classes, but tend to be the most liquid. Many option classes currently not in the Pilot have lower

trading volume than those currently in the Pilot. It is not clear the extent to which similar benefits might be realized should penny quoting be expanded to include such option classes.

With the passage of time, some Pilot option classes (which may have had high trading volume at the time of inclusion) may have become less active, to the point that they would no longer be selected for the Pilot if the decision were made today. Among the Pilot option classes, those with the lowest current volume and market capitalization are the most similar to the options outside the Pilot. Analysis of these options could provide insight into the benefits that might be experienced by less liquid options upon inclusion.

Table 22 provides characteristics of Pilot option classes as well as matched control options as of February 2016. Control samples were constructed by matching Pilot options with non-Pilot options on the basis of option class volume, underlying market capitalization, and underlying price.[6] To ensure robustness, control samples were designed so that the matching was completed with replacement (i.e., an out-of-Pilot option class can match with any number of in-Pilot option classes), as well as without replacement (i.e., an out-of-Pilot option class can match with only one in-Pilot option class). Even with the passage of time, Pilot options are more liquid than the overall option universe, with the top quartile of Pilot options by option volume in the top three percentiles of the overall universe. Moreover, even the smallest Pilot option classes have option volumes greater than the volume of the 40th percentile in the overall option class

[6] Each Pilot option class was matched with a control option outside the Pilot by rank ordering the entire universe of traded options on option class volume, underlying market capitalization, and underlying price as of February 2016, and then minimizing the difference in ranks between the Pilot option and the control option.

universe; hence, the identification of the impact of inclusion of option classes below the 40th percentile is not possible using this sample.

Table 23 analyzes the difference in spreads between the Pilot option classes and the control options as of February 2016.[7] Results are reported by option volume quartiles to analyze if there is a discontinuity at which point the benefits of being in the Pilot taper off. Analyzing the results across the different quartiles, the difference in spreads is negative and mostly statistically significant for the top two quartiles. Hence, consistent with the difference-in-differences analysis, the Pilot appears to be beneficial for the top two quartiles of Pilot options. The top two quartiles are in the 95th percentile of the overall option universe. Thus, these results show that the penny tick size is associated with the benefit of narrower spreads for option classes in the top 5% of option volume.[8] Analyzing the difference in spreads for the bottom two quartiles, the test statistics are negative, but most are not statistically significant, suggesting that the benefits of the Pilot decline as option liquidity declines. However, the absence of evidence that market quality has deteriorated suggests that inclusion of lower-volume option classes may not be not harmful.

VIII. Conclusion

This research has examined data covering the entire history of the Option Penny Pilot from its inception and has analyzed how inclusion in the Pilot has impacted effective spreads and

[7] Note that this is a difference in spreads specification, rather than the difference-in-differences specification used previously.

[8] We note two limitations of our analysis–one, the control sample of options have significantly lower volume than the Penny Pilot options since most of the high volume options are in the Pilot, and two, that our analysis is limited to liquidity metrics that can be calculated using available data. For example, we are unable to comment on the impact of the Pilot on overall trading costs faced by institutions with large orders.

quoted spreads for option classes added to the Pilot through January 2016. The results indicate that inclusion in the Pilot is associated with a statistically significant decline in effective spreads and quoted spreads. This result is found to hold across all subperiods, but the magnitude of the effect appears to be smaller for additions after 2012. Results are presented for options with varying levels of trading volume and underlying market capitalization and appear to be robust across categories. The results presented above focus on options on common stock, although similar results are found for ETF options as discussed above. Similar results are found for complex trades and are presented in the Appendix. The impact of inclusion in the Pilot on other dimensions of market quality, such as quoted depth, are also presented in the Appendix.

This research further seeks to provide evidence to assist the staff in evaluating whether the program should be expanded (or contracted) by examining the spreads of Pilot option classes vis-à-vis matched controls as of February 2016. The results show a benefit of narrower spreads for option classes in the top 5% of the universe. However, there is less less evidence of benefit for lower-volume option classes. We find no evidence of a harmful increase in spreads for any category of option classes.

In summary, the evidence suggests that the existing Pilot program has resulted in improvements in market quality (as measured by quoted and effective spreads) for the Pilot option classes. This research does not provide any clear evidence that expanding the Pilot to include lower-volume stocks would result in similar benefits.

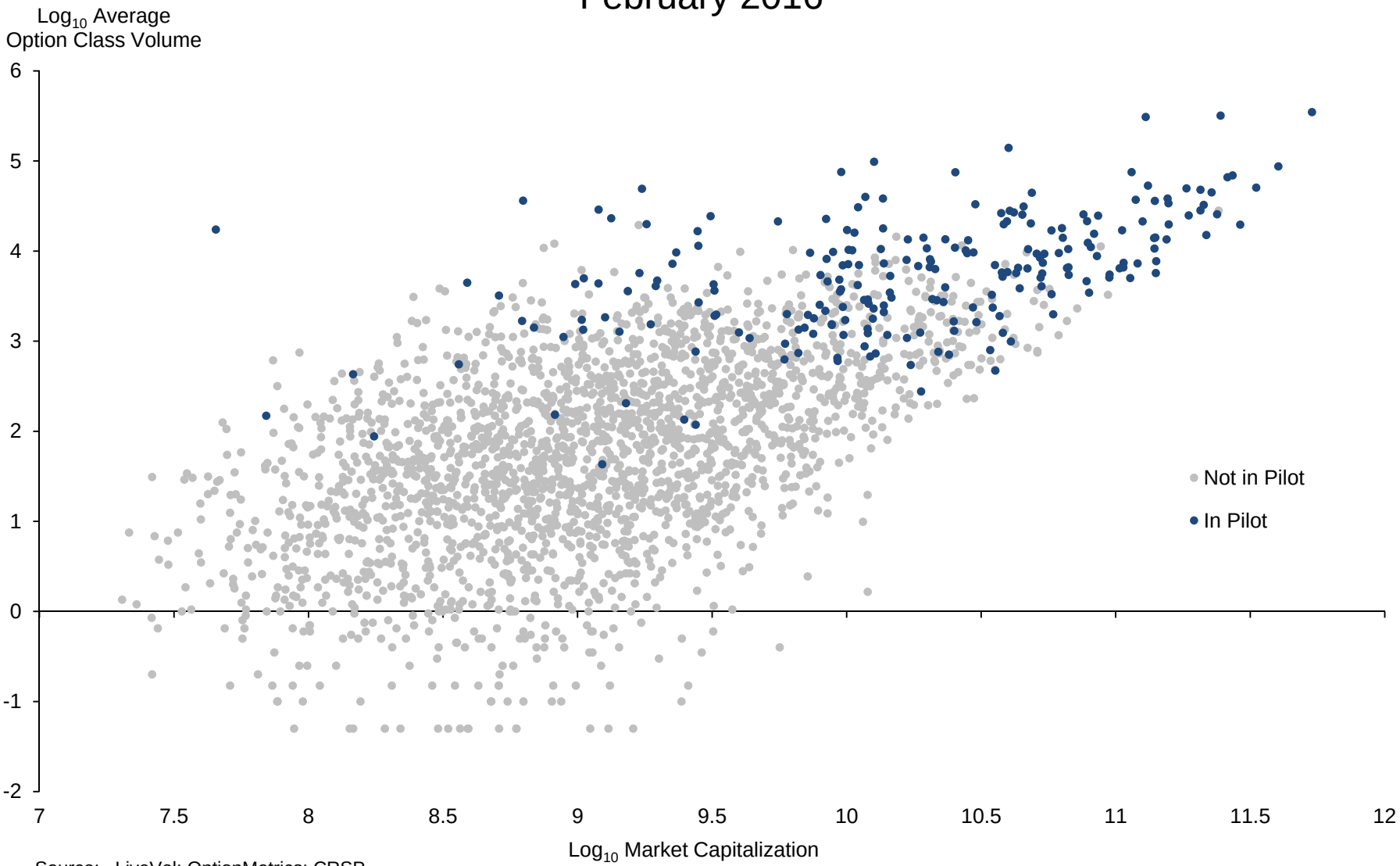
It is worth noting that this research does not account for the different fee structure option exchanges have for classes within and outside the Pilot. It is common among exchanges to have separate fee structures for Penny Pilot options. The research summarized herein does not attempt to disentangle whether the observed improvements in market quality can be attributed to

the Pilot alone, or if they may also be influenced by the differential fee structure. The average declines in execution costs for the most liquid option classes appear to be substantially higher than the potential impact of any fee adjustments.

Figure 1

Average Daily Option Class Volume vs. Market Capitalization

February 2016



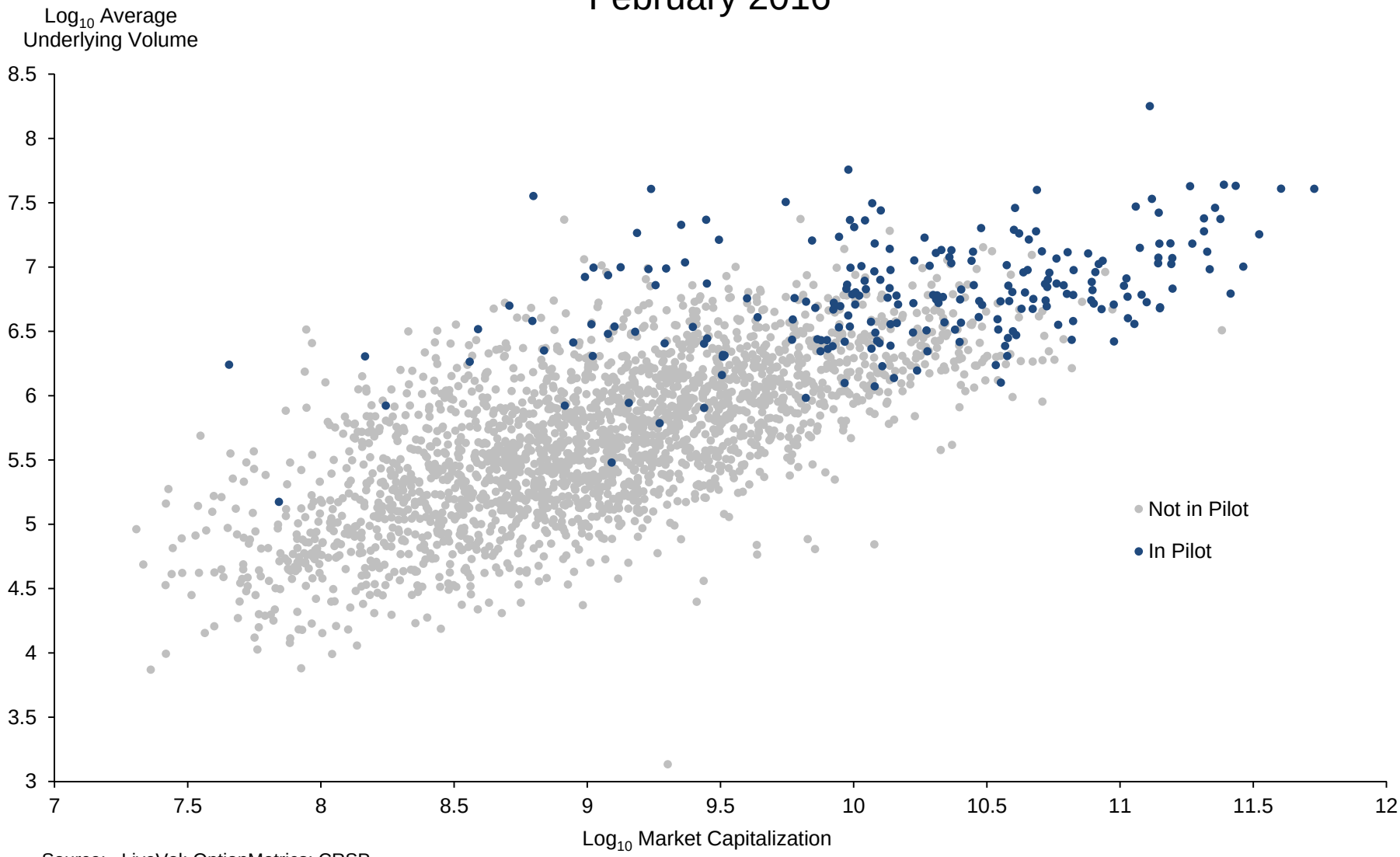
Source: LiveVol; OptionMetrics; CRSP.

Note: Includes all option classes on common stock for which LiveVol has data in February 2016. Share codes 10 and 11 are used to identify common stock in the CRSP data.

Figure 2

Average Daily Underlying Volume vs. Market Capitalization

February 2016



Source: LiveVol; OptionMetrics; CRSP.

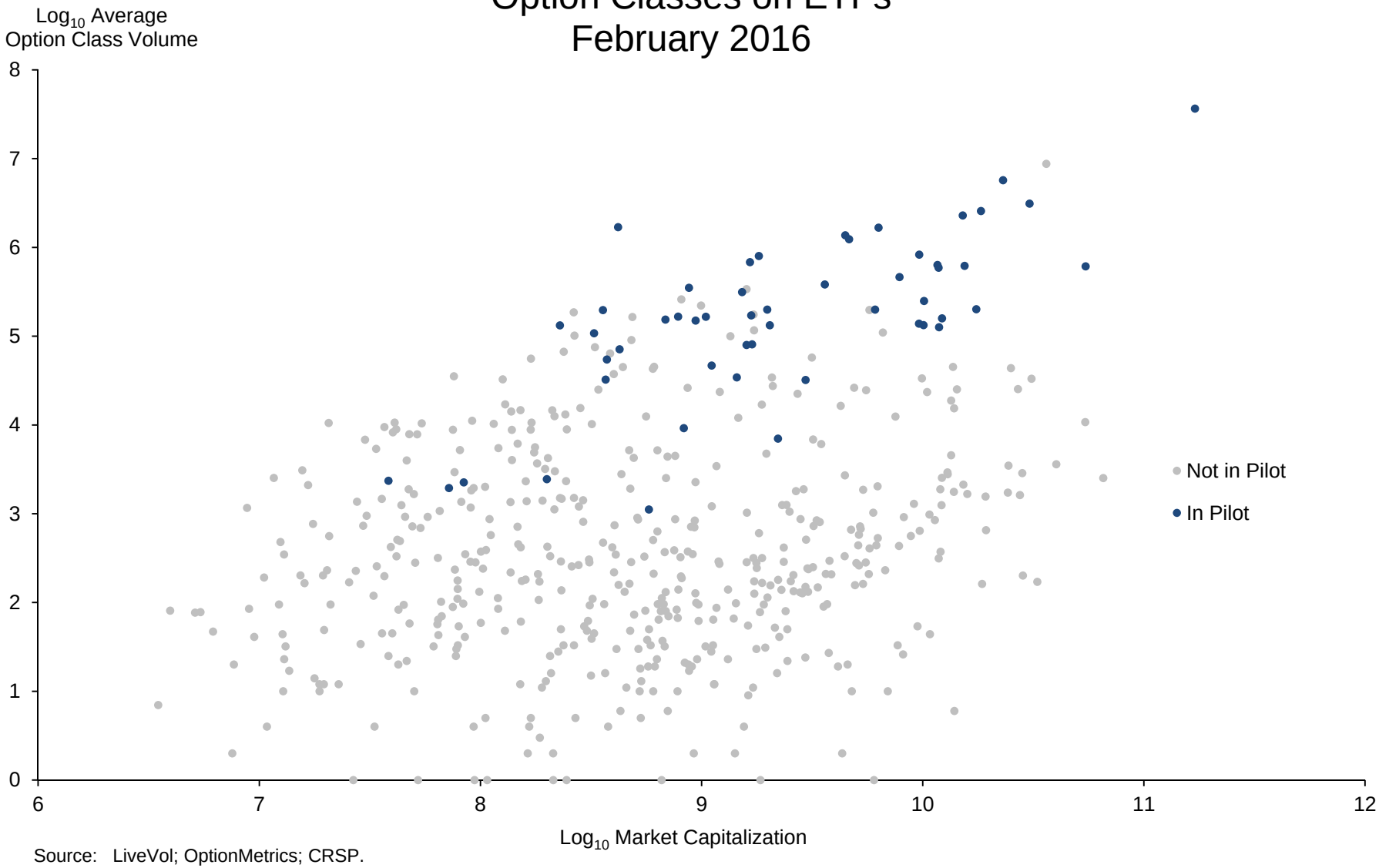
Note: Includes all option classes on common stock for which LiveVol has data in February 2016. Share codes 10 and 11 are used to identify common stock in the CRSP data.

Figure 3

Average Daily Option Class Volume vs. Market Capitalization

Option Classes on ETFs

February 2016



Source: LiveVol; OptionMetrics; CRSP.

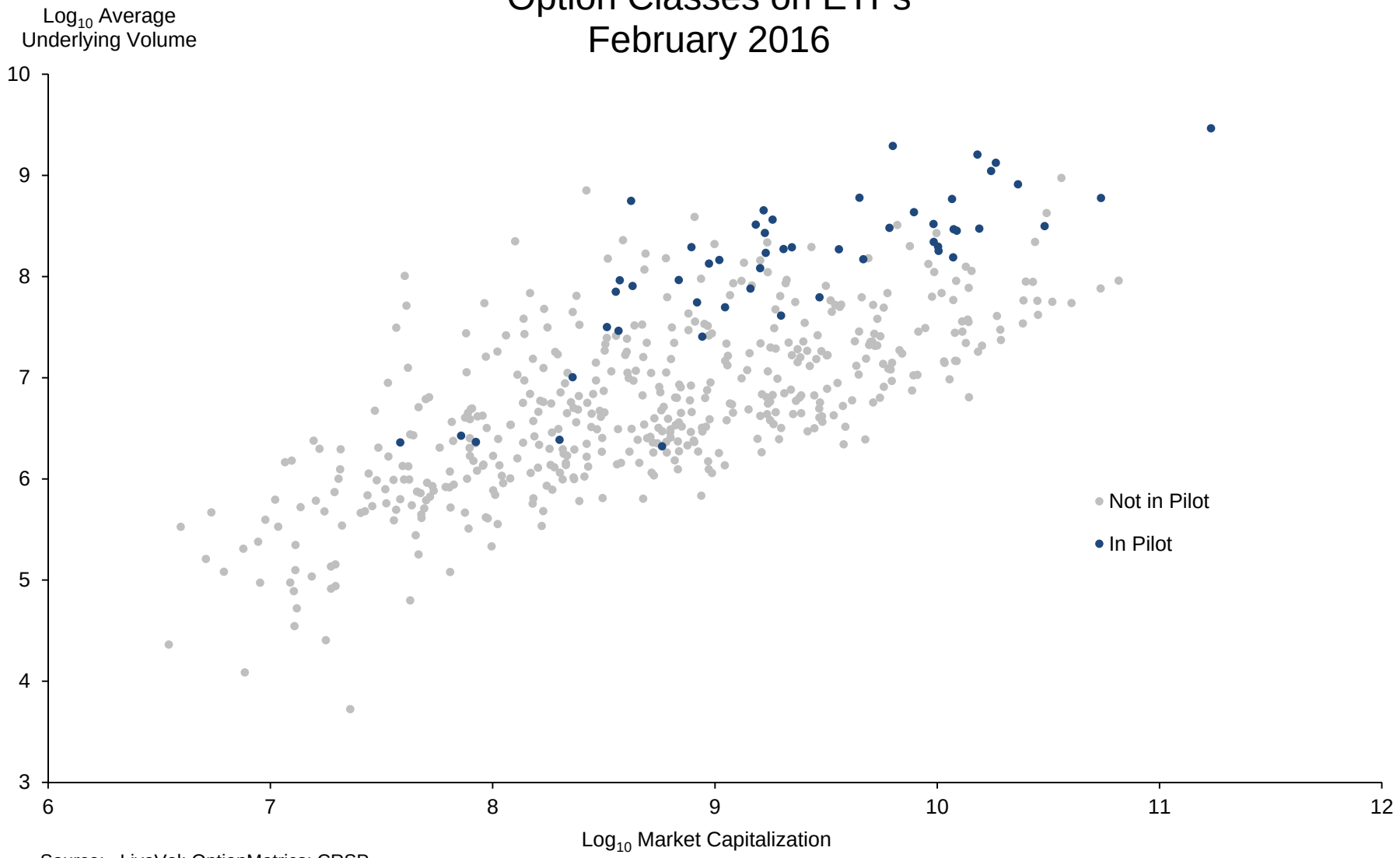
Note: Includes all option classes on ETFs for which LiveVol has data in February 2016. Share code 73 is used to identify ETFs in the CRSP data.

Figure 4

Average Daily Underlying Volume vs. Market Capitalization

Option Classes on ETFs

February 2016

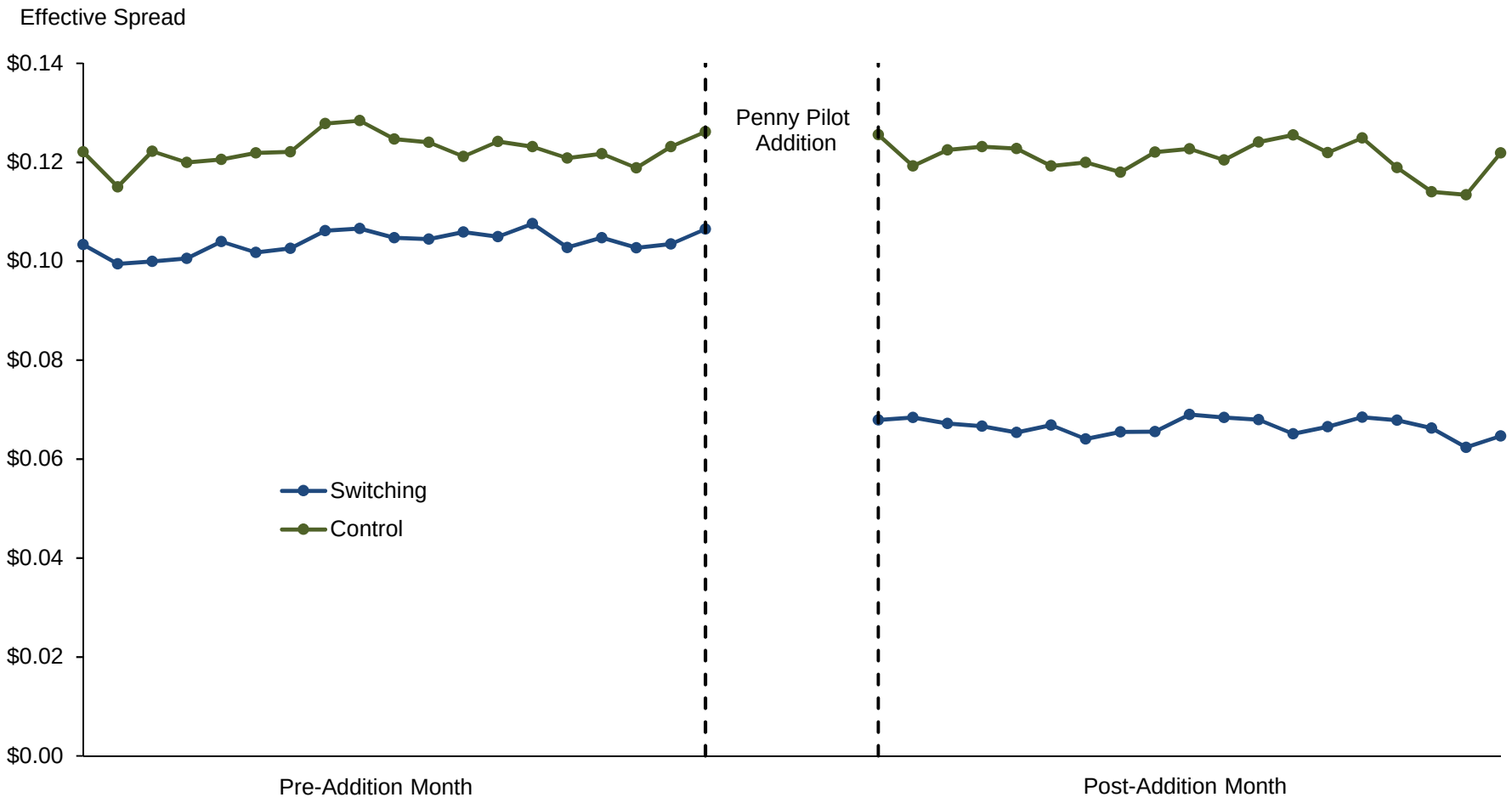


Source: LiveVol; OptionMetrics; CRSP.

Note: Includes all option classes on ETFs for which LiveVol has data in February 2016. Share code 73 is used to identify ETFs in the CRSP data.

Figure 5

Impact of Addition to the Penny Pilot on Effective Spreads ($)

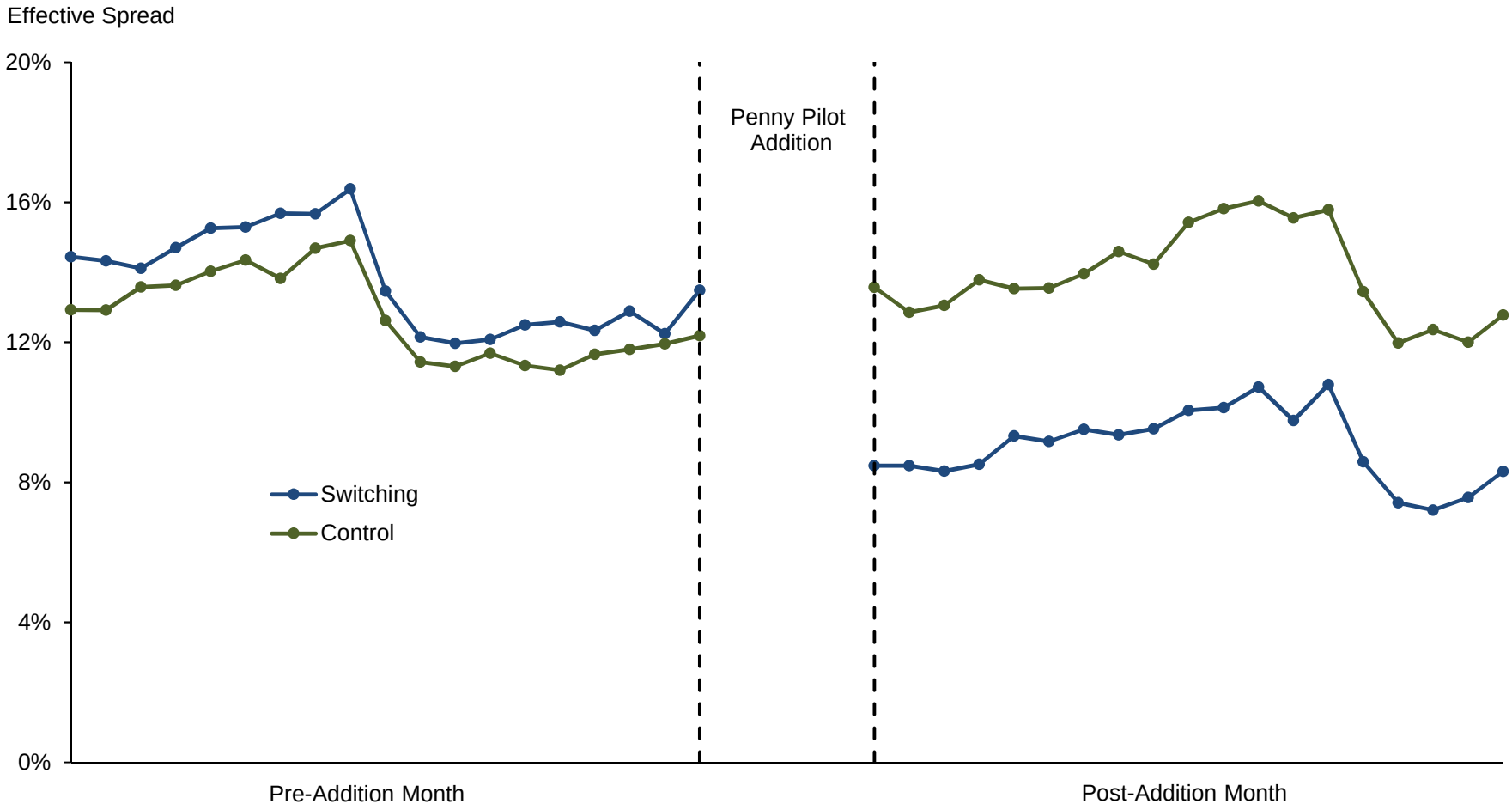


Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 235 option classes on common stock that were added to the Penny Pilot between January 26, 2007 and July 6, 2015 for which LiveVol has data. 12 option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Effective spreads for the switching and control samples are averaged across each trading day.

Figure 6

Impact of Addition to the Penny Pilot on Effective Spreads (%)

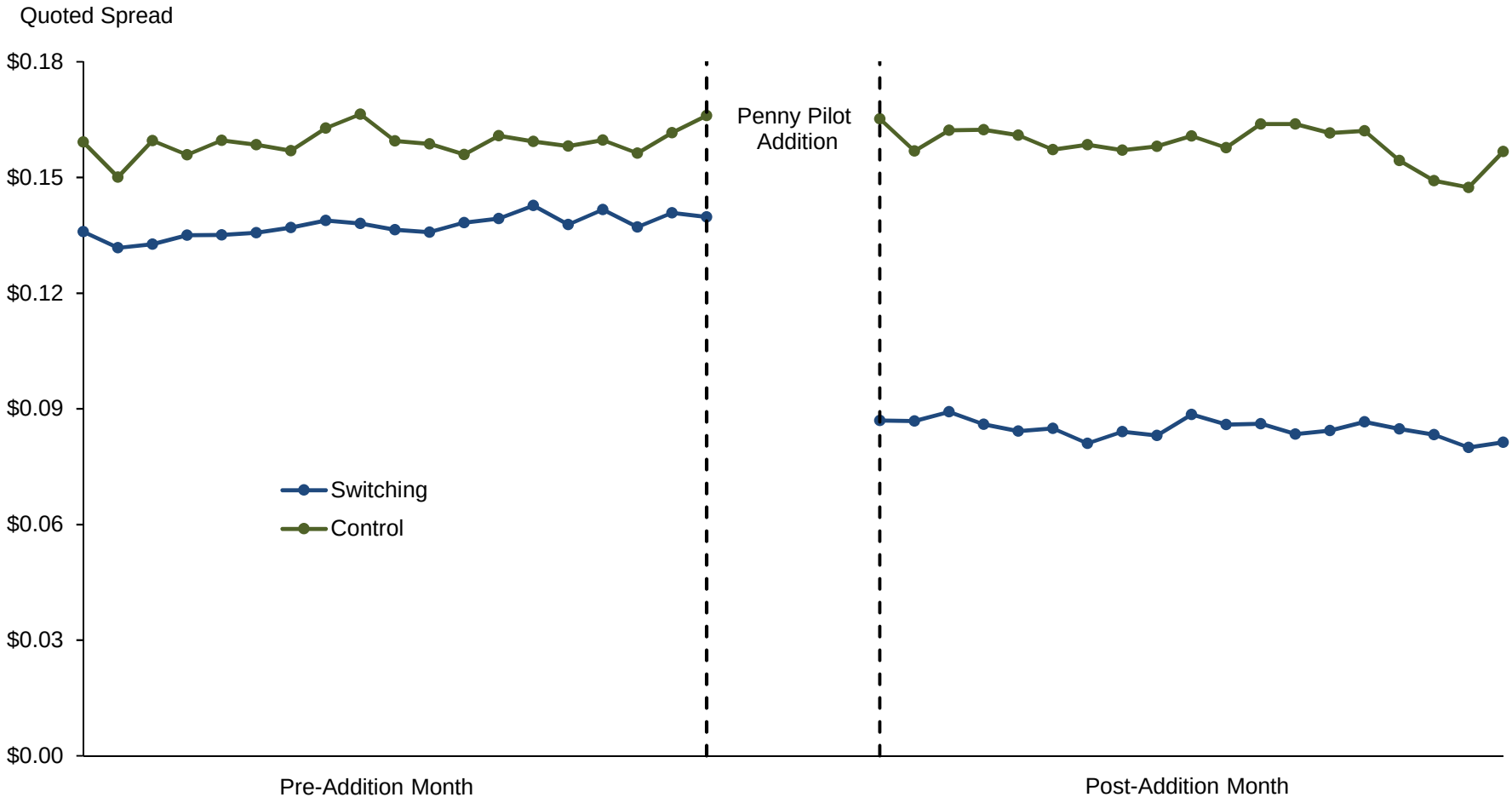


Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 235 option classes on common stock that were added to the Penny Pilot between January 26, 2007 and July 6, 2015 for which LiveVol has data. 12 option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Effective spreads for the switching and control samples are averaged across each trading day.

Figure 7

Impact of Addition to the Penny Pilot on Quoted Spreads ($)

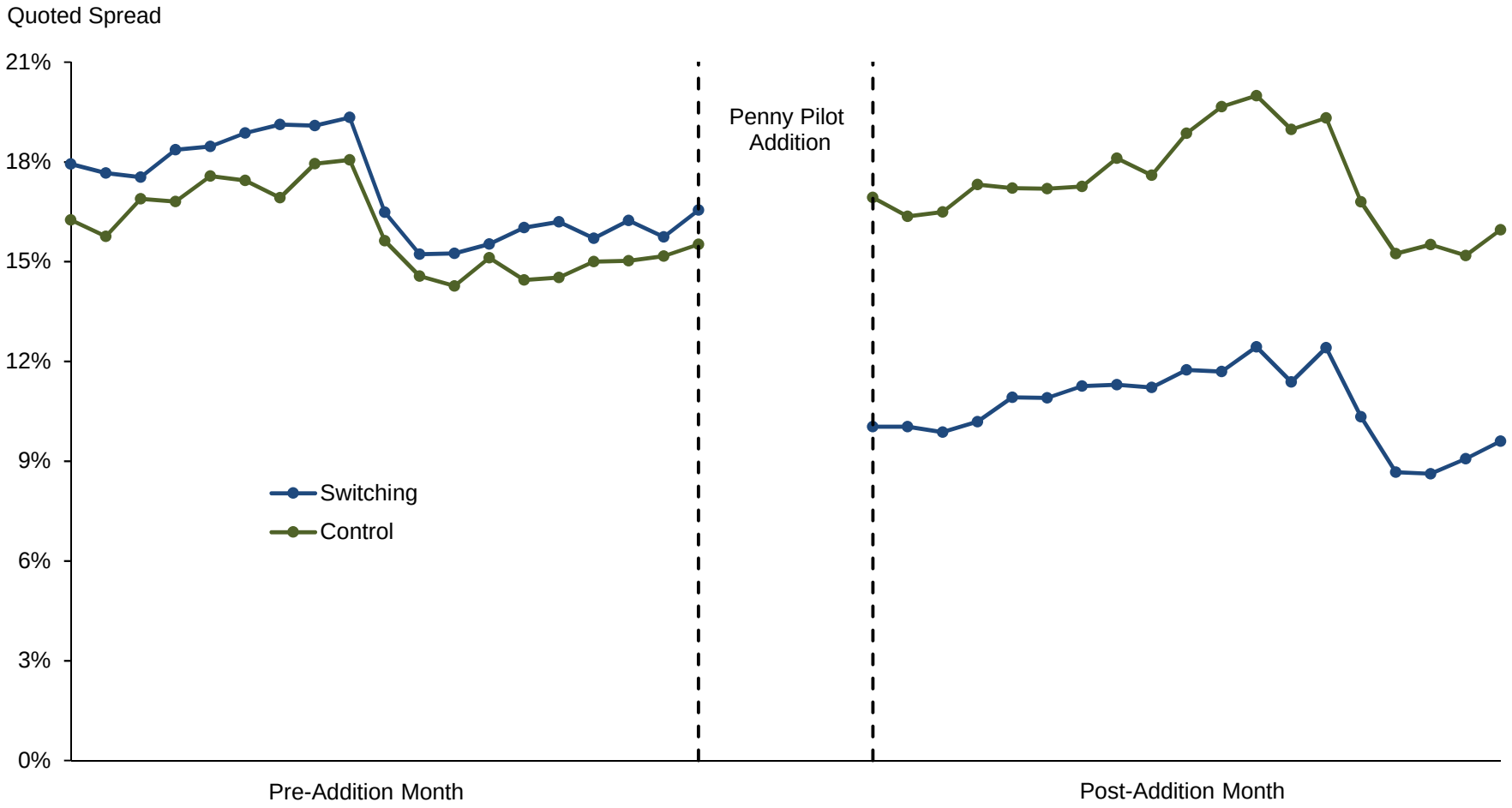


Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 235 option classes on common stock that were added to the Penny Pilot between January 26, 2007 and July 6, 2015 for which LiveVol has data. 12 option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Quoted spreads for the switching and control samples are averaged across each trading day.

Figure 8

Impact of Addition to the Penny Pilot on Quoted Spreads (%)



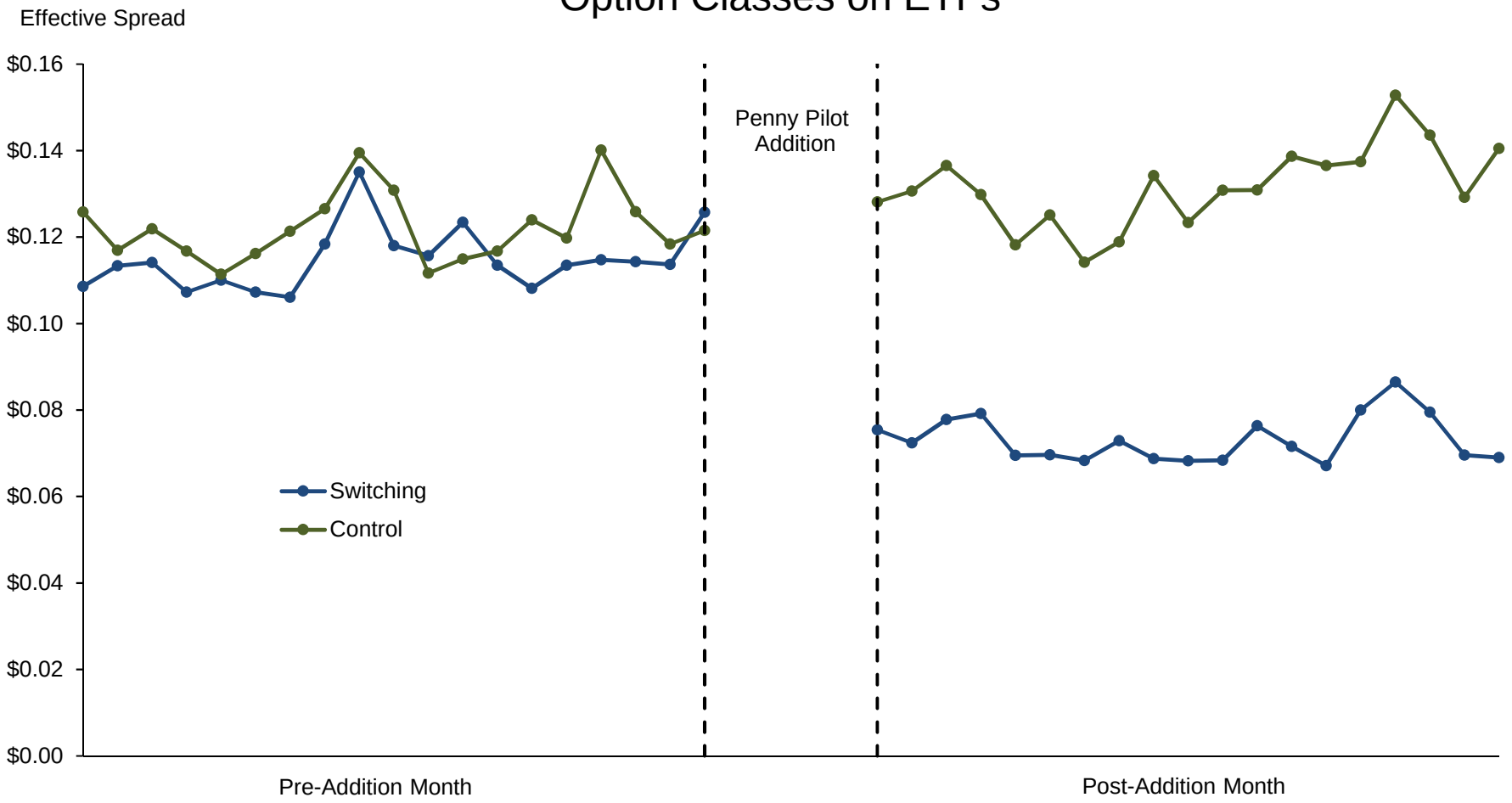
Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 235 option classes on common stock that were added to the Penny Pilot between January 26, 2007 and July 6, 2015 for which LiveVol has data. 12 option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Quoted spreads for the switching and control samples are averaged across each trading day.

Figure 9

Impact of Addition to the Penny Pilot on Effective Spreads ($)

Option Classes on ETFs



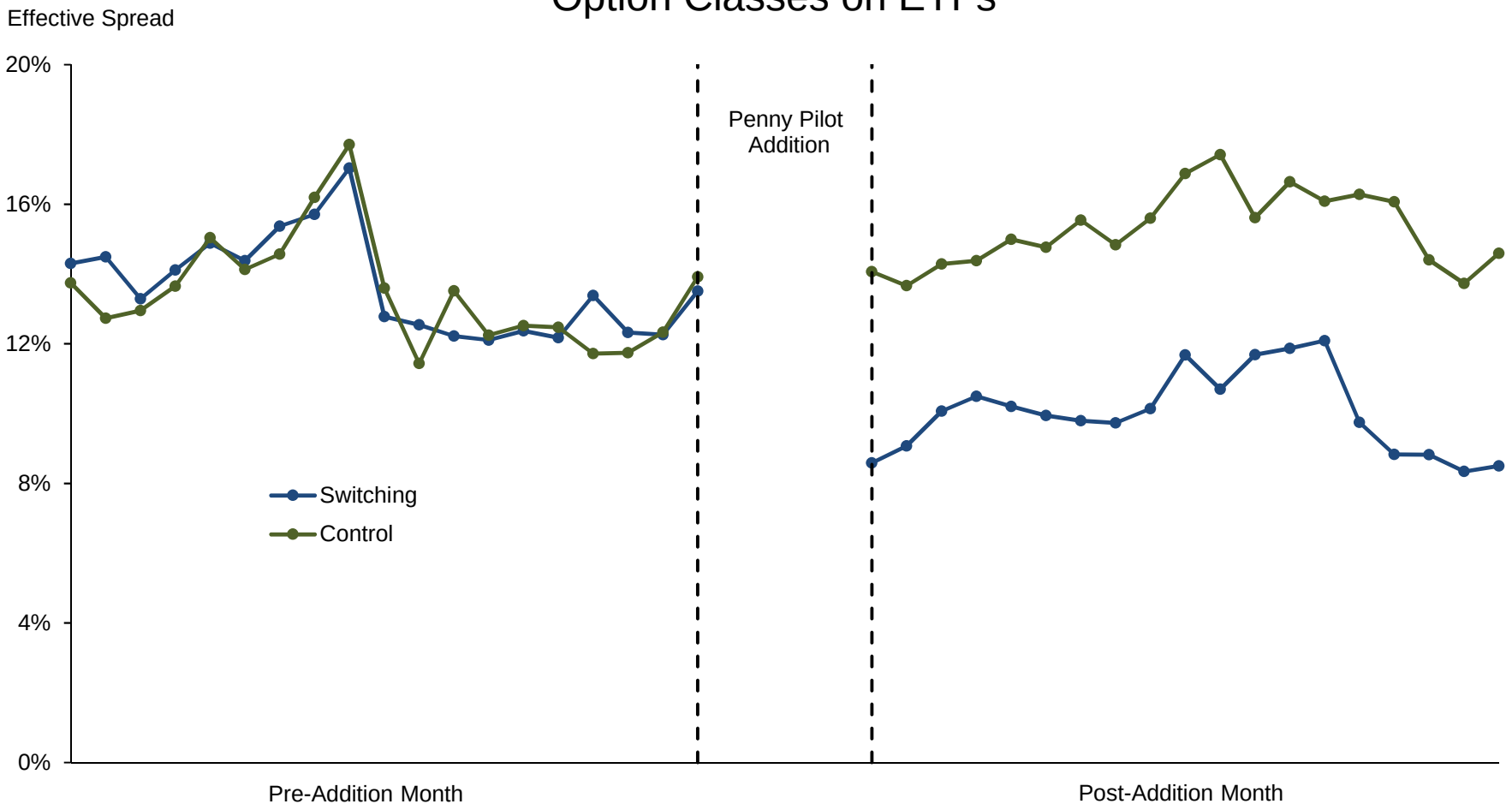
Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 53 option classes on ETFs that were added to the Penny Pilot between January 26, 2007 and January 5, 2016 for which LiveVol has data. Two option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Effective spreads for the switching and control samples are averaged across each trading day.

Figure 10

Impact of Addition to the Penny Pilot on Effective Spreads (%)

Option Classes on ETFs



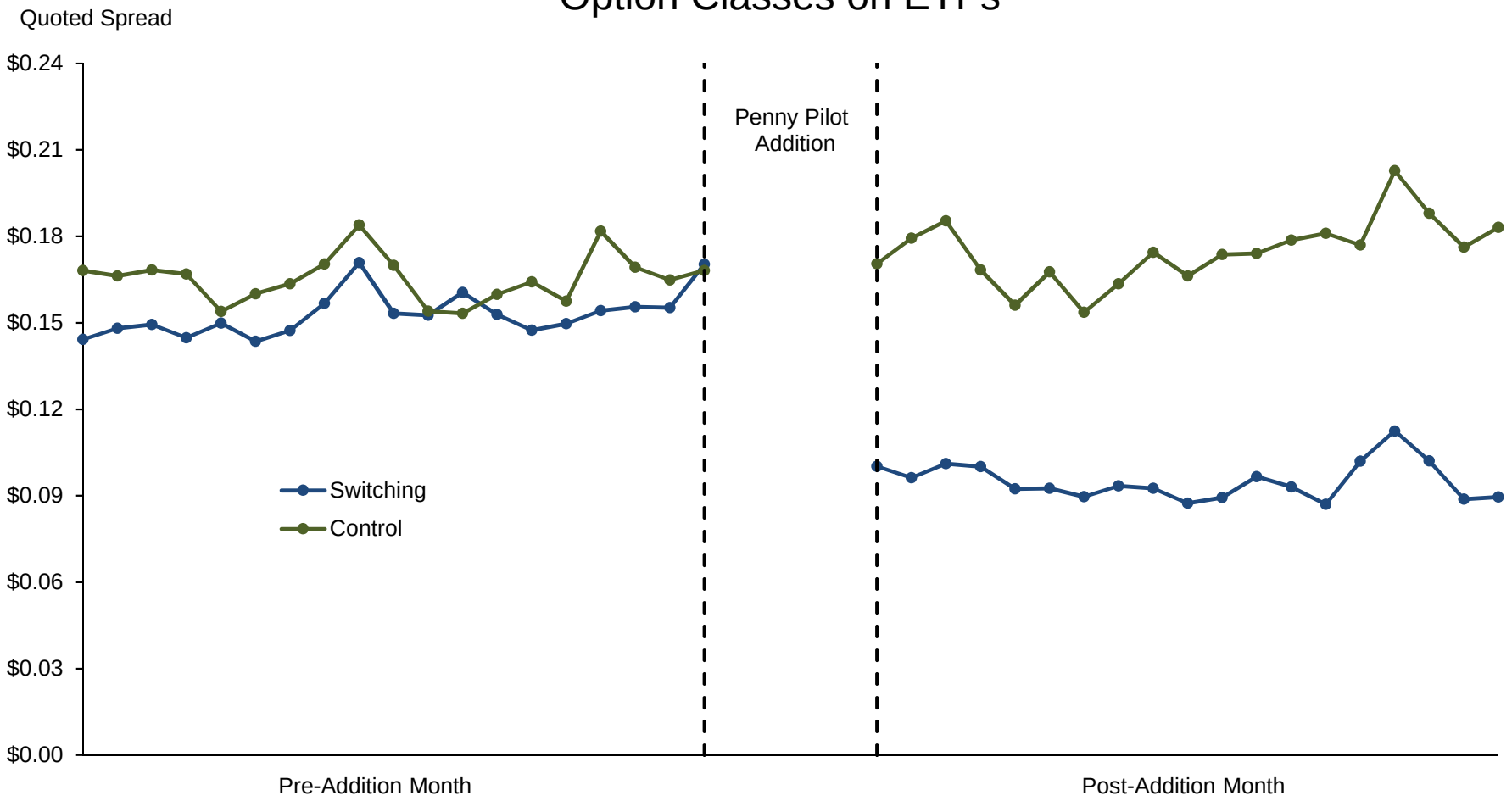
Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 53 option classes on ETFs that were added to the Penny Pilot between January 26, 2007 and January 5, 2016 for which LiveVol has data. Two option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Effective spreads for the switching and control samples are averaged across each trading day.

Figure 11

Impact of Addition to the Penny Pilot on Quoted Spreads ($)

Option Classes on ETFs



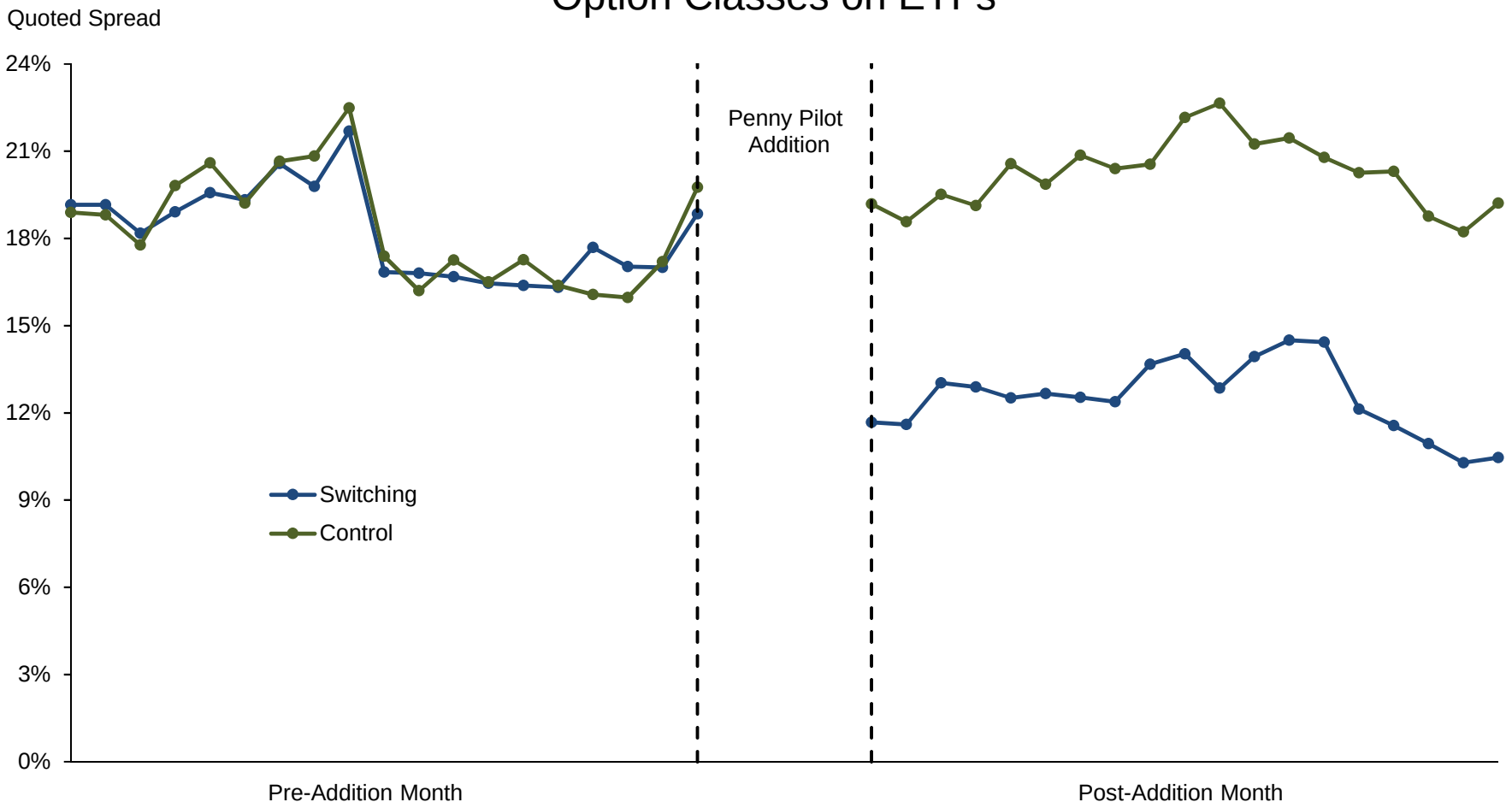
Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 53 option classes on ETFs that were added to the Penny Pilot between January 26, 2007 and January 5, 2016 for which LiveVol has data. Two option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Quoted spreads for the switching and control samples are averaged across each trading day.

Figure 12

Impact of Addition to the Penny Pilot on Quoted Spreads (%)

Option Classes on ETFs



Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 53 option classes on ETFs that were added to the Penny Pilot between January 26, 2007 and January 5, 2016 for which LiveVol has data. Two option classes were removed because the switching option class or the control option class was missing data on an option class-day in the pre-addition or post-addition month. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Quoted spreads for the switching and control samples are averaged across each trading day.

Table 1

Option Classes Added to Penny Pilot Since Inception

Date	New Option Classes Added	(%)
1/26/2007	13	3.19%
9/28/2007	22	5.39%
3/28/2008	23	5.64%
11/2/2009	75	18.38%
1/5/2010	4	0.98%
2/1/2010	75	18.38%
5/3/2010	75	18.38%
7/6/2010	3	0.74%
8/2/2010	75	18.38%
1/4/2011	2	0.49%
7/6/2011	4	0.98%
1/4/2012	3	0.74%
7/3/2012	2	0.49%
1/3/2013	9	2.21%
7/3/2013	2	0.49%
1/3/2014	7	1.72%
7/3/2014	4	0.98%
1/5/2015	2	0.49%
7/6/2015	6	1.47%
1/5/2016	2	0.49%
7/6/2016	7	1.69%
Total	415	100.00%

Source: ISE Penny Pilot Addition Dates.

Table 2

Liquidity Metrics for Penny Pilot Addition Dates

Option Classes on Common Stock

	Number of Option Classes			Daily Volume of Option Class (Contracts)			Daily Volume of Underlying Stock (Thousands)			Market Cap of Underlying Stock ($Millions)		
Month	Not in Pilot	Switching	In Pilot	Not in Pilot	Switching	In Pilot	Not in Pilot	Switching	In Pilot	Not in Pilot	Switching	In Pilot
Dec-06	2,030	9	0	1,636	32,572	–	1,390	26,137	–	6,920	102,942	–
Aug-07	2,011	15	9	1,843	51,330	29,632	1,983	22,195	35,759	6,341	94,746	106,900
Feb-08	2,001	20	25	1,481	30,794	48,095	1,684	21,527	30,027	4,951	88,186	80,364
Oct-09	1,890	41	43	1,177	22,411	65,407	1,596	17,257	39,943	3,144	43,505	68,857
Dec-09	1,950	3	85	755	10,000	33,977	1,205	11,925	23,211	3,365	23,018	60,045
Jan-10	1,823	50	87	866	9,080	44,974	1,260	8,250	30,600	2,719	22,664	57,192
Apr-10	1,839	49	140	652	7,528	35,862	1,281	6,237	23,736	2,881	10,254	49,019
Jul-10	1,767	46	180	457	3,807	20,062	1,042	5,379	15,530	2,361	13,425	36,905
Dec-10	1,790	1	224	477	4,869	18,171	838	8,813	10,840	2,763	209	36,900
Jun-11	1,824	3	225	502	15,136	15,679	960	7,886	10,004	2,902	20,199	38,065
Dec-11	1,888	1	233	381	11,989	14,393	878	4,695	9,122	2,637	5,077	35,131
Jun-12	1,899	2	233	502	15,814	15,015	976	18,695	9,575	2,781	9,861	38,136
Dec-12	1,885	5	225	378	40,885	16,414	764	16,823	8,422	2,892	12,502	40,393
Jun-13	1,989	1	233	486	64,427	15,264	865	9,097	9,000	3,276	13,037	43,755
Dec-13	2,047	3	226	567	16,306	16,847	773	5,198	7,072	3,809	6,630	50,908
Jun-14	2,144	1	227	505	123,725	15,879	803	31,263	6,311	3,951	24,170	52,975
Dec-14	2,187	1	229	437	8,256	16,487	821	5,921	7,014	4,003	26,587	55,218
Jun-15	2,206	2	227	391	18,684	13,805	830	7,078	6,817	4,035	6,374	55,257

Source: CRSP; OptionMetrics; LiveVol.

Note: Liquidity metrics are shown for the month prior to each addition date. The liquidity metrics includes all option classes on common stock for which LiveVol has data. Share codes 10 and 11 are used to identify common stock in the CRSP data. The sample excludes option classes for which the underlying stock traded below $1 or above $1,000 on any day on which an average spread is calculated during the December 2006 through February 2016 period. Data for the July 2010 and January 2016 additions is not shown above because none of the option classes that switched on those dates are in the sample of option classes on common stock.

Table 3

Liquidity Metrics for Penny Pilot Addition Dates

Matched Pairs Sample

Month	Number of Option Classes	Daily Volume of Option Class (Contracts)			Daily Volume of Underlying Stock (Thousands)			Market Cap of Underlying Stock ($Millions)		
		Switching	Unconstrained	Constrained	Switching	Unconstrained	Constrained	Switching	Unconstrained	Constrained
Dec-06	9	32,572	27,896	27,896	26,137	18,426	18,426	102,942	76,960	76,960
Aug-07	15	51,330	36,314	36,353	22,195	27,659	18,002	94,746	101,936	85,218
Feb-08	20	30,794	44,490	22,451	21,527	31,756	16,848	88,186	85,362	65,385
Oct-09	41	22,411	23,793	11,851	17,257	17,117	9,666	43,505	37,261	25,440
Jan-10	50	9,080	9,246	6,915	8,250	7,668	5,598	22,664	18,788	14,558
Apr-10	46	7,990	9,654	5,705	6,271	7,387	7,463	10,010	10,163	9,934
Jul-10	46	3,807	3,853	3,241	5,379	5,516	3,930	13,425	13,119	11,582
Dec-10	1	4,869	1,793	1,793	8,813	1,993	1,993	209	259	259
Jun-11	3	15,136	14,755	8,719	7,886	12,246	2,248	20,199	20,167	11,981
Dec-11	1	11,989	15,117	6,524	4,695	11,795	3,703	5,077	5,099	4,783
Jun-12	2	15,814	11,767	11,767	18,695	6,119	6,119	9,861	9,777	9,777
Dec-12	5	40,885	37,142	8,880	16,823	17,370	4,000	12,502	13,173	10,139
Jun-13	1	64,427	37,025	9,730	9,097	3,079	2,784	13,037	12,438	9,251
Dec-13	3	16,306	15,206	9,946	5,198	4,131	4,420	6,630	6,930	7,677
Jun-14	1	123,725	59,340	26,590	31,263	2,402	9,795	24,170	26,476	33,033
Dec-14	1	8,256	8,265	7,583	5,921	8,410	8,833	26,587	29,393	28,724
Jun-15	2	18,684	25,054	8,856	7,078	13,617	23,484	6,374	6,202	6,616

Source: CRSP; OptionMetrics; LiveVol.

Note: Liquidity metrics are shown for the month prior to each addition date. The matched pairs sample is constructed from the universe of option classes on common stock for which LiveVol has data. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Data for the January 2010 and July 2010 additions are not shown above because the post-month for these two addition dates overlapped with the February 1, 2010 and August 2, 2010 additions respectively. Data for the January 2016 additions is not shown above because none of the option classes that switched on that date are in the sample of option classes on common stock.

Table 4

Liquidity Metrics for Penny Pilot Addition Dates

Matched Pairs Sample: Option Classes on ETFs

		Daily Volume of Option Class (Contracts)			Daily Volume of Underlying Stock (Thousands)			Market Cap of Underlying Stock ($Millions)		
Month	Number of Option Classes	Switching	Unconstrained	Constrained	Switching	Unconstrained	Constrained	Switching	Unconstrained	Constrained
Dec-06	3	140,034	77,111	63,380	50,208	22,732	21,345	10,224	23,872	24,586
Aug-07	4	230,200	208,085	208,085	101,194	49,351	49,351	22,471	9,615	9,615
Feb-08	1	43,739	584,226	584,226	22,226	151,137	151,137	25,362	16,420	16,420
Oct-09	19	27,803	90,613	6,741	24,030	32,762	8,190	6,404	8,236	2,567
Jan-10	6	10,953	9,705	8,186	17,443	9,969	5,050	1,811	2,324	2,473
Apr-10	7	5,283	6,152	2,920	7,414	7,624	3,770	2,368	2,462	2,083
Jul-10	6	1,727	2,390	1,696	3,552	3,273	2,817	1,190	1,123	1,047
Dec-10	0	–	–	–	–	–	–	–	–	–
Jun-11	0	–	–	–	–	–	–	–	–	–
Dec-11	0	–	–	–	–	–	–	–	–	–
Jun-12	0	–	–	–	–	–	–	–	–	–
Dec-12	1	15,267	6,892	6,685	7,671	3,712	1,399	726	763	767
Jun-13	0	–	–	–	–	–	–	–	–	–
Dec-13	2	16,713	10,133	7,237	7,116	3,259	2,045	6,446	6,666	7,653
Jun-14	0	–	–	–	–	–	–	–	–	–
Dec-14	0	–	–	–	–	–	–	–	–	–
Jun-15	3	10,538	12,301	11,827	7,536	5,672	3,882	5,606	5,249	7,690
Dec-15	1	8,011	12,763	4,426	1,600	834	3,386	400	340	464

Source: CRSP; OptionMetrics; LiveVol.

Note: Liquidity metrics are shown for the month prior to each addition date. The matched pairs sample is constructed from the universe of ETFs for which LiveVol has data. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Data for the January 2010 and July 2010 additions are not shown above because the post-month for these two addition dates overlapped with the February 1, 2010 and August 2, 2010 additions respectively.

Table 5

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Unconstrained Matching

				Switching				Non-Switching				Difference-in-Differences		
Addition Dates	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
All	247	912	16,940	0.105	0.068	-0.037	0.000	0.096	0.094	-0.002	0.195	-0.035	0.000	0.000
2007 – 2009	85	1,363	30,563	0.109	0.066	-0.042	0.000	0.101	0.093	-0.009	0.000	-0.033	0.000	0.000
2010 – 2011	146	443	7,181	0.098	0.062	-0.036	0.000	0.090	0.093	0.002	0.213	-0.038	0.000	0.000
2012 – 2015	16	2,795	33,618	0.144	0.129	-0.015	0.011	0.122	0.120	-0.001	0.779	-0.014	0.019	0.009
Effective Spread (%)														
All	247	912	16,940	0.138	0.090	-0.048	0.000	0.113	0.122	0.009	0.004	-0.058	0.000	0.000
2007 – 2009	85	1,363	30,563	0.140	0.085	-0.055	0.000	0.113	0.116	0.004	0.252	-0.058	0.000	0.000
2010 – 2011	146	443	7,181	0.132	0.087	-0.046	0.000	0.111	0.126	0.015	0.004	-0.060	0.000	0.000
2012 – 2015	16	2,795	33,618	0.179	0.138	-0.041	0.000	0.131	0.122	-0.009	0.223	-0.032	0.003	0.006
Quoted Spread ($)														
All	247	912	16,940	0.139	0.087	-0.053	0.000	0.124	0.122	-0.001	0.531	-0.051	0.000	0.000
2007 – 2009	85	1,363	30,563	0.136	0.080	-0.056	0.000	0.122	0.113	-0.009	0.000	-0.047	0.000	0.000
2010 – 2011	146	443	7,181	0.131	0.080	-0.052	0.000	0.118	0.122	0.004	0.203	-0.055	0.000	0.000
2012 – 2015	16	2,795	33,618	0.230	0.186	-0.043	0.000	0.180	0.176	-0.004	0.613	-0.040	0.003	0.005
Quoted Spread (%)														
All	247	912	16,940	0.173	0.106	-0.067	0.000	0.138	0.149	0.012	0.002	-0.079	0.000	0.000
2007 – 2009	85	1,363	30,563	0.165	0.096	-0.069	0.000	0.130	0.136	0.006	0.098	-0.074	0.000	0.000
2010 – 2011	146	443	7,181	0.169	0.104	-0.065	0.000	0.138	0.156	0.018	0.003	-0.083	0.000	0.000
2012 – 2015	16	2,795	33,618	0.256	0.183	-0.073	0.000	0.175	0.165	-0.010	0.275	-0.063	0.000	0.003

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 6

Univariate Statistics Reported by Underlying Market Capitalization

Unconstrained Matching

Market Cap Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
95th +	69	1,279	30,296	0.102	0.061	-0.041	0.000	0.085	0.079	-0.006	0.012	-0.035	0.000	0.000
75th – 94th	123	811	12,444	0.107	0.071	-0.036	0.000	0.106	0.106	0.000	0.954	-0.035	0.000	0.000
50th – 74th	38	780	11,117	0.106	0.069	-0.037	0.000	0.085	0.084	-0.001	0.874	-0.036	0.000	0.000
Below 50th	17	449	8,279	0.095	0.066	-0.029	0.001	0.093	0.093	0.000	0.941	-0.029	0.003	0.004
Effective Spread (%)														
95th +	69	1,279	30,296	0.132	0.075	-0.057	0.000	0.098	0.101	0.003	0.281	-0.060	0.000	0.000
75th – 94th	123	811	12,444	0.128	0.084	-0.045	0.000	0.109	0.111	0.002	0.504	-0.047	0.000	0.000
50th – 74th	38	780	11,117	0.163	0.112	-0.051	0.000	0.132	0.158	0.026	0.040	-0.077	0.000	0.000
Below 50th	17	449	8,279	0.176	0.142	-0.035	0.020	0.160	0.214	0.054	0.083	-0.088	0.011	0.001
Quoted Spread ($)														
95th +	69	1,279	30,296	0.130	0.074	-0.056	0.000	0.104	0.099	-0.005	0.059	-0.050	0.000	0.000
75th – 94th	123	811	12,444	0.143	0.092	-0.051	0.000	0.137	0.139	0.002	0.479	-0.053	0.000	0.000
50th – 74th	38	780	11,117	0.151	0.094	-0.057	0.000	0.116	0.113	-0.003	0.655	-0.053	0.000	0.000
Below 50th	17	449	8,279	0.130	0.086	-0.043	0.000	0.124	0.122	-0.003	0.586	-0.041	0.001	0.002
Quoted Spread (%)														
95th +	69	1,279	30,296	0.158	0.085	-0.073	0.000	0.114	0.119	0.005	0.103	-0.078	0.000	0.000
75th – 94th	123	811	12,444	0.162	0.099	-0.063	0.000	0.133	0.136	0.003	0.284	-0.067	0.000	0.000
50th – 74th	38	780	11,117	0.211	0.136	-0.074	0.000	0.167	0.197	0.029	0.048	-0.104	0.000	0.000
Below 50th	17	449	8,279	0.226	0.176	-0.050	0.011	0.200	0.263	0.062	0.085	-0.112	0.009	0.001

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 7

Univariate Statistics Reported by Option Class Volume

Unconstrained Matching

Option Volume Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
98th+	49	2,461	48,820	0.129	0.089	-0.041	0.000	0.102	0.093	-0.009	0.002	-0.032	0.000	0.000
95th – 97th	77	869	15,309	0.105	0.064	-0.041	0.000	0.082	0.077	-0.005	0.011	-0.037	0.000	0.000
90th – 94th	73	411	6,691	0.098	0.064	-0.034	0.000	0.101	0.105	0.004	0.178	-0.037	0.000	0.000
Below 90th	48	162	2,600	0.088	0.058	-0.030	0.000	0.106	0.108	0.002	0.620	-0.032	0.000	0.000
Effective Spread (%)														
98th+	49	2,461	48,820	0.136	0.092	-0.044	0.000	0.108	0.108	0.000	0.989	-0.044	0.000	0.000
95th – 97th	77	869	15,309	0.135	0.086	-0.049	0.000	0.111	0.122	0.011	0.138	-0.060	0.000	0.000
90th – 94th	73	411	6,691	0.138	0.090	-0.048	0.000	0.100	0.107	0.008	0.021	-0.055	0.000	0.000
Below 90th	48	162	2,600	0.144	0.092	-0.052	0.000	0.142	0.162	0.020	0.067	-0.072	0.000	0.000
Quoted Spread ($)														
98th+	49	2,461	48,820	0.165	0.109	-0.057	0.000	0.124	0.115	-0.009	0.007	-0.047	0.000	0.000
95th – 97th	77	869	15,309	0.142	0.082	-0.060	0.000	0.105	0.100	-0.005	0.018	-0.055	0.000	0.000
90th – 94th	73	411	6,691	0.134	0.085	-0.049	0.000	0.134	0.139	0.006	0.160	-0.055	0.000	0.000
Below 90th	48	162	2,600	0.117	0.074	-0.042	0.000	0.138	0.139	0.002	0.748	-0.044	0.000	0.000
Quoted Spread (%)														
98th+	49	2,461	48,820	0.163	0.105	-0.058	0.000	0.124	0.125	0.001	0.774	-0.059	0.000	0.000
95th – 97th	77	869	15,309	0.171	0.101	-0.069	0.000	0.135	0.149	0.014	0.096	-0.083	0.000	0.000
90th – 94th	73	411	6,691	0.176	0.109	-0.067	0.000	0.126	0.135	0.009	0.013	-0.075	0.000	0.000
Below 90th	48	162	2,600	0.182	0.110	-0.072	0.000	0.174	0.197	0.024	0.056	-0.096	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 8

Univariate Statistics Reported by Quoted Price

Unconstrained Matching

				Switching				Non-Switching				Difference-in-Differences		
Quoted Price	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
< $1	247	322	7,690	0.054	0.027	-0.027	0.000	0.044	0.044	0.000	0.761	-0.027	0.000	0.000
$1 – $3	247	307	5,496	0.075	0.046	-0.029	0.000	0.066	0.066	0.000	0.809	-0.029	0.000	0.000
$3 – $5	245	102	1,447	0.122	0.084	-0.039	0.000	0.112	0.115	0.004	0.099	-0.042	0.000	0.000
> $5	234	148	1,720	0.195	0.145	-0.050	0.000	0.189	0.185	-0.004	0.291	-0.046	0.000	0.000
Effective Spread (%)														
< $1	247	322	7,690	0.324	0.195	-0.129	0.000	0.259	0.265	0.006	0.252	-0.135	0.000	0.000
$1 – $3	247	307	5,496	0.044	0.027	-0.018	0.000	0.038	0.038	0.000	0.899	-0.018	0.000	0.000
$3 – $5	245	102	1,447	0.033	0.022	-0.010	0.000	0.030	0.031	0.001	0.105	-0.011	0.000	0.000
> $5	234	148	1,720	0.022	0.016	-0.006	0.000	0.021	0.021	-0.001	0.261	-0.006	0.000	0.000
Quoted Spread ($)														
< $1	247	322	7,690	0.071	0.032	-0.039	0.000	0.055	0.055	0.000	0.789	-0.039	0.000	0.000
$1 – $3	247	307	5,496	0.098	0.056	-0.042	0.000	0.082	0.083	0.001	0.454	-0.043	0.000	0.000
$3 – $5	245	102	1,447	0.166	0.111	-0.055	0.000	0.147	0.151	0.004	0.034	-0.060	0.000	0.000
> $5	234	148	1,720	0.264	0.195	-0.069	0.000	0.247	0.249	0.002	0.742	-0.070	0.000	0.000
Quoted Spread (%)														
< $1	247	322	7,690	0.401	0.228	-0.173	0.000	0.312	0.318	0.006	0.272	-0.179	0.000	0.000
$1 – $3	247	307	5,496	0.058	0.033	-0.025	0.000	0.048	0.049	0.001	0.206	-0.026	0.000	0.000
$3 – $5	245	102	1,447	0.044	0.029	-0.015	0.000	0.039	0.040	0.001	0.041	-0.016	0.000	0.000
> $5	234	148	1,720	0.031	0.022	-0.009	0.000	0.028	0.028	0.000	0.846	-0.009	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Trades for a given option-class are grouped according to the bid and ask price. Instances in which the bid and ask fall into separate groups are excluded from the calculation (2.8% of trades). The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 9

Univariate Statistics Reported by Expiration Date

Unconstrained Matching

				Switching				Non-Switching				Difference-in-Differences		
Expiration Date	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
< 1 week	247	133	2,242	0.090	0.056	-0.034	0.000	0.082	0.083	0.001	0.838	-0.034	0.000	0.000
1 – 2 weeks	246	98	1,751	0.080	0.048	-0.031	0.000	0.073	0.071	-0.002	0.377	-0.030	0.000	0.000
2 – 4 weeks	247	146	2,541	0.078	0.047	-0.031	0.000	0.072	0.071	-0.001	0.627	-0.030	0.000	0.000
+4 weeks	247	535	10,412	0.110	0.074	-0.036	0.000	0.101	0.101	0.000	0.938	-0.036	0.000	0.000
Effective Spread (%)														
< 1 week	247	133	2,242	0.413	0.303	-0.110	0.000	0.357	0.364	0.007	0.487	-0.117	0.000	0.000
1 – 2 weeks	246	98	1,751	0.330	0.205	-0.125	0.000	0.260	0.264	0.005	0.594	-0.130	0.000	0.000
2 – 4 weeks	247	146	2,541	0.246	0.147	-0.100	0.000	0.191	0.204	0.014	0.038	-0.113	0.000	0.000
+4 weeks	247	535	10,412	0.102	0.061	-0.041	0.000	0.083	0.087	0.004	0.215	-0.045	0.000	0.000
Quoted Spread ($)														
< 1 week	247	133	2,242	0.118	0.071	-0.047	0.000	0.104	0.107	0.003	0.414	-0.049	0.000	0.000
1 – 2 weeks	246	98	1,751	0.104	0.060	-0.045	0.000	0.092	0.092	0.000	0.958	-0.045	0.000	0.000
2 – 4 weeks	247	146	2,541	0.104	0.059	-0.045	0.000	0.093	0.091	-0.001	0.512	-0.044	0.000	0.000
+4 weeks	247	535	10,412	0.148	0.095	-0.052	0.000	0.130	0.131	0.001	0.728	-0.053	0.000	0.000
Quoted Spread (%)														
< 1 week	247	133	2,242	0.475	0.344	-0.131	0.000	0.401	0.422	0.021	0.054	-0.152	0.000	0.000
1 – 2 weeks	246	98	1,751	0.388	0.237	-0.150	0.000	0.300	0.313	0.013	0.166	-0.164	0.000	0.000
2 – 4 weeks	247	146	2,541	0.299	0.171	-0.128	0.000	0.230	0.243	0.013	0.059	-0.141	0.000	0.000
+4 weeks	247	535	10,412	0.131	0.073	-0.058	0.000	0.104	0.109	0.005	0.190	-0.063	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Trades for a given option-class are grouped according to the time to an option series' expiration. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 10

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Unconstrained Matching

Option Classes on ETFs

				Switching				Non-Switching				Difference-in-Differences		
Addition Dates	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
All	53	1,149	39,965	0.115	0.077	-0.037	0.000	0.095	0.107	0.012	0.041	-0.050	0.000	0.000
2007 – 2009	27	1,889	70,848	0.123	0.073	-0.050	0.000	0.099	0.105	0.006	0.420	-0.056	0.000	0.000
2010 – 2011	19	239	5,950	0.105	0.061	-0.043	0.000	0.096	0.111	0.016	0.199	-0.059	0.000	0.000
2012 – 2015	7	766	13,169	0.111	0.138	0.027	0.455	0.078	0.106	0.028	0.079	-0.001	0.983	0.297
Effective Spread (%)														
All	53	1,149	39,965	0.136	0.099	-0.037	0.000	0.117	0.130	0.013	0.002	-0.050	0.000	0.000
2007 – 2009	27	1,889	70,848	0.120	0.088	-0.032	0.000	0.115	0.132	0.017	0.003	-0.049	0.000	0.000
2010 – 2011	19	239	5,950	0.146	0.101	-0.045	0.000	0.118	0.132	0.014	0.080	-0.059	0.000	0.000
2012 – 2015	7	766	13,169	0.175	0.138	-0.037	0.000	0.121	0.119	-0.002	0.858	-0.035	0.006	0.031
Quoted Spread ($)														
All	53	1,149	39,965	0.154	0.102	-0.052	0.000	0.124	0.139	0.016	0.032	-0.068	0.000	0.000
2007 – 2009	27	1,889	70,848	0.156	0.092	-0.064	0.000	0.124	0.133	0.008	0.369	-0.072	0.000	0.000
2010 – 2011	19	239	5,950	0.140	0.078	-0.062	0.000	0.127	0.146	0.020	0.173	-0.082	0.000	0.000
2012 – 2015	7	766	13,169	0.183	0.204	0.022	0.684	0.112	0.145	0.033	0.087	-0.012	0.830	0.297
Quoted Spread (%)														
All	53	1,149	39,965	0.183	0.125	-0.058	0.000	0.152	0.166	0.014	0.005	-0.072	0.000	0.000
2007 – 2009	27	1,889	70,848	0.151	0.104	-0.046	0.000	0.145	0.162	0.017	0.004	-0.064	0.000	0.000
2010 – 2011	19	239	5,950	0.192	0.126	-0.067	0.000	0.154	0.171	0.016	0.085	-0.083	0.000	0.000
2012 – 2015	7	766	13,169	0.281	0.201	-0.080	0.000	0.173	0.168	-0.005	0.762	-0.075	0.009	0.031

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 11

Univariate Statistics Reported by Underlying Market Capitalization

Unconstrained Matching

Option Classes on ETFs

Market Cap Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
75th+	14	2,213	103,814	0.125	0.077	-0.049	0.028	0.081	0.085	0.004	0.519	-0.053	0.016	0.000
50th – 74th	17	947	24,294	0.102	0.061	-0.042	0.000	0.093	0.110	0.017	0.170	-0.058	0.001	0.000
Below 50th	22	628	11,443	0.118	0.091	-0.027	0.070	0.105	0.120	0.015	0.185	-0.042	0.017	0.000
Effective Spread (%)														
75th+	14	2,213	103,814	0.126	0.086	-0.040	0.000	0.095	0.108	0.012	0.044	-0.052	0.000	0.000
50th – 74th	17	947	24,294	0.128	0.095	-0.033	0.000	0.117	0.135	0.019	0.035	-0.052	0.000	0.000
Below 50th	22	628	11,443	0.149	0.110	-0.039	0.000	0.131	0.141	0.009	0.176	-0.048	0.000	0.000
Quoted Spread ($)														
75th+	14	2,213	103,814	0.158	0.096	-0.062	0.009	0.104	0.105	0.001	0.888	-0.063	0.007	0.000
50th – 74th	17	947	24,294	0.135	0.078	-0.057	0.000	0.120	0.143	0.023	0.110	-0.080	0.000	0.000
Below 50th	22	628	11,443	0.166	0.124	-0.042	0.040	0.138	0.158	0.019	0.147	-0.061	0.009	0.000
Quoted Spread (%)														
75th+	14	2,213	103,814	0.165	0.107	-0.057	0.000	0.119	0.131	0.012	0.056	-0.069	0.000	0.000
50th – 74th	17	947	24,294	0.168	0.115	-0.053	0.000	0.151	0.172	0.021	0.025	-0.075	0.000	0.000
Below 50th	22	628	11,443	0.206	0.144	-0.063	0.000	0.173	0.183	0.010	0.283	-0.072	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 12

Univariate Statistics Reported by Option Class Volume

Unconstrained Matching

Option Classes on ETFs

Option Volume Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
95th+	15	2,350	111,135	0.128	0.091	-0.036	0.173	0.107	0.126	0.018	0.185	-0.055	0.076	0.005
90th – 94th	19	1,118	18,709	0.114	0.079	-0.035	0.001	0.075	0.081	0.006	0.361	-0.040	0.000	0.000
Below 90th	19	233	5,034	0.106	0.065	-0.041	0.000	0.105	0.119	0.015	0.228	-0.056	0.000	0.000
Effective Spread (%)														
95th+	15	2,350	111,135	0.115	0.078	-0.037	0.000	0.104	0.116	0.012	0.076	-0.048	0.000	0.000
90th – 94th	19	1,118	18,709	0.141	0.111	-0.030	0.000	0.121	0.136	0.015	0.038	-0.045	0.000	0.000
Below 90th	19	233	5,034	0.149	0.103	-0.046	0.000	0.124	0.136	0.012	0.138	-0.058	0.000	0.000
Quoted Spread ($)														
95th+	15	2,350	111,135	0.159	0.119	-0.040	0.215	0.133	0.155	0.022	0.200	-0.062	0.096	0.007
90th – 94th	19	1,118	18,709	0.162	0.108	-0.055	0.000	0.102	0.108	0.006	0.454	-0.060	0.000	0.000
Below 90th	19	233	5,034	0.141	0.083	-0.059	0.000	0.137	0.158	0.021	0.138	-0.080	0.000	0.000
Quoted Spread (%)														
95th+	15	2,350	111,135	0.148	0.097	-0.051	0.000	0.131	0.143	0.012	0.087	-0.063	0.000	0.000
90th – 94th	19	1,118	18,709	0.197	0.143	-0.054	0.000	0.158	0.170	0.012	0.142	-0.067	0.000	0.000
Below 90th	19	233	5,034	0.196	0.128	-0.067	0.000	0.162	0.180	0.017	0.094	-0.085	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Table 13

Penny Pilot Regression Results[1]

Impact on Effective Spreads

Option Classes on Common Stock

	Full Sample[2]		Dec. 2006 – Dec. 2009[3]		Jan. 2010 – Aug. 2011[4]		Dec. 2011 – Feb. 2016[5]	
Parameter	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Addition Indicator[6]	-0.088**	-0.074**	-0.034**	-0.062**	-0.080**	-0.084**	-0.005	-0.006
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.821)	(0.434)
Equity Volatility[7]	0.831**	0.587**	0.410**	0.286**	0.737**	0.305**	0.958**	0.630**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log of Option Volume[8]	-0.015**	-0.012**	-0.006**	-0.005**	-0.010**	-0.006**	-0.019**	-0.011**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log of Underlying Volume[9]	0.004*	-0.005**	0.007**	-0.002	0.010**	0.005**	0.007**	-0.003*
	(0.011)	(0.000)	(0.000)	(0.222)	(0.000)	(0.009)	(0.001)	(0.033)
Number of Class/Days	1,331,185	1,331,185	292,670	292,670	411,698	411,698	626,768	626,768
Number of Classes	3,833	3,833	2,625	2,625	2,358	2,358	3,078	3,078

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on effective spreads in the options market. The sample includes data for all options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average effective spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Effective spreads that are greater than $5 when the price is less than $100 and effective spreads that are greater than $10 otherwise are excluded from the average effective spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average effective spread is calculated, the entire option class is removed from the sample. Date and option class fixed effects are used. Standard errors are estimated by clustering on option class and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] The model is estimated over the time period from December 1, 2006 to February 29, 2016. The sample includes 38 calendar months of data.

[3] Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the December 2006 – December 2009 period.

[4] Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the January 2010 – August 2011 period.

[5] Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the December 2011 – February 2016 period.

[6] An indicator variable that equals one in the post-addition period and zero otherwise.

[7] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.

[8] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.

[9] The natural log of the volume for the underlying stock.

Table 14

Penny Pilot Regression Results[1]

Impact on Quoted Spreads

Option Classes on Common Stock

	Full Sample[2]		Dec. 2006 – Dec. 2009[3]		Jan. 2010 – Aug. 2011[4]		Dec. 2011 – Feb. 2016[5]	
Parameter	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Addition Indicator[6]	-0.161**	-0.137**	-0.053**	-0.091**	-0.122**	-0.119**	-0.037	-0.049**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.239)	(0.000)
Equity Volatility[7]	0.907**	0.705**	0.441**	0.331**	0.812**	0.360**	1.048**	0.769**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log of Option Volume[8]	-0.026**	-0.021**	-0.008**	-0.008**	-0.015**	-0.012**	-0.034**	-0.023**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log of Underlying Volume[9]	0.009**	-0.005**	0.008**	-0.002	0.014**	0.005*	0.014**	-0.005*
	(0.000)	(0.001)	(0.000)	(0.204)	(0.000)	(0.025)	(0.000)	(0.023)
Number of Class/Days	1,331,123	1,331,123	292,668	292,668	411,691	411,691	626,715	626,715
Number of Classes	3,832	3,832	2,625	2,625	2,358	2,358	3,077	3,077

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on quoted spreads in the options market. The sample includes data for all options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average quoted spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Quoted spreads that are greater than $5 when the price is less than $100 and quoted spreads that are greater than $10 otherwise are excluded from the average quoted spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average quoted spread is calculated, the entire option class is removed from the sample. Date and option class fixed effects are used. Standard errors are estimated by clustering on option class and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] The model is estimated over the time period from December 1, 2006 to February 29, 2016. The sample included 38 calendar months of data.

[3] Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the December 2006 – December 2009 period.

[4] Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the January 2010 – August 2011 period.

[5] Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the December 2011 – February 2016 period.

[6] An indicator variable that equals one in the post-addition period and zero otherwise.

[7] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.

[8] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.

[9] The natural log of the volume for the underlying stock.

Table 15

Penny Pilot Regression Results[1]

Impact on Effective Spreads

Unconstrained Matching[2]

	Full Sample[3]		Dec. 2006 – Dec. 2009[4]		Jan. 2010 – Aug. 2011[5]		Dec. 2011 – Aug. 2015[6]	
Parameter	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[7]	-0.036**	-0.058**	-0.034**	-0.059**	-0.040**	-0.060**	-0.011*	-0.032**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.036)	(0.001)
Equity Volatility[8]	0.360**	-0.200	0.286**	-0.194**	0.391**	-0.251	0.362**	0.158
	(0.000)	(0.110)	(0.000)	(0.009)	(0.000)	(0.196)	(0.002)	(0.206)
Log of Option Volume[9]	0.002**	-0.001	0.002**	0.000	0.002*	-0.002	0.001	0.016**
	(0.004)	(0.439)	(0.008)	(0.959)	(0.022)	(0.234)	(0.653)	(0.005)
Log of Underlying Volume[10]	0.008**	0.009	0.010**	0.009*	0.006**	0.010	0.018**	-0.018
	(0.000)	(0.074)	(0.000)	(0.027)	(0.001)	(0.148)	(0.001)	(0.236)
Number of Class/Days	21,025	21,025	7,368	7,368	12,369	12,369	1,288	1,288
Number of Classes	494	494	170	170	292	292	32	32

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on effective spreads in the options market. The sample includes data for options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average effective spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Option classes on common stock are identified using share code 10 and 11 in the CRSP data. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Effective spreads that are greater than $5 when the price is less than $100 and effective spreads that are greater than $10 otherwise are excluded from the average effective spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average effective spread is calculated, the entire option class is removed from the sample. Date and option event fixed effects are used. Standard errors are estimated by clustering on option class-event and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.
[3] The model is estimated over the time period from December 1, 2006 to August 31, 2015.
[3] Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the December 2006 – December 2009 period.
[4] Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the January 2010 – August 2011 period.
[5] Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the December 2011 – August 2015 period.
[7] An indicator variable that equals one in the post-switch period and zero otherwise.
[8] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.
[9] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.
[10] The natural log of the volume for the underlying stock.

Table 16

Penny Pilot Regression Results[1]

Impact on Quoted Spreads

Unconstrained Matching[2]

	Full Sample[3]		Dec. 2006 – Dec. 2009[4]		Jan. 2010 – Aug. 2011[5]		Dec. 2011 – Feb. 2015[6]	
Parameter	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**	**Dollar**	**Percent**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[7]	-0.052**	-0.078**	-0.048**	-0.075**	-0.056**	-0.082**	-0.036**	-0.062**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility[8]	0.393**	-0.195	0.274**	-0.228**	0.439**	-0.247	0.405*	0.313*
	(0.000)	(0.161)	(0.002)	(0.003)	(0.000)	(0.253)	(0.011)	(0.021)
Log of Option Volume[9]	0.000	-0.004*	0.001	-0.001	0.000	-0.004*	-0.002	0.003
	(0.698)	(0.019)	(0.256)	(0.452)	(0.795)	(0.023)	(0.759)	(0.600)
Log of Underlying Volume[10]	0.011**	0.011*	0.014**	0.011**	0.008**	0.012	0.029**	-0.009
	(0.000)	(0.032)	(0.000)	(0.009)	(0.000)	(0.105)	(0.000)	(0.321)
Number of Class/Days	21,025	21,025	7,368	7,368	12,369	12,369	1,288	1,288
Number of Classes	494	494	170	170	292	292	32	32

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on quoted spreads in the options market. The sample includes data for options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average quoted spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Option classes on common stock are identified using share code 10 and 11 in the CRSP data. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Quoted spreads that are greater than $5 when the price is less than $100 and quoted spreads that are greater than $10 otherwise are excluded from the average quoted spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average quoted spread is calculated, the entire option class is removed from the sample. Date and option event fixed effects are used. Standard errors are estimated by clustering on option class-event and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.
[3] The model is estimated over the time period from December 1, 2006 to August 31, 2015.
[3] Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the December 2006 – December 2009 period.
[4] Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the January 2010 – August 2011 period.
[5] Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the December 2011 – August 2015 period.
[7] An indicator variable that equals one in the post-switch period and zero otherwise.
[8] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.
[9] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.
[10] The natural log of the volume for the underlying stock.

Table 17

Penny Pilot Regression Results[1]

Impact on Effective Spreads

Unconstrained Matching[2]

	Market Capitalization Percentile[3]							
	95th and Above		75th – 94th		50th – 74th		Below 50th	
Parameter	Dollar	Percent	Dollar	Percent	Dollar	Percent	Dollar	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[4]	-0.035**	-0.060**	-0.036**	-0.047**	-0.037**	-0.076**	-0.032**	-0.087**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility[5]	0.602**	-0.083	0.407**	-0.056	0.334**	-0.536	0.286**	-0.097
	(0.000)	(0.378)	(0.000)	(0.300)	(0.000)	(0.085)	(0.000)	(0.781)
Log of Option Volume[6]	0.002**	0.001	0.002*	-0.001	0.001	0.000	0.001	-0.015
	(0.009)	(0.439)	(0.013)	(0.542)	(0.799)	(0.959)	(0.568)	(0.150)
Log of Underlying Volume[7]	0.009**	0.007**	0.010**	0.007*	0.007	0.034*	0.001	-0.005
	(0.000)	(0.004)	(0.000)	(0.010)	(0.104)	(0.027)	(0.792)	(0.664)
Number of Class/Days	5,923	5,923	10,465	10,465	3,198	3,198	1,439	1,439
Number of Classes	138	138	246	246	76	76	34	34

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on effective spreads in the options market. The sample includes data for options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average effective spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Effective spreads that are greater than $5 when the price is less than $100 and effective spreads that are greater than $10 otherwise are excluded from the average effective spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average effective spread is calculated, the entire option class is removed from the sample. Date and option event fixed effects are used. Standard errors are estimated by clustering on option class-event and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.

[3] Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE.

[4] An indicator variable that equals one in the post-switch period and zero otherwise.

[5] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.

[6] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.

[7] The natural log of the volume for the underlying stock.

Table 18

Penny Pilot Regression Results[1]

Impact on Quoted Spreads

Unconstrained Matching[2]

	Market Capitalization Percentile[3]							
	95th and Above		75th – 94th		50th – 74th		Below 50th	
Parameter	Dollar	Percent	Dollar	Percent	Dollar	Percent	Dollar	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[4]	-0.050**	-0.078**	-0.054**	-0.066**	-0.053**	-0.101**	-0.044**	-0.112**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility[5]	0.626**	-0.116	0.414**	-0.048	0.454**	-0.457	0.338**	-0.150
	(0.000)	(0.224)	(0.000)	(0.452)	(0.000)	(0.167)	(0.000)	(0.712)
Log of Option Volume[6]	0.001	0.000	0.001	-0.002	-0.001	-0.004	-0.001	-0.022*
	(0.222)	(0.993)	(0.642)	(0.105)	(0.656)	(0.446)	(0.713)	(0.048)
Log of Underlying Volume[7]	0.012**	0.009**	0.014**	0.008**	0.008	0.035*	0.001	0.002
	(0.000)	(0.000)	(0.000)	(0.010)	(0.098)	(0.019)	(0.811)	(0.891)
Number of Class/Days	5,923	5,923	10,465	10,465	3,198	3,198	1,439	1,439
Number of Classes	138	138	246	246	76	76	34	34

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on quoted spreads in the options market. The sample includes data for options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average quoted spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Quoted spreads that are greater than $5 when the price is less than $100 and quoted spreads that are greater than $10 otherwise are excluded from the average quoted spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average quoted spread is calculated, the entire option class is removed from the sample. Date and option class-event fixed effects are used. Standard errors are estimated by clustering on option class-event and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.

[3] Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE.

[4] An indicator variable that equals one in the post-switch period and zero otherwise.

[5] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.

[6] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.

[7] The natural log of the volume for the underlying stock.

Table 19

Penny Pilot Regression Results[1]

Impact on Effective Spreads

Unconstrained Matching[2]

	Option Volume Percentile[3]							
	98th and Above		95th – 97th		90th – 94th		Below 90th	
Parameter	Dollar	Percent	Dollar	Percent	Dollar	Percent	Dollar	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[4]	-0.033**	-0.045**	-0.038**	-0.061**	-0.037**	-0.055**	-0.034**	-0.070**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility[5]	0.374**	-0.054	0.277**	-0.307	0.422**	0.051	0.368**	-0.423
	(0.000)	(0.502)	(0.000)	(0.129)	(0.000)	(0.443)	(0.000)	(0.273)
Log of Option Volume[6]	0.003*	0.001	0.003**	0.001	0.003*	0.002	-0.001	-0.005
	(0.039)	(0.511)	(0.002)	(0.575)	(0.026)	(0.241)	(0.599)	(0.106)
Log of Underlying Volume[7]	0.012**	0.005	0.006*	0.002	0.007**	0.003	0.006	0.023
	(0.000)	(0.236)	(0.047)	(0.620)	(0.000)	(0.470)	(0.093)	(0.120)
Number of Class/Days	4,208	4,208	6,609	6,609	6,156	6,156	4,052	4,052
Number of Classes	98	98	154	154	146	146	96	96

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on effective spreads in the options market. The sample includes data for options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average effective spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Effective spreads that are greater than $5 when the price is less than $100 and effective spreads that are greater than $10 otherwise are excluded from the average effective spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average effective spread is calculated, the entire option class is removed from the sample. Date and option class-event fixed effects are used. Standard errors are estimated by clustering on option class-event and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.

[3] Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

[4] An indicator variable that equals one in the post-switch period and zero otherwise.

[5] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.

[6] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.

[7] The natural log of the volume for the underlying stock.

Table 20

Penny Pilot Regression Results[1]

Impact on Quoted Spreads

Unconstrained Matching[2]

	Option Volume Percentile[3]							
	98th and Above		95th – 97th		90th – 94th		Below 90th	
Parameter	Dollar	Percent	Dollar	Percent	Dollar	Percent	Dollar	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[4]	-0.048**	-0.059**	-0.056**	-0.084**	-0.055**	-0.075**	-0.045**	-0.092**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility[5]	0.415**	-0.025	0.266**	-0.365	0.487**	0.090	0.421**	-0.368
	(0.000)	(0.762)	(0.001)	(0.123)	(0.000)	(0.281)	(0.001)	(0.362)
Log of Option Volume[6]	0.002	0.000	0.002	0.000	0.001	-0.001	-0.003	-0.008**
	(0.156)	(0.928)	(0.083)	(0.920)	(0.559)	(0.722)	(0.115)	(0.009)
Log of Underlying Volume[7]	0.015**	0.006	0.010**	0.003	0.010**	0.006	0.008*	0.026
	(0.000)	(0.148)	(0.009)	(0.529)	(0.000)	(0.186)	(0.049)	(0.094)
Number of Class/Days	4,208	4,208	6,609	6,609	6,156	6,156	4,052	4,052
Number of Classes	98	98	154	154	146	146	96	96

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on quoted spreads in the options market. The sample includes data for options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average quoted spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Quoted spreads that are greater than $5 when the price is less than $100 and quoted spreads that are greater than $10 otherwise are excluded from the average quoted spread calculation. If the underlying stocks traded below $1 or above $1,000 on any day for which an average quoted spread is calculated, the entire option class is removed from the sample. Date and option class-event fixed effects are used. Standard errors are estimated by clustering on option class-event and date. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.

[2] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.

[3] Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

[4] An indicator variable that equals one in the post-switch period and zero otherwise.

[5] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.

[6] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.

[7] The natural log of the volume for the underlying stock.

Table 21

Penny Pilot Regression Results[1]

Option Classes on ETFs

	Full Sample[2]				Unconstrained Matching[3]			
	Effective Spread		Quoted Spread		Effective Spread		Quoted Spread	
Parameter	Dollar	Percent	Dollar	Percent	Dollar	Percent	Dollar	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[4]	0.008	-0.032**	-0.045*	-0.093**	-0.049**	-0.050**	-0.066**	-0.072**
	(0.664)	(0.000)	(0.034)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Equity Volatility[5]	2.293**	0.149	2.331**	-0.055	1.067**	0.190	1.304**	0.097
	(0.000)	(0.144)	(0.000)	(0.682)	(0.000)	(0.120)	(0.000)	(0.501)
Log of Option Volume[6]	-0.023**	-0.014**	-0.031**	-0.021**	0.001	0.001	0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.399)	(0.782)	(0.729)	(0.659)
Log of Underlying Volume[7]	-0.029**	-0.010**	-0.040**	-0.011**	0.003	-0.008**	0.001	-0.011**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.602)	(0.001)	(0.860)	(0.000)
Number of Class/Days	194,694	194,694	194,659	194,659	4,537	4,537	4,537	4,537
Number of Classes	693	693	693	693	106	106	106	106

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on quoted and effective spreads in the options market. The sample includes data for all options on ETFs that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average quoted or average effective spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. Quoted spreads that are greater than $5 when the price is less than $100 and quoted spreads that are greater than $10 otherwise are excluded from the average quoted spread calculation. The same restrictions are used to calculate average effective spreads. If the underlying ETF traded below $1 or above $1,000 on any day for which an average quoted spread or effective spread is calculated, the entire option class is removed from the sample. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] All option classes on common stock for which LiveVol has data are included. Date and option class fixed effects are used. Standard errors are estimated by clustering on option class and date.
[3] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Date and option class-event fixed effects are used. Standard errors are estimated by clustering on option class-event and date.
[4] An indicator variable that equals one in the post-switch period and zero otherwise. Note that under unconstrained matching, a switching option class may match with an option class that is already in the Pilot, in which case the option class that is already in the Pilot, acting as the control option class, has a value of zero in the pre-switch and post-switch period.
[5] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.
[6] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.
[7] The natural log of the volume for the underlying stock.

Table 22

Liquidity Metrics for In-Pilot Option Classes and Control Samples

February 2016

Option Volume Quartile for In-Pilot Option Classes	Percentile Range in Universe of Option Classes	Number of Option Classes	Number of Clusters for Matching with Replacement[1]	Daily Volume of Option Class (Contracts)			Market Cap of Underlying Stock (Millions)		
				In-Pilot	With Replacement[2]	Without Replacement[3]	In-Pilot	With Replacement[2]	Without Replacement[3]
First Quartile	41.4% - 88.3%	56	53	1,044	1,053	825	10,963	10,434	8,789
Second Quartile	88.4% - 95.0%	57	41	3,906	3,734	2,122	27,821	21,220	14,311
Third Quartile	95.0% - 97.7%	57	25	10,005	6,208	2,841	50,927	37,125	19,441
Fourth Quartile	97.7% - 100.0%	56	23	53,504	10,977	4,990	107,613	71,809	24,334

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] The number of unique control option classes in matching with replacement. In matching with replacement, an in-Pilot option class can match with any number of switching option classes.
[2] Each in-Pilot option class is matched to an out-of-Pilot option classes based on underlying market capitalization, underlying price, and option volume. Matching is completed with replacement, i.e. an out-of-Pilot option class can match with any number of in-Pilot option classes.
[3] Each in-Pilot option class is matched to an out-of-Pilot option classes based on underlying market capitalization, underlying price, and option volume. Matching is completed without replacement, i.e. an out-of-Pilot option class can match with only one in-Pilot option class.

Table 23

Penny Pilot Impact on Quoted and Effective Spreads[1]

February 2016

	Matching without Replacement[2]				Matching with Replacement[3]			
	Quoted Spread		Effective Spread		Quoted Spread		Effective Spread	
Option Volume Quartile	Dollar	Percent	Dollar	Percent	Dollar	Percent	Dollar	Percent
	(1)	(2)	(3)	(4)	(5)	(6)	(5)	(6)
First Quartile	-0.014 (0.730)	-0.044 (0.066)	-0.015 (0.536)	-0.030 (0.061)	0.000 (0.995)	-0.055* (0.035)	-0.004 (0.852)	-0.037* (0.043)
Second Quartile	-0.124* (0.012)	-0.052 (0.093)	-0.075* (0.016)	-0.021 (0.321)	-0.078 (0.119)	-0.015 (0.605)	-0.052 (0.103)	0.002 (0.917)
Third Quartile	-0.195** (0.000)	-0.074** (0.000)	-0.117** (0.000)	-0.033** (0.001)	-0.096** (0.000)	-0.071** (0.000)	-0.056** (0.001)	-0.032** (0.007)
Fourth Quartile	-0.200** (0.000)	-0.075** (0.000)	-0.124** (0.000)	-0.031** (0.000)	-0.218 (0.084)	-0.072** (0.001)	-0.150 (0.122)	-0.031** (0.005)

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a paired t-test that estimates the difference in spreads for options in the Penny Pilot versus options outside the Penny Pilot as of February 2016. The variable of interest is the average spread. The average spread is calculated by (1) calculating the volume weighted spread for an option series-day and then (2) equally weighting across option series to calculate the average spread for an option class-day. Canceled trades and trades that were executed during a locked or crossed market are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 (i.e. trades corresponding to regular trades and intermarket sweep orders) are included. Spreads that are greater than $5 when the price is less than $100 and spreads that are greater than $10 otherwise are excluded from the average spread calculation. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] Each in-Pilot option class is matched to an out-of-Pilot option classes based on underlying market capitalization, underlying price, and option volume. Matching is completed without replacement, i.e. an out-of-Pilot option class can match with only one in-Pilot option class.
[3] Each in-Pilot option class is matched to an out-of-Pilot option classes based on underlying market capitalization, underlying price, and option volume. Matching is completed with replacement, i.e. an out-of-Pilot option class can match with any number of in-Pilot option classes. Standard errors are clustered on the out-of-Pilot option class.

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Appendix A

Univariate Statistics Reported by Underlying Market Capitalization

Complex Options: Option Spread Trades

Market Cap Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
95th +	69	47	1,161	0.071	0.048	-0.023	0.000	0.061	0.062	0.000	0.870	-0.023	0.000	0.000
75th – 94th	123	38	633	0.076	0.057	-0.019	0.000	0.076	0.077	0.001	0.662	-0.020	0.000	0.000
50th – 74th	38	43	686	0.083	0.059	-0.023	0.001	0.078	0.074	-0.004	0.687	-0.020	0.122	0.000
Below 50th	16	13	325	0.084	0.061	-0.023	0.025	0.078	0.083	0.005	0.387	-0.028	0.013	0.018
Quoted Spread ($)														
95th +	69	47	1,161	0.224	0.110	-0.114	0.000	0.164	0.166	0.002	0.723	-0.116	0.000	0.000
75th – 94th	123	38	633	0.270	0.144	-0.126	0.000	0.244	0.248	0.004	0.552	-0.129	0.000	0.000
50th – 74th	38	43	686	0.278	0.164	-0.114	0.000	0.247	0.241	-0.006	0.716	-0.108	0.000	0.000
Below 50th	16	13	325	0.259	0.162	-0.097	0.000	0.267	0.343	0.076	0.024	-0.174	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Spread trades are identified by filtering to instances in which two calls or puts were traded in the same second, both of which had a trade condition id designating a spread (35). The best bid, best ask, and trade price for the trade were calculated by taking the difference between the best bid from leg one and the best ask from leg two, the difference between the best ask from leg one and the best bid from leg two, and the difference between the trade price across the two legs. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Percentiles are defined using the stocks listed on the NYSE. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Option Class Volume

Complex Options: Option Spread Trades

Option Volume Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
98th+	49	111	1,964	0.083	0.058	-0.024	0.000	0.070	0.061	-0.008	0.002	-0.016	0.000	0.000
95th – 97th	77	36	853	0.071	0.048	-0.023	0.000	0.058	0.060	0.001	0.437	-0.024	0.000	0.000
90th – 94th	73	17	295	0.076	0.053	-0.023	0.000	0.073	0.076	0.003	0.108	-0.026	0.000	0.000
Below 90th	47	6	125	0.079	0.066	-0.013	0.006	0.098	0.101	0.003	0.703	-0.016	0.138	0.001
Quoted Spread ($)														
98th+	49	111	1,964	0.258	0.143	-0.115	0.000	0.177	0.166	-0.011	0.083	-0.104	0.000	0.000
95th – 97th	77	36	853	0.246	0.123	-0.123	0.000	0.173	0.171	-0.002	0.685	-0.121	0.000	0.000
90th – 94th	73	17	295	0.256	0.142	-0.114	0.000	0.240	0.257	0.017	0.012	-0.130	0.000	0.000
Below 90th	47	6	125	0.279	0.155	-0.124	0.000	0.330	0.353	0.023	0.271	-0.147	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Spread trades are identified by filtering to instances in which two calls or puts were traded in the same second, both of which had a trade condition id designating a spread (35). The best bid, best ask, and trade price for the trade were calculated by taking the difference between the best bid from leg one and the best ask from leg two, the difference between the best ask from leg one and the best bid from leg two, and the difference between the trade price across the two legs. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Complex Options: Option Spread Trades

Average Trade Size (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	246	39	770	31	26	-5.577	0.037	29	32	2.466	0.538	-8.043	0.084	0.202
2007 – 2009	85	46	1,173	37	27	-9.943	0.011	38	34	-3.619	0.542	-6.324	0.379	0.265
2010 – 2011	145	19	400	30	26	-3.238	0.406	25	32	6.342	0.277	-9.580	0.152	0.564
2012 – 2015	16	184	1,979	18	15	-3.579	0.308	19	19	-0.330	0.926	-3.249	0.504	0.433
Market Capitalization Percentiles														
95th +	69	47	1,161	32	27	-4.096	0.068	32	35	3.125	0.643	-7.221	0.324	0.062
75th – 94th	123	38	633	33	25	-7.710	0.112	28	28	-0.581	0.899	-7.129	0.280	0.567
50th – 74th	38	43	686	26	23	-3.076	0.602	32	44	12.199	0.490	-15.275	0.365	0.983
Below 50th	16	13	325	28	26	-1.509	0.775	21	21	-0.066	0.982	-1.443	0.782	0.744
Option Volume Percentiles														
98th+	49	111	1,964	32	28	-4.202	0.086	37	32	-5.025	0.172	0.823	0.864	0.495
95th – 97th	77	36	853	39	26	-13.506	0.016	33	34	0.857	0.898	-14.363	0.093	0.174
90th – 94th	73	17	295	27	27	-0.024	0.997	24	25	0.879	0.880	-0.903	0.913	0.665
Below 90th	47	6	125	25	22	-2.648	0.567	24	39	15.377	0.309	-18.024	0.218	0.950

Source: LiveVol; OptionMetrics; CRSP.

Note: Spread trades are identified by filtering to instances in which two calls or two puts were traded in the same second, both of which had a trade condition id designating a spread (35). Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Complex Options: Option Spread Trades

Log Average Daily Volume (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	246	39	770	5.94	5.87	-0.07	0.312	5.83	5.62	-0.21	0.004	0.14	0.136	0.056
2007 – 2009	85	46	1,173	6.61	6.51	-0.11	0.303	6.64	6.43	-0.21	0.038	0.10	0.462	0.172
2010 – 2011	145	19	400	5.44	5.39	-0.06	0.555	5.24	5.00	-0.25	0.023	0.19	0.164	0.130
2012 – 2015	16	184	1,979	6.92	6.93	0.01	0.975	6.89	6.99	0.10	0.536	-0.09	0.737	0.900
Market Capitalization Percentiles														
95th +	69	47	1,161	6.50	6.37	-0.12	0.091	6.49	6.48	-0.02	0.896	-0.11	0.421	0.617
75th – 94th	123	38	633	5.77	5.81	0.04	0.738	5.63	5.46	-0.17	0.078	0.21	0.123	0.065
50th – 74th	38	43	686	5.80	5.61	-0.19	0.382	5.70	5.28	-0.41	0.062	0.22	0.484	0.198
Below 50th	16	13	325	5.20	4.85	-0.35	0.154	4.83	3.95	-0.89	0.045	0.54	0.278	0.404
Option Volume Percentiles														
98th+	49	111	1,964	7.21	7.17	-0.03	0.743	7.21	7.06	-0.15	0.168	0.12	0.419	0.096
95th – 97th	77	36	853	6.48	6.18	-0.30	0.003	6.31	6.02	-0.29	0.035	-0.01	0.934	0.982
90th – 94th	73	17	295	5.49	5.50	0.00	0.979	5.48	5.37	-0.11	0.400	0.11	0.540	0.457
Below 90th	47	6	125	4.44	4.60	0.16	0.326	4.17	3.86	-0.31	0.161	0.47	0.103	0.068

Source: LiveVol; OptionMetrics; CRSP.

Note: Spread trades are identified by filtering to instances in which two calls or two puts were traded in the same second, both of which had a trade condition id designating a spread (35). Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Underlying Market Capitalization

Complex Options: Option Straddle Trades

Market Cap Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
95th +	69	9	429	0.090	0.061	-0.029	0.000	0.084	0.075	-0.009	0.041	-0.020	0.000	0.000
75th – 94th	123	7	169	0.088	0.070	-0.017	0.000	0.095	0.096	0.001	0.791	-0.019	0.001	0.000
50th – 74th	36	5	111	0.090	0.063	-0.027	0.000	0.072	0.079	0.007	0.367	-0.034	0.000	0.000
Below 50th	14	6	113	0.088	0.063	-0.025	0.028	0.080	0.080	0.000	0.985	-0.026	0.246	0.326
Effective Spread (%)														
95th +	69	9	429	0.032	0.022	-0.010	0.000	0.028	0.028	0.000	0.931	-0.010	0.000	0.000
75th – 94th	123	7	169	0.034	0.026	-0.009	0.000	0.035	0.039	0.004	0.240	-0.013	0.001	0.000
50th – 74th	36	5	111	0.048	0.041	-0.006	0.452	0.041	0.055	0.013	0.121	-0.020	0.125	0.009
Below 50th	14	6	113	0.070	0.038	-0.031	0.027	0.049	0.107	0.058	0.249	-0.089	0.092	0.030
Quoted Spread ($)														
95th +	69	9	429	0.233	0.112	-0.121	0.000	0.187	0.170	-0.017	0.115	-0.104	0.000	0.000
75th – 94th	123	7	169	0.259	0.138	-0.121	0.000	0.239	0.251	0.012	0.118	-0.132	0.000	0.000
50th – 74th	36	5	111	0.267	0.148	-0.120	0.000	0.215	0.220	0.005	0.781	-0.125	0.000	0.000
Below 50th	14	6	113	0.236	0.131	-0.105	0.000	0.224	0.257	0.033	0.092	-0.138	0.000	0.000
Quoted Spread (%)														
95th +	69	9	429	0.092	0.036	-0.057	0.000	0.056	0.057	0.001	0.788	-0.058	0.000	0.000
75th – 94th	123	7	169	0.107	0.044	-0.063	0.000	0.087	0.100	0.014	0.041	-0.077	0.000	0.000
50th – 74th	36	5	111	0.149	0.123	-0.026	0.634	0.121	0.159	0.038	0.089	-0.064	0.295	0.000
Below 50th	14	6	113	0.172	0.075	-0.097	0.000	0.127	0.221	0.093	0.122	-0.190	0.006	0.002

Source: LiveVol; OptionMetrics; CRSP.

Note: Straddle trades are identified by filtering to instances in which a call and a put were traded in the same second, both of which had a trade condition id designating a straddle (36). The best bid, best ask, and trade price for the trade were calculated by summing the best bid, best ask, and trade price across the two legs. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Option Class Volume

Complex Options: Option Straddle Trades

Option Volume Percentile	N	Average Daily Trade Count	Average Daily Volume	Switching				Non-Switching				Difference-in-Differences		
				Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)														
98th+	49	12	506	0.108	0.072	-0.036	0.000	0.098	0.079	-0.019	0.004	-0.017	0.011	0.003
95th – 97th	77	8	246	0.081	0.057	-0.023	0.000	0.073	0.073	-0.001	0.769	-0.023	0.000	0.000
90th – 94th	72	6	134	0.088	0.074	-0.014	0.012	0.088	0.096	0.007	0.236	-0.022	0.009	0.000
Below 90th	44	3	59	0.084	0.064	-0.020	0.000	0.099	0.104	0.005	0.542	-0.025	0.011	0.013
Effective Spread (%)														
98th+	49	12	506	0.037	0.026	-0.011	0.000	0.032	0.032	0.000	0.984	-0.011	0.002	0.001
95th – 97th	77	8	246	0.035	0.026	-0.009	0.000	0.033	0.050	0.017	0.067	-0.026	0.009	0.000
90th – 94th	72	6	134	0.037	0.026	-0.011	0.001	0.034	0.035	0.002	0.732	-0.013	0.031	0.022
Below 90th	44	3	59	0.043	0.034	-0.009	0.184	0.042	0.050	0.008	0.277	-0.017	0.110	0.007
Quoted Spread ($)														
98th+	49	12	506	0.261	0.138	-0.123	0.000	0.203	0.165	-0.038	0.007	-0.085	0.000	0.000
95th – 97th	77	8	246	0.245	0.117	-0.128	0.000	0.173	0.173	0.000	0.987	-0.128	0.000	0.000
90th – 94th	72	6	134	0.252	0.142	-0.111	0.000	0.234	0.263	0.029	0.006	-0.139	0.000	0.000
Below 90th	44	3	59	0.251	0.134	-0.116	0.000	0.298	0.315	0.017	0.338	-0.133	0.000	0.000
Quoted Spread (%)														
98th+	49	12	506	0.100	0.040	-0.060	0.000	0.060	0.063	0.003	0.539	-0.064	0.000	0.000
95th – 97th	77	8	246	0.109	0.045	-0.064	0.000	0.072	0.107	0.035	0.017	-0.099	0.000	0.000
90th – 94th	72	6	134	0.115	0.048	-0.067	0.000	0.085	0.088	0.003	0.724	-0.070	0.000	0.000
Below 90th	44	3	59	0.131	0.101	-0.030	0.502	0.136	0.167	0.031	0.030	-0.061	0.213	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Straddle trades are identified by filtering to instances in which a call and a put were traded in the same second, both of which had a trade condition id designating a straddle (36). The best bid, best ask, and trade price for the trade were calculated by summing the best bid, best ask, and trade price across the two legs. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Complex Options: Option Straddle Trades

Average Trade Size (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	242	7	231	36	30	-5.745	0.060	34	32	-2.087	0.452	-3.657	0.396	0.038
2007 – 2009	85	9	406	53	42	-11.011	0.130	54	51	-3.508	0.647	-7.503	0.503	0.240
2010 – 2011	141	6	138	27	24	-2.841	0.324	24	22	-1.530	0.205	-1.312	0.668	0.103
2012 – 2015	16	10	123	18	15	-3.352	0.206	15	16	0.548	0.885	-3.900	0.403	0.528
Market Capitalization Percentiles														
95^{th} +	69	9	429	56	42	-14.550	0.089	54	48	-5.746	0.515	-8.803	0.499	0.119
75^{th} – 94^{th}	123	7	169	29	27	-1.852	0.601	27	27	-0.282	0.898	-1.570	0.711	0.162
50^{th} – 74^{th}	36	5	111	24	22	-2.241	0.378	21	23	2.485	0.339	-4.726	0.205	0.271
Below 50^{th}	14	6	113	22	16	-5.554	0.066	29	17	-11.670	0.003	6.116	0.201	0.268
Option Volume Percentiles														
98^{th}+	49	12	506	59	45	-13.071	0.278	64	54	-10.099	0.427	-2.973	0.873	0.743
95^{th} – 97^{th}	77	8	246	34	29	-5.083	0.076	33	35	1.401	0.628	-6.484	0.113	0.047
90^{th} – 94^{th}	72	6	134	27	20	-7.349	0.005	23	20	-2.881	0.053	-4.468	0.156	0.193
Below 90^{th}	44	3	59	26	30	3.882	0.625	20	22	2.029	0.375	1.853	0.824	0.147

Source: LiveVol; OptionMetrics; CRSP.

Note: Straddle trades are identified by filtering to instances in which a call and a put were traded in the same second, both of which had a trade condition id designating a straddle (36). Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix A

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Complex Options: Option Straddle Trades

Log Average Daily Volume (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	242	7	231	4.83	4.67	-0.16	0.025	4.87	4.48	-0.39	0.000	0.22	0.041	0.044
2007 – 2009	85	9	406	5.51	5.43	-0.08	0.459	5.62	5.39	-0.23	0.032	0.15	0.370	0.378
2010 – 2011	141	6	138	4.51	4.26	-0.25	0.007	4.49	3.93	-0.56	0.000	0.31	0.048	0.032
2012 – 2015	16	10	123	4.08	4.34	0.25	0.498	4.24	4.59	0.36	0.233	-0.10	0.784	0.706
Market Capitalization Percentiles														
95^{th} +	69	9	429	5.59	5.42	-0.17	0.121	5.71	5.41	-0.31	0.009	0.14	0.439	0.544
75^{th} – 94^{th}	123	7	169	4.70	4.53	-0.16	0.131	4.64	4.32	-0.33	0.010	0.17	0.311	0.246
50^{th} – 74^{th}	36	5	111	4.17	4.18	0.01	0.956	4.19	4.08	-0.11	0.491	0.12	0.611	0.468
Below 50^{th}	14	6	113	4.05	3.50	-0.55	0.183	4.39	2.40	-1.99	0.000	1.44	0.032	0.058
Option Volume Percentiles														
98^{th}+	49	12	506	5.71	5.75	0.03	0.825	5.93	5.78	-0.15	0.259	0.18	0.418	0.489
95^{th} – 97^{th}	77	8	246	5.22	4.94	-0.28	0.009	5.17	4.83	-0.34	0.012	0.06	0.722	0.958
90^{th} – 94^{th}	72	6	134	4.50	4.31	-0.19	0.180	4.58	4.06	-0.52	0.005	0.33	0.134	0.102
Below 90^{th}	44	3	59	3.72	3.61	-0.11	0.576	3.63	3.12	-0.51	0.021	0.39	0.221	0.134

Source: LiveVol; OptionMetrics; CRSP.

Note: Straddle trades are identified by filtering to instances in which a call and a put were traded in the same second, both of which had a trade condition id designating a straddle (36). Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix B

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Unconstrained Matching

Average Trade Size (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	247	912	16,940	21	16	-5.089	0.000	20	19	-0.757	0.031	-4.332	0.000	0.000
2007 – 2009	85	1,363	30,563	27	20	-6.429	0.000	24	24	-0.371	0.557	-6.057	0.000	0.000
2010 – 2011	146	443	7,181	19	14	-4.415	0.000	18	17	-0.870	0.055	-3.545	0.000	0.000
2012 – 2015	16	2,795	33,618	15	11	-4.120	0.031	16	14	-1.775	0.086	-2.345	0.308	0.323
Market Capitalization Percentiles														
95th +	69	1,279	30,296	26	19	-6.858	0.000	22	22	-0.218	0.699	-6.640	0.000	0.000
75th – 94th	123	811	12,444	20	15	-4.589	0.000	19	17	-1.283	0.010	-3.307	0.000	0.000
50th – 74th	38	780	11,117	19	15	-3.386	0.000	20	18	-1.410	0.073	-1.976	0.087	0.059
Below 50th	17	449	8,279	20	14	-5.326	0.004	19	22	2.322	0.299	-7.647	0.014	0.023
Option Volume Percentiles														
98th+	49	2,461	48,820	28	21	-6.752	0.000	25	25	-0.800	0.342	-5.951	0.000	0.000
95th – 97th	77	869	15,309	21	16	-5.214	0.000	21	21	-0.386	0.591	-4.828	0.000	0.000
90th – 94th	73	411	6,691	20	15	-4.956	0.000	16	15	-0.757	0.089	-4.199	0.000	0.000
Below 90th	48	162	2,600	17	14	-3.391	0.000	18	17	-1.308	0.139	-2.083	0.033	0.041

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix B

Penny Pilot Regression Results[1]

Impact on Average Trade Size
Option Classes on Common Stock

	Full Sample[2]				Unconstrained Matching[3]			
Parameter	**12/06 – 2/16[4]**	**12/06 – 12/09[5]**	**1/10 – 8/11[6]**	**12/11 – 2/16[7]**	**12/06 – 2/16[4]**	**12/06 – 12/09[5]**	**1/10 – 8/11[6]**	**12/11 – 2/16[7]**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-Switch Indicator[8]	-7.521**	-11.895**	-4.556**	-3.873*	-6.305**	-8.368**	-5.682**	-2.294
	(0.000)	(0.000)	(0.000)	(0.032)	(0.000)	(0.000)	(0.000)	(0.092)
Equity Volatility[9]	-37.177**	-52.963**	-53.406**	-40.350**	-102.146**	-163.175**	-81.018**	-84.556
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.166)
Log of Option Volume[10]	5.524**	6.906**	6.246**	5.552**	10.475**	15.720**	8.959**	10.372**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log of Underlying Volume[11]	-3.425**	-4.269**	-3.335**	-3.502**	-6.990**	-10.934**	-5.964**	-6.307**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of Class/Days	1,331,188	292,671	411,698	626,770	21,025	7,368	12,369	1,288
Number of Classes	3,833	2,625	2,358	3,078	494	170	292	32

Sources: LiveVol; CRSP; OptionMetrics; ISE Penny Pilot Addition Dates.

[1] This table reports results from a panel regression estimating the effects of switching to trading in pennies on average trade size in the options market. The sample includes data for all options on common stock that traded in the calendar month before and calendar month after the Penny Pilot addition dates. The dependent variable is the average trade size. The average trade size is calculated as the total volume divided by the total trade count for a given option class-day. Canceled trades are excluded. Options with non-standard settlement types are excluded. Only trades with a condition code in 0, 18, 95, and 106 are included. Condition codes 0, 18, 95, and 106 correspond to regular trades and intermarket sweep orders. If the underlying stocks traded below $1 or above $1,000 on any day for which an average trade size is calculated, the entire option class is removed from the sample. The "Permno" in CRSP is used to identify option classes over time. P-values are reported in parentheses below the coefficient estimates. Coefficient estimates that are statistically different from zero at the 5% significance level are marked with one asterisk and those that are statistically different from zero at the 1% significance level are marked with two asterisks.
[2] All option classes on common stock for which LiveVol has data are included. Date and option class fixed effects are used. Standard errors are estimated by clustering on option class and date.
[3] Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume.
[4] The model is estimated over the time period from December 1, 2006 to February 29, 2016.
[5] Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the December 2006 – December 2009 period
[6] Pilot addition dates 1/5/10, 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the January 2010 – August 2011 period.
[7] Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the December 2011 – February 2016 period.
[8] An indicator variable that equals one in the post-switch period and zero otherwise. Note that under unconstrained matching, a switching option class may match with an option class that is already in the pilot, in which case the option class that is already in the pilot, acting as the control option class, has a value of zero in the pre-switch and post-switch period.
[9] The underlying stock volatility as measured by the high price minus the low price divided by the closing price.
[10] The natural log of the option class volume. The option class volume excludes canceled trades and only includes trades with a condition code in 0, 18, 95, and 106.
[11] The natural log of the volume for the underlying stock.

Appendix B

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Unconstrained Matching

Average Daily Volume (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Average Change	P-Value	Pre	Post	Average Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	247	912	16,940	16,905	17,519	0.133	0.012	17,067	14,731	-0.088	0.029	0.221	0.000	0.000
2007 – 2009	85	1,363	30,563	30,563	31,919	0.134	0.128	31,307	27,652	-0.101	0.042	0.235	0.010	0.014
2010 – 2011	146	443	7,181	7,171	6,672	0.106	0.102	7,737	6,158	-0.094	0.119	0.200	0.018	0.001
2012 – 2015	16	2,795	33,618	33,171	39,994	0.375	0.263	26,545	24,309	0.042	0.707	0.332	0.310	0.348
Market Capitalization Percentiles														
95th +	69	1,279	30,296	30,296	29,461	-0.050	0.270	31,668	28,230	-0.013	0.878	-0.037	0.701	0.625
75th – 94th	123	811	12,444	12,438	14,653	0.292	0.001	12,010	10,176	-0.107	0.040	0.400	0.000	0.000
50th – 74th	38	780	11,117	10,907	10,427	0.085	0.457	10,616	9,290	-0.131	0.174	0.215	0.140	0.059
Below 50th	17	449	8,279	8,279	5,638	-0.171	0.439	8,806	5,053	-0.152	0.421	-0.018	0.953	0.890
Option Volume Percentiles														
98th+	49	2,461	48,820	48,674	50,817	0.038	0.615	47,203	41,655	-0.091	0.124	0.129	0.168	0.242
95th – 97th	77	869	15,309	15,290	14,600	-0.033	0.663	16,804	13,333	-0.140	0.028	0.107	0.231	0.039
90th – 94th	73	411	6,691	6,691	7,449	0.182	0.137	6,656	6,392	0.009	0.929	0.172	0.237	0.097
Below 90th	48	162	2,600	2,600	3,525	0.422	0.002	2,557	2,168	-0.148	0.034	0.570	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix B

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Unconstrained Matching

Option Classes on ETFs

Average Daily Volume (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Average Change	P-Value	Pre	Post	Average Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	53	1,149	39,965	39,892	42,336	0.043	0.498	67,208	59,770	-0.175	0.004	0.219	0.019	0.018
2007 – 2009	27	1,889	70,848	70,848	75,242	-0.032	0.717	124,798	110,451	-0.193	0.016	0.161	0.183	0.168
2010 – 2011	19	239	5,950	5,950	6,113	0.098	0.394	6,086	4,990	-0.241	0.005	0.339	0.061	0.087
2012 – 2015	7	766	13,169	12,617	13,736	0.186	0.302	10,975	12,972	0.072	0.788	0.114	0.647	0.578
Market Capitalization Percentiles														
75th+	14	2,213	103,814	103,612	121,414	0.169	0.167	217,704	199,024	-0.070	0.555	0.239	0.153	0.135
50th – 74th	17	947	24,294	24,294	19,023	-0.022	0.854	20,232	12,777	-0.295	0.009	0.274	0.123	0.174
Below 50th	22	628	11,443	11,396	10,029	0.013	0.898	7,736	7,466	-0.150	0.106	0.163	0.280	0.184
Option Volume Percentiles														
95th+	15	2,350	111,135	110,877	123,701	0.125	0.313	193,553	179,344	-0.081	0.503	0.206	0.214	0.252
90th – 94th	19	1,118	18,709	18,709	14,227	-0.164	0.084	30,190	22,165	-0.095	0.348	-0.068	0.552	0.891
Below 90th	19	233	5,034	5,034	6,210	0.186	0.106	4,478	2,974	-0.330	0.001	0.515	0.006	0.008

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix B

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Unconstrained Matching

NBBO Size (Contracts)

				Switching				Non-Switching				Difference-in-Differences		
	N	Average Daily Trade Count	Average Daily Volume	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods														
All	247	912	16,940	4,516	1,021	-3495	0.000	2,297	2,417	120	0.045	-3616	0.000	0.000
2007 – 2009	85	1,363	30,563	6,635	1,612	-5023	0.000	3,497	3,798	301	0.021	-5324	0.000	0.000
2010 – 2011	146	443	7,181	3,333	678	-2655	0.000	1,649	1,677	29	0.645	-2683	0.000	0.000
2012 – 2015	16	2,795	33,618	4,061	1,014	-3047	0.005	1,829	1,830	1	0.998	-3048	0.001	0.000
Market Capitalization Percentiles														
95th +	69	1,279	30,296	6,475	1,579	-4896	0.000	2,980	3,260	280	0.031	-5176	0.000	0.000
75th – 94th	123	811	12,444	4,061	864	-3197	0.000	2,074	2,212	137	0.067	-3335	0.000	0.000
50th – 74th	38	780	11,117	3,375	703	-2672	0.000	2,133	1,954	-179	0.306	-2493	0.000	0.000
Below 50th	17	449	8,279	2,413	608	-1805	0.000	1,500	1,520	20	0.924	-1825	0.001	0.000
Option Volume Percentiles														
98th+	49	2,461	48,820	6,629	1,881	-4748	0.000	3,127	3,755	629	0.003	-5377	0.000	0.000
95th – 97th	77	869	15,309	5,219	1,043	-4176	0.000	2,695	2,580	-115	0.312	-4061	0.000	0.000
90th – 94th	73	411	6,691	3,576	745	-2831	0.000	1,786	1,934	148	0.016	-2979	0.000	0.000
Below 90th	48	162	2,600	2,663	528	-2135	0.000	1,588	1,525	-63	0.346	-2072	0.000	0.000

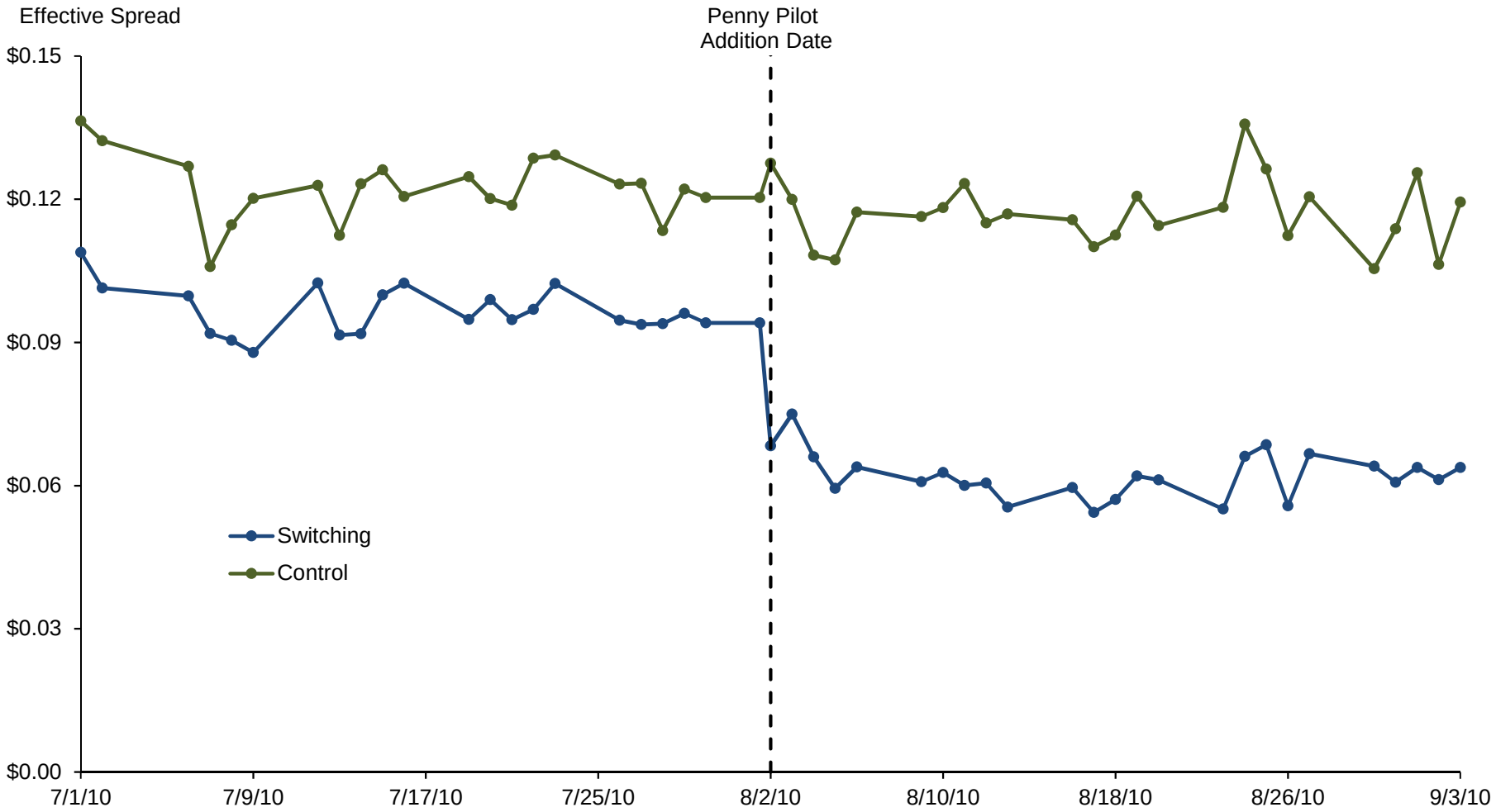
Source: LiveVol; OptionMetrics; CRSP.

Note: The total size reflects the total size offered and the national best bid and national best offer across all exchanges. The total size is winsorized at the 99th percentile to control for outliers. Instances in which the spread was locked or cross and instances in which the best bid (ask) size was zero, but the best bid (ask) price was non-zero, were removed. Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data. The average daily volume and average daily trade count are calculated on a per symbol basis and are calculated using the month prior to the month the option class was added to the Pilot (the "pre" month).

Appendix C

Impact of Addition to the Penny Pilot on Effective Spreads ($)

Addition Date: August 2, 2010



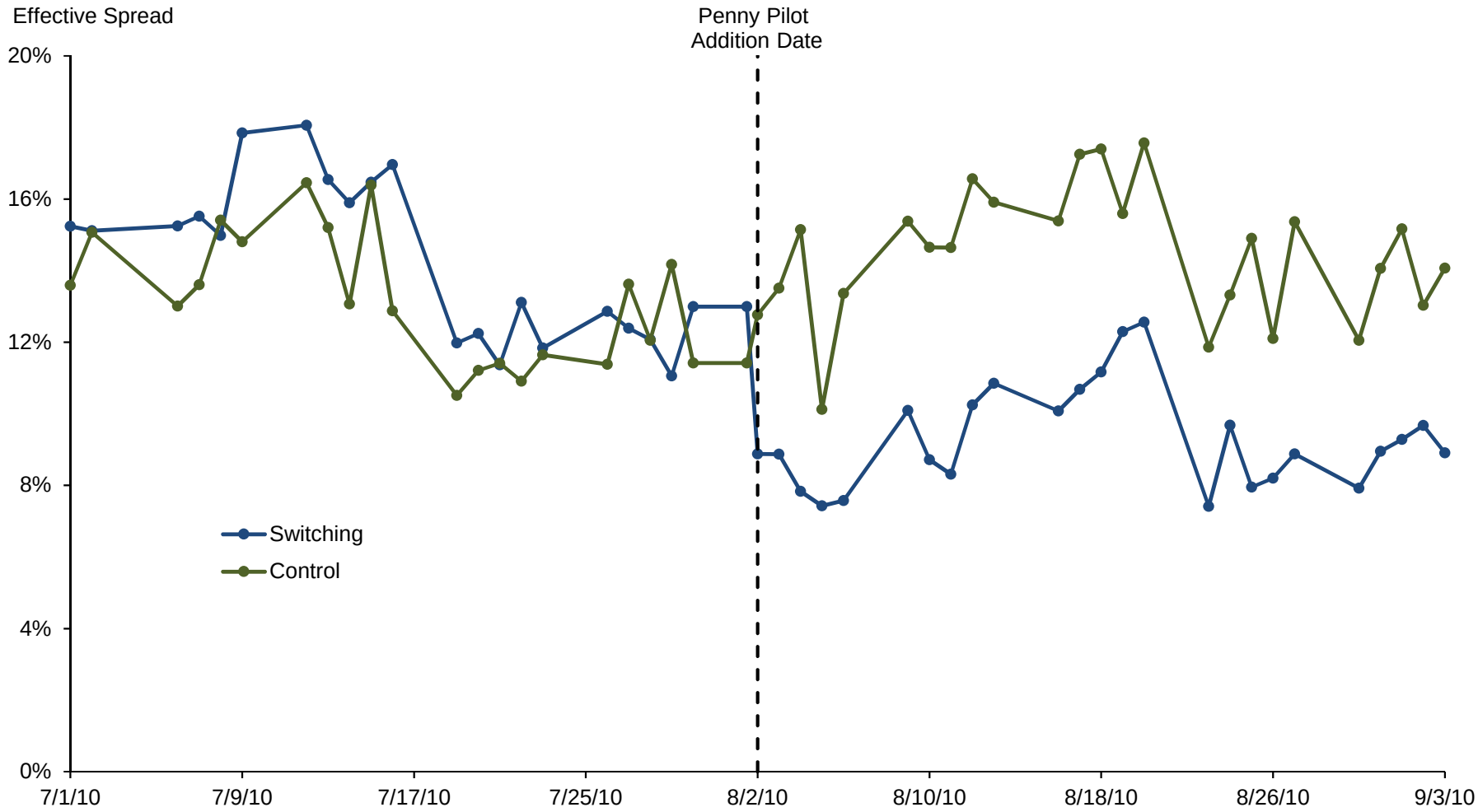
Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 46 option classes on common stock that were added to the Penny Pilot on August 2, 2010 for which LiveVol has data. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Effective spreads for the switching and control samples are averaged across each date.

Appendix C

Impact of Addition to the Penny Pilot on Effective Spreads (%)

Addition Date: August 2, 2010

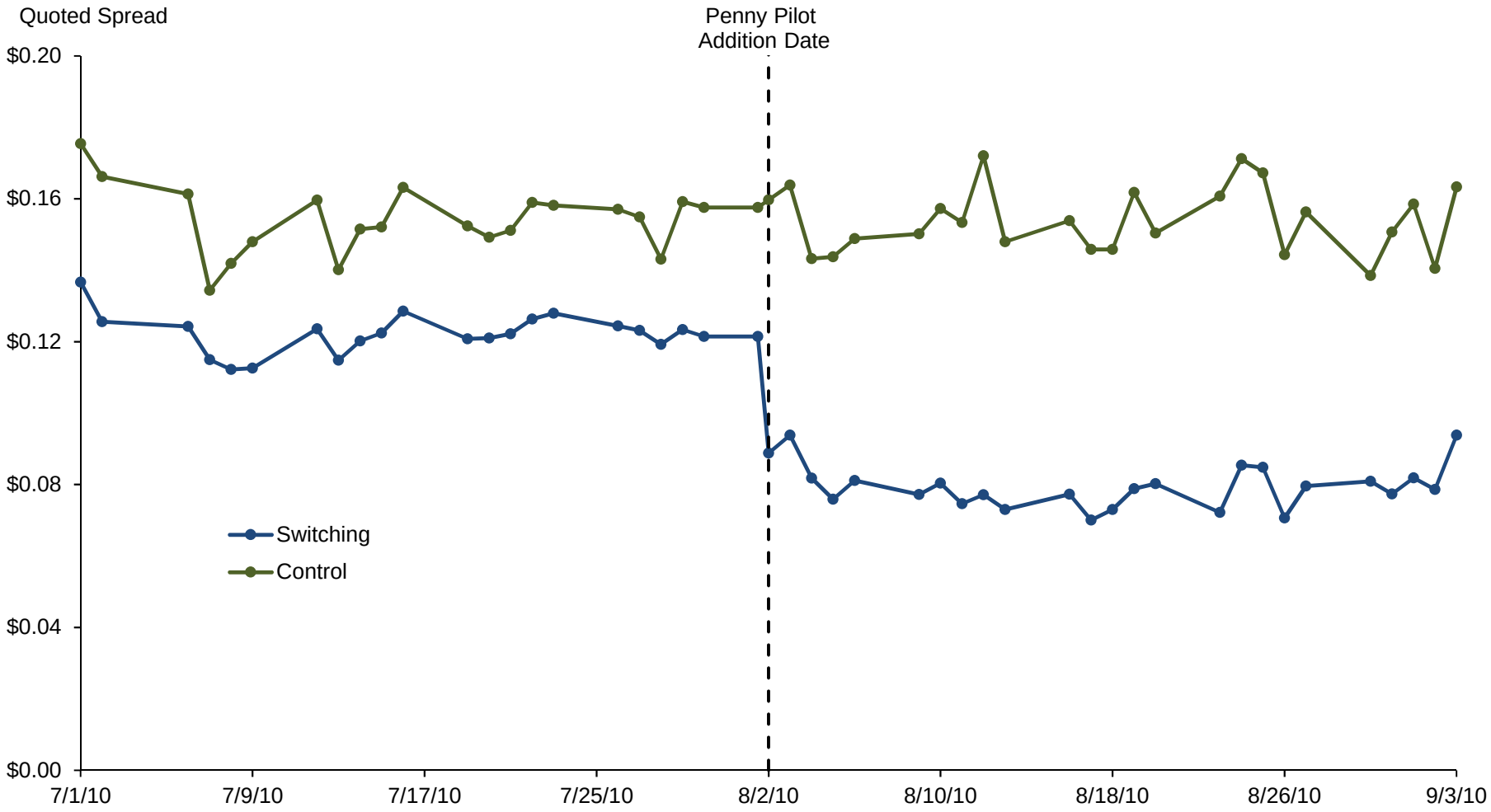


Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 46 option classes on common stock that were added to the Penny Pilot on August 2, 2010 for which LiveVol has data. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Effective spreads for the switching and control samples are averaged across each date.

Impact of Addition to the Penny Pilot on Quoted Spreads ($)

Addition Date: August 2, 2010

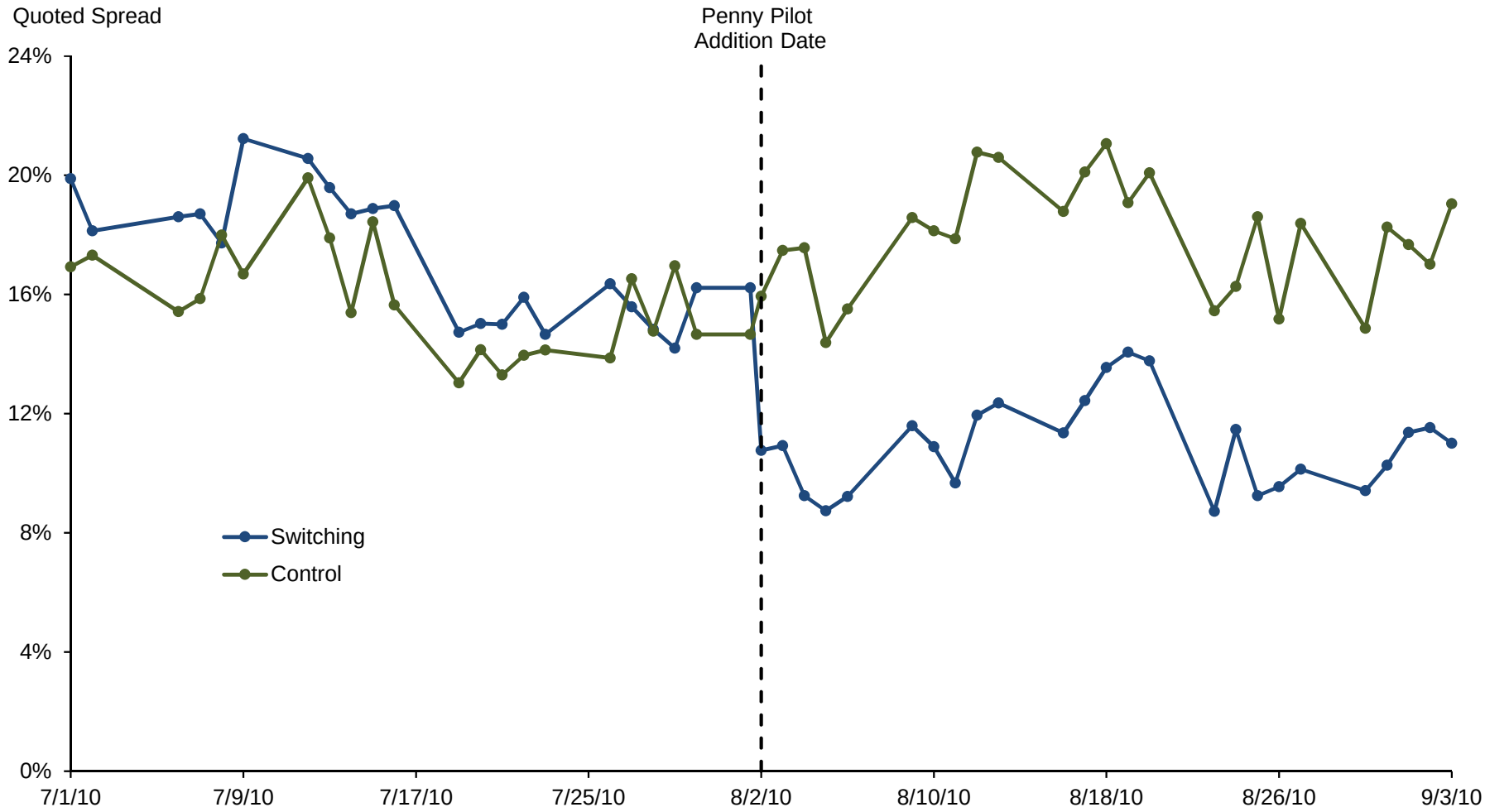


Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 46 option classes on common stock that were added to the Penny Pilot on August 2, 2010 for which LiveVol has data. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Quoted spreads for the switching and control samples are averaged across each date.

Impact of Addition to the Penny Pilot on Quoted Spreads (%)

Addition Date: August 2, 2010



Source: LiveVol; OptionMetrics, CRSP.

Note: Includes 46 option classes on common stock that were added to the Penny Pilot on August 2, 2010 for which LiveVol has data. Each switching option class is matched with a non-switching option class outside the Pilot based on underlying market capitalization and option volume. Quoted spreads for the switching and control samples are averaged across each date.

Appendix D

Univariate Statistics Reported by Addition Date

Unconstrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread ($)						
1/26/2007	9	0.078	0.052	-0.026	0.000	0.104	0.095	-0.009	0.032	-0.017	0.000	0.004
9/28/2007	15	0.147	0.100	-0.047	0.000	0.137	0.117	-0.020	0.006	-0.027	0.001	0.002
3/28/2008	20	0.108	0.072	-0.036	0.000	0.118	0.115	-0.003	0.575	-0.034	0.000	0.000
11/2/2009	41	0.102	0.055	-0.047	0.000	0.080	0.072	-0.008	0.005	-0.039	0.000	0.000
2/1/2010	50	0.089	0.053	-0.036	0.000	0.089	0.087	-0.002	0.333	-0.034	0.000	0.000
5/3/2010	46	0.107	0.066	-0.042	0.000	0.099	0.104	0.005	0.273	-0.047	0.000	0.000
8/2/2010	46	0.097	0.065	-0.032	0.000	0.081	0.085	0.004	0.159	-0.036	0.000	0.000
1/4/2011	1	0.076	0.039	-0.036	–	0.081	0.077	-0.004	–	-0.032	–	–
7/6/2011	3	0.125	0.102	-0.022	–	0.126	0.130	0.004	–	-0.026	–	–
1/4/2012	1	0.134	0.141	0.007	–	0.031	0.054	0.023	–	-0.016	–	–
7/3/2012	2	0.084	0.054	-0.030	–	0.090	0.078	-0.012	–	-0.018	–	–
1/3/2013	5	0.100	0.090	-0.010	–	0.101	0.094	-0.007	–	-0.003	–	–
7/3/2013	1	0.254	0.245	-0.009	–	0.212	0.198	-0.014	–	0.005	–	–
1/3/2014	3	0.188	0.179	-0.008	–	0.102	0.106	0.004	–	-0.012	–	–
7/3/2014	1	0.133	0.092	-0.041	–	0.493	0.492	-0.001	–	-0.040	–	–
1/5/2015	1	0.176	0.120	-0.056	–	0.075	0.051	-0.024	–	-0.033	–	–
7/6/2015	2	0.186	0.183	-0.002	–	0.071	0.093	0.023	–	-0.025	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Appendix D

Univariate Statistics Reported by Addition Date

Unconstrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread (%)						
1/26/2007	9	0.171	0.107	-0.064	0.001	0.153	0.149	-0.004	0.814	-0.059	0.063	0.027
9/28/2007	15	0.136	0.071	-0.065	0.000	0.123	0.113	-0.010	0.087	-0.055	0.000	0.000
3/28/2008	20	0.140	0.085	-0.055	0.000	0.099	0.100	0.000	0.970	-0.056	0.000	0.000
11/2/2009	41	0.134	0.085	-0.049	0.000	0.106	0.118	0.012	0.006	-0.061	0.000	0.000
2/1/2010	50	0.126	0.071	-0.055	0.000	0.107	0.109	0.002	0.486	-0.057	0.000	0.000
5/3/2010	46	0.124	0.100	-0.024	0.000	0.105	0.141	0.035	0.003	-0.059	0.000	0.000
8/2/2010	46	0.143	0.086	-0.056	0.000	0.120	0.129	0.009	0.385	-0.066	0.000	0.000
1/4/2011	1	0.387	0.213	-0.173	–	0.222	0.240	0.018	–	-0.192	–	–
7/6/2011	3	0.129	0.124	-0.006	–	0.119	0.116	-0.003	–	-0.003	–	–
1/4/2012	1	0.145	0.086	-0.058	–	0.162	0.101	-0.060	–	0.002	–	–
7/3/2012	2	0.245	0.168	-0.077	–	0.141	0.141	0.000	–	-0.077	–	–
1/3/2013	5	0.219	0.167	-0.052	–	0.156	0.136	-0.020	–	-0.031	–	–
7/3/2013	1	0.105	0.103	-0.002	–	0.089	0.078	-0.011	–	0.009	–	–
1/3/2014	3	0.140	0.113	-0.027	–	0.098	0.099	0.001	–	-0.028	–	–
7/3/2014	1	0.135	0.096	-0.039	–	0.104	0.102	-0.002	–	-0.036	–	–
1/5/2015	1	0.201	0.159	-0.041	–	0.142	0.096	-0.046	–	0.005	–	–
7/6/2015	2	0.134	0.123	-0.012	–	0.122	0.158	0.037	–	-0.049	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Appendix D

Univariate Statistics Reported by Addition Date

Unconstrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread ($)						
1/26/2007	9	0.089	0.058	-0.031	0.000	0.115	0.106	-0.009	0.033	-0.022	0.000	0.004
9/28/2007	15	0.168	0.110	-0.058	0.000	0.161	0.136	-0.026	0.002	-0.032	0.001	0.003
3/28/2008	20	0.123	0.081	-0.042	0.000	0.134	0.132	-0.002	0.670	-0.041	0.000	0.000
11/2/2009	41	0.140	0.073	-0.068	0.000	0.104	0.098	-0.006	0.082	-0.062	0.000	0.000
2/1/2010	50	0.125	0.070	-0.055	0.000	0.120	0.118	-0.002	0.414	-0.053	0.000	0.000
5/3/2010	46	0.146	0.085	-0.061	0.000	0.132	0.135	0.003	0.708	-0.064	0.000	0.000
8/2/2010	46	0.122	0.083	-0.039	0.000	0.099	0.110	0.010	0.018	-0.050	0.000	0.000
1/4/2011	1	0.097	0.050	-0.048	–	0.107	0.107	-0.001	–	-0.047	–	–
7/6/2011	3	0.161	0.132	-0.028	–	0.163	0.169	0.006	–	-0.034	–	–
1/4/2012	1	0.197	0.198	0.001	–	0.038	0.072	0.034	–	-0.033	–	–
7/3/2012	2	0.130	0.079	-0.051	–	0.142	0.119	-0.023	–	-0.028	–	–
1/3/2013	5	0.158	0.133	-0.025	–	0.158	0.140	-0.018	–	-0.007	–	–
7/3/2013	1	0.389	0.366	-0.023	–	0.271	0.261	-0.010	–	-0.013	–	–
1/3/2014	3	0.297	0.252	-0.046	–	0.158	0.152	-0.007	–	-0.039	–	–
7/3/2014	1	0.208	0.129	-0.078	–	0.693	0.721	0.028	–	-0.106	–	–
1/5/2015	1	0.279	0.186	-0.093	–	0.111	0.090	-0.022	–	-0.071	–	–
7/6/2015	2	0.331	0.262	-0.069	–	0.107	0.142	0.036	–	-0.105	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Appendix D

Univariate Statistics Reported by Addition Date

Unconstrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread (%)						
1/26/2007	9	0.188	0.115	-0.073	0.000	0.169	0.162	-0.008	0.663	-0.066	0.036	0.020
9/28/2007	15	0.152	0.077	-0.075	0.000	0.139	0.127	-0.012	0.088	-0.063	0.000	0.000
3/28/2008	20	0.153	0.088	-0.065	0.000	0.106	0.108	0.001	0.789	-0.066	0.000	0.000
11/2/2009	41	0.170	0.103	-0.067	0.000	0.130	0.147	0.017	0.000	-0.085	0.000	0.000
2/1/2010	50	0.168	0.085	-0.082	0.000	0.137	0.139	0.002	0.602	-0.084	0.000	0.000
5/3/2010	46	0.159	0.120	-0.040	0.000	0.133	0.170	0.037	0.009	-0.076	0.000	0.000
8/2/2010	46	0.173	0.101	-0.072	0.000	0.139	0.157	0.017	0.150	-0.089	0.000	0.000
1/4/2011	1	0.476	0.254	-0.221	–	0.291	0.325	0.034	–	-0.255	–	–
7/6/2011	3	0.154	0.145	-0.009	–	0.146	0.142	-0.003	–	-0.005	–	–
1/4/2012	1	0.191	0.111	-0.080	–	0.175	0.109	-0.066	–	-0.014	–	–
7/3/2012	2	0.305	0.223	-0.083	–	0.197	0.180	-0.017	–	-0.065	–	–
1/3/2013	5	0.284	0.214	-0.069	–	0.191	0.167	-0.024	–	-0.045	–	–
7/3/2013	1	0.154	0.145	-0.010	–	0.108	0.104	-0.005	–	-0.005	–	–
1/3/2014	3	0.223	0.155	-0.067	–	0.143	0.140	-0.004	–	-0.064	–	–
7/3/2014	1	0.208	0.122	-0.086	–	0.143	0.150	0.007	–	-0.093	–	–
1/5/2015	1	0.338	0.214	-0.124	–	0.200	0.158	-0.042	–	-0.083	–	–
7/6/2015	2	0.253	0.177	-0.076	–	0.199	0.252	0.053	–	-0.129	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. P-values are not reported for sample sizes smaller than six.

Appendix E

Univariate Statistics Reported by Addition Date

Unconstrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread ($)						
1/26/2007	3	0.076	0.049	-0.028	–	0.092	0.092	0.000	–	-0.028	–	–
9/28/2007	4	0.138	0.076	-0.062	–	0.198	0.257	0.060	–	-0.122	–	–
3/28/2008	1	0.422	0.130	-0.292	–	0.040	0.043	0.003	–	-0.295	–	–
11/2/2009	19	0.112	0.073	-0.038	0.000	0.082	0.078	-0.004	0.325	-0.034	0.000	0.000
2/1/2010	6	0.086	0.056	-0.030	0.011	0.097	0.089	-0.008	0.369	-0.022	0.096	0.094
5/3/2010	7	0.073	0.047	-0.026	0.000	0.084	0.136	0.052	0.070	-0.078	0.014	0.016
8/2/2010	6	0.159	0.083	-0.077	0.002	0.109	0.106	-0.003	0.874	-0.074	0.004	0.031
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.152	0.111	-0.041	–	0.065	0.055	-0.010	–	-0.031	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.101	0.192	0.091	–	0.063	0.069	0.006	–	0.084	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.082	0.116	0.034	–	0.104	0.169	0.065	–	-0.031	–	–
1/5/2016	1	0.173	0.123	-0.050	–	0.044	0.044	0.000	–	-0.050	–	–

Appendix E

Univariate Statistics Reported by Addition Date

Unconstrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread (%)						
1/26/2007	3	0.126	0.082	-0.044	–	0.111	0.129	0.018	–	-0.062	–	–
9/28/2007	4	0.091	0.054	-0.037	–	0.093	0.088	-0.005	–	-0.032	–	–
3/28/2008	1	0.102	0.076	-0.026	–	0.108	0.099	-0.009	–	-0.017	–	–
11/2/2009	19	0.125	0.096	-0.029	0.000	0.121	0.143	0.023	0.002	-0.052	0.000	0.000
2/1/2010	6	0.157	0.107	-0.050	0.010	0.106	0.102	-0.004	0.482	-0.046	0.028	0.031
5/3/2010	7	0.143	0.101	-0.042	0.015	0.113	0.154	0.041	0.013	-0.083	0.002	0.016
8/2/2010	6	0.137	0.094	-0.044	0.012	0.137	0.136	0.000	0.968	-0.043	0.012	0.063
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.130	0.071	-0.060	–	0.097	0.071	-0.027	–	-0.033	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.128	0.098	-0.030	–	0.124	0.136	0.012	–	-0.042	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.192	0.160	-0.032	–	0.126	0.137	0.011	–	-0.044	–	–
1/5/2016	1	0.263	0.221	-0.043	–	0.127	0.082	-0.045	–	0.003	–	–

Appendix E

Univariate Statistics Reported by Addition Date

Unconstrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread ($)						
1/26/2007	3	0.089	0.054	-0.035	–	0.106	0.104	-0.002	–	-0.033	–	–
9/28/2007	4	0.163	0.089	-0.074	–	0.232	0.305	0.073	–	-0.147	–	–
3/28/2008	1	0.447	0.141	-0.306	–	0.043	0.047	0.004	–	-0.310	–	–
11/2/2009	19	0.150	0.096	-0.054	0.000	0.109	0.105	-0.004	0.364	-0.050	0.000	0.000
2/1/2010	6	0.122	0.072	-0.050	0.004	0.132	0.116	-0.017	0.125	-0.034	0.069	0.094
5/3/2010	7	0.102	0.058	-0.044	0.000	0.113	0.176	0.063	0.057	-0.107	0.007	0.016
8/2/2010	6	0.203	0.107	-0.096	0.002	0.136	0.142	0.005	0.793	-0.101	0.001	0.031
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.256	0.172	-0.083	–	0.095	0.079	-0.016	–	-0.067	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.166	0.285	0.119	–	0.088	0.099	0.011	–	0.108	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.144	0.161	0.017	–	0.151	0.229	0.078	–	-0.061	–	–
1/5/2016	1	0.261	0.206	-0.054	–	0.064	0.057	-0.007	–	-0.047	–	–

Appendix E

Univariate Statistics Reported by Addition Date

Unconstrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread (%)						
1/26/2007	3	0.146	0.089	-0.057	–	0.127	0.143	0.016	–	-0.073	–	–
9/28/2007	4	0.106	0.060	-0.045	–	0.107	0.104	-0.003	–	-0.042	–	–
3/28/2008	1	0.110	0.080	-0.030	–	0.110	0.097	-0.013	–	-0.017	–	–
11/2/2009	19	0.163	0.117	-0.046	0.000	0.157	0.181	0.023	0.004	-0.069	0.000	0.000
2/1/2010	6	0.206	0.133	-0.073	0.004	0.144	0.133	-0.011	0.211	-0.062	0.024	0.031
5/3/2010	7	0.194	0.123	-0.071	0.001	0.150	0.194	0.044	0.017	-0.115	0.000	0.016
8/2/2010	6	0.177	0.122	-0.056	0.016	0.169	0.181	0.012	0.519	-0.067	0.015	0.063
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.188	0.095	-0.094	–	0.139	0.104	-0.034	–	-0.059	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.215	0.141	-0.073	–	0.169	0.189	0.020	–	-0.093	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.325	0.237	-0.088	–	0.185	0.195	0.010	–	-0.099	–	–
1/5/2016	1	0.375	0.318	-0.056	–	0.179	0.105	-0.074	–	0.018	–	–

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. P-values are not reported for sample sizes smaller than six.

Appendix F

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Dates	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
All	247	0.105	0.068	-0.037	0.000	0.122	0.120	-0.003	0.178	-0.034	0.000	0.000
2007 – 2009	85	0.109	0.066	-0.042	0.000	0.125	0.116	-0.010	0.000	-0.032	0.000	0.000
2010 – 2011	146	0.098	0.062	-0.036	0.000	0.120	0.122	0.002	0.441	-0.038	0.000	0.000
2012 – 2015	16	0.144	0.129	-0.015	0.011	0.130	0.123	-0.006	0.370	-0.008	0.344	0.433
Effective Spread (%)												
All	247	0.138	0.090	-0.048	0.000	0.129	0.144	0.015	0.003	-0.063	0.000	0.000
2007 – 2009	85	0.140	0.085	-0.055	0.000	0.126	0.131	0.006	0.083	-0.060	0.000	0.000
2010 – 2011	146	0.132	0.087	-0.046	0.000	0.127	0.149	0.022	0.006	-0.068	0.000	0.000
2012 – 2015	16	0.179	0.138	-0.041	0.000	0.166	0.157	-0.009	0.299	-0.032	0.008	0.008
Quoted Spread ($)												
All	247	0.139	0.087	-0.053	0.000	0.160	0.157	-0.002	0.366	-0.050	0.000	0.000
2007 – 2009	85	0.136	0.080	-0.056	0.000	0.154	0.144	-0.009	0.001	-0.047	0.000	0.000
2010 – 2011	146	0.131	0.080	-0.052	0.000	0.158	0.161	0.003	0.458	-0.054	0.000	0.000
2012 – 2015	16	0.230	0.186	-0.043	0.000	0.205	0.193	-0.012	0.181	-0.031	0.013	0.018
Quoted Spread (%)												
All	247	0.173	0.106	-0.067	0.000	0.163	0.180	0.017	0.001	-0.084	0.000	0.000
2007 – 2009	85	0.165	0.096	-0.069	0.000	0.150	0.157	0.007	0.031	-0.076	0.000	0.000
2010 – 2011	146	0.169	0.104	-0.065	0.000	0.161	0.186	0.025	0.003	-0.090	0.000	0.000
2012 – 2015	16	0.256	0.183	-0.073	0.000	0.246	0.238	-0.007	0.458	-0.065	0.001	0.001

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period.

Appendix F

Univariate Statistics Reported by Underlying Market Capitalization

Constrained Matching

Market Cap Percentile	N	Switching				Non-Switching				Difference-in-Differences		
		Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
95th +	69	0.102	0.061	-0.041	0.000	0.125	0.120	-0.005	0.074	-0.036	0.000	0.000
75th – 94th	123	0.107	0.071	-0.036	0.000	0.131	0.130	0.000	0.876	-0.035	0.000	0.000
50th – 74th	38	0.106	0.069	-0.037	0.000	0.100	0.095	-0.005	0.255	-0.032	0.000	0.000
Below 50th	17	0.095	0.066	-0.029	0.001	0.101	0.100	-0.001	0.849	-0.028	0.005	0.007
Effective Spread (%)												
95th +	69	0.132	0.075	-0.057	0.000	0.121	0.128	0.007	0.029	-0.064	0.000	0.000
75th – 94th	123	0.128	0.084	-0.045	0.000	0.121	0.123	0.002	0.408	-0.047	0.000	0.000
50th – 74th	38	0.163	0.112	-0.051	0.000	0.152	0.211	0.059	0.048	-0.111	0.001	0.000
Below 50th	17	0.176	0.142	-0.035	0.020	0.168	0.204	0.037	0.006	-0.071	0.000	0.000
Quoted Spread ($)												
95th +	69	0.130	0.074	-0.056	0.000	0.157	0.153	-0.004	0.285	-0.052	0.000	0.000
75th – 94th	123	0.143	0.092	-0.051	0.000	0.170	0.172	0.002	0.703	-0.053	0.000	0.000
50th – 74th	38	0.151	0.094	-0.057	0.000	0.141	0.130	-0.011	0.131	-0.045	0.000	0.000
Below 50th	17	0.130	0.086	-0.043	0.000	0.137	0.132	-0.005	0.326	-0.038	0.002	0.003
Quoted Spread (%)												
95th +	69	0.158	0.085	-0.073	0.000	0.147	0.156	0.009	0.015	-0.081	0.000	0.000
75th – 94th	123	0.162	0.099	-0.063	0.000	0.152	0.156	0.004	0.208	-0.067	0.000	0.000
50th – 74th	38	0.211	0.136	-0.074	0.000	0.202	0.266	0.064	0.036	-0.138	0.000	0.000
Below 50th	17	0.226	0.176	-0.050	0.011	0.213	0.254	0.041	0.006	-0.091	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE.

Appendix F

Univariate Statistics Reported by Option Class Volume

Constrained Matching

Option Volume Percentile	N	Switching				Non-Switching				Difference-in-Differences		
		Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
98th+	49	0.129	0.089	-0.041	0.000	0.126	0.114	-0.012	0.001	-0.028	0.000	0.000
95th – 97th	77	0.105	0.064	-0.041	0.000	0.113	0.113	0.000	0.947	-0.041	0.000	0.000
90th – 94th	73	0.098	0.064	-0.034	0.000	0.141	0.140	-0.001	0.794	-0.033	0.000	0.000
Below 90th	48	0.088	0.058	-0.030	0.000	0.104	0.105	0.001	0.759	-0.032	0.000	0.000
Effective Spread (%)												
98th+	49	0.136	0.092	-0.044	0.000	0.137	0.137	0.000	0.944	-0.044	0.000	0.000
95th – 97th	77	0.135	0.086	-0.049	0.000	0.125	0.137	0.012	0.004	-0.061	0.000	0.000
90th – 94th	73	0.138	0.090	-0.048	0.000	0.119	0.142	0.023	0.116	-0.071	0.000	0.000
Below 90th	48	0.144	0.092	-0.052	0.000	0.142	0.163	0.021	0.047	-0.074	0.000	0.000
Quoted Spread ($)												
98th+	49	0.165	0.109	-0.057	0.000	0.157	0.144	-0.013	0.003	-0.044	0.000	0.000
95th – 97th	77	0.142	0.082	-0.060	0.000	0.150	0.151	0.001	0.805	-0.061	0.000	0.000
90th – 94th	73	0.134	0.085	-0.049	0.000	0.188	0.187	-0.001	0.893	-0.048	0.000	0.000
Below 90th	48	0.117	0.074	-0.042	0.000	0.135	0.136	0.001	0.888	-0.043	0.000	0.000
Quoted Spread (%)												
98th+	49	0.163	0.105	-0.058	0.000	0.167	0.169	0.002	0.622	-0.060	0.000	0.000
95th – 97th	77	0.171	0.101	-0.069	0.000	0.161	0.176	0.015	0.001	-0.085	0.000	0.000
90th – 94th	73	0.176	0.109	-0.067	0.000	0.155	0.177	0.022	0.119	-0.089	0.000	0.000
Below 90th	48	0.182	0.110	-0.072	0.000	0.174	0.200	0.026	0.036	-0.098	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

Appendix F

Univariate Statistics Reported by Quoted Price

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Quoted Price	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
< $1	247	0.054	0.027	-0.027	0.000	0.059	0.059	0.000	0.869	-0.027	0.000	0.000
$1 – $3	247	0.075	0.046	-0.029	0.000	0.083	0.083	0.000	0.883	-0.029	0.000	0.000
$3 – $5	243	0.122	0.084	-0.039	0.000	0.134	0.136	0.002	0.366	-0.041	0.000	0.000
> $5	235	0.196	0.145	-0.051	0.000	0.227	0.225	-0.002	0.716	-0.049	0.000	0.000
Effective Spread (%)												
< $1	247	0.324	0.195	-0.129	0.000	0.310	0.321	0.010	0.132	-0.140	0.000	0.000
$1 – $3	247	0.044	0.027	-0.018	0.000	0.049	0.049	0.000	0.993	-0.018	0.000	0.000
$3 – $5	243	0.033	0.022	-0.010	0.000	0.036	0.036	0.000	0.357	-0.011	0.000	0.000
> $5	235	0.023	0.016	-0.006	0.000	0.025	0.025	0.000	0.468	-0.006	0.000	0.000
Quoted Spread ($)												
< $1	247	0.071	0.032	-0.039	0.000	0.076	0.076	-0.001	0.244	-0.038	0.000	0.000
$1 – $3	247	0.098	0.056	-0.042	0.000	0.107	0.108	0.001	0.402	-0.043	0.000	0.000
$3 – $5	243	0.166	0.111	-0.056	0.000	0.179	0.183	0.003	0.130	-0.059	0.000	0.000
> $5	235	0.265	0.196	-0.069	0.000	0.297	0.301	0.004	0.521	-0.073	0.000	0.000
Quoted Spread (%)												
< $1	247	0.401	0.228	-0.173	0.000	0.386	0.395	0.008	0.231	-0.182	0.000	0.000
$1 – $3	247	0.058	0.033	-0.025	0.000	0.062	0.063	0.001	0.275	-0.026	0.000	0.000
$3 – $5	243	0.044	0.029	-0.015	0.000	0.047	0.048	0.001	0.117	-0.016	0.000	0.000
> $5	235	0.031	0.022	-0.009	0.000	0.034	0.034	0.000	0.685	-0.009	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Trades for a given option-class are grouped according to the bid and ask price. Instances in which the bid and ask fall into separate groups are excluded from the calculation. (2.8% of trades)

Appendix F

Univariate Statistics Reported by Expiration Date

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Expiration Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
< 1 week	246	0.090	0.056	-0.034	0.000	0.108	0.109	0.001	0.690	-0.035	0.000	0.000
1 – 2 weeks	245	0.080	0.048	-0.031	0.000	0.095	0.094	-0.001	0.593	-0.030	0.000	0.000
2 – 4 weeks	247	0.078	0.047	-0.031	0.000	0.093	0.092	-0.001	0.477	-0.030	0.000	0.000
+4 weeks	247	0.110	0.074	-0.036	0.000	0.128	0.127	-0.001	0.690	-0.035	0.000	0.000
Effective Spread (%)												
< 1 week	246	0.413	0.303	-0.110	0.000	0.390	0.401	0.012	0.267	-0.122	0.000	0.000
1 – 2 weeks	245	0.330	0.206	-0.124	0.000	0.296	0.301	0.005	0.615	-0.129	0.000	0.000
2 – 4 weeks	247	0.246	0.147	-0.100	0.000	0.223	0.243	0.020	0.011	-0.120	0.000	0.000
+4 weeks	247	0.102	0.061	-0.041	0.000	0.096	0.103	0.008	0.140	-0.049	0.000	0.000
Quoted Spread ($)												
< 1 week	246	0.118	0.071	-0.047	0.000	0.140	0.142	0.003	0.441	-0.049	0.000	0.000
1 – 2 weeks	245	0.104	0.060	-0.045	0.000	0.122	0.124	0.002	0.524	-0.047	0.000	0.000
2 – 4 weeks	247	0.104	0.059	-0.045	0.000	0.122	0.120	-0.002	0.353	-0.043	0.000	0.000
+4 weeks	247	0.148	0.095	-0.052	0.000	0.168	0.167	0.000	0.910	-0.052	0.000	0.000
Quoted Spread (%)												
< 1 week	246	0.475	0.344	-0.131	0.000	0.454	0.471	0.017	0.130	-0.149	0.000	0.000
1 – 2 weeks	245	0.387	0.238	-0.150	0.000	0.350	0.366	0.016	0.097	-0.166	0.000	0.000
2 – 4 weeks	247	0.299	0.171	-0.128	0.000	0.278	0.296	0.019	0.022	-0.146	0.000	0.000
+4 weeks	247	0.131	0.073	-0.058	0.000	0.124	0.132	0.008	0.131	-0.066	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Trades for a given option-class are grouped according to the time to an option series' expiration.

Appendix F

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Constrained Matching

Average Trade Size (Contracts)

		Switching				Non-Switching				Difference-in-Differences		
	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods												
All	247	21	16	-5.089	0.000	21	20	-1.586	0.000	-3.503	0.000	0.000
2007 – 2009	85	27	20	-6.429	0.000	26	25	-1.484	0.035	-4.945	0.000	0.000
2010 – 2011	146	19	14	-4.415	0.000	19	17	-1.329	0.012	-3.086	0.000	0.000
2012 – 2015	16	15	11	-4.120	0.031	20	15	-4.475	0.022	0.355	0.904	0.706
Market Capitalization Percentiles												
95th +	69	26	19	-6.858	0.000	24	22	-1.849	0.017	-5.009	0.000	0.000
75th – 94th	123	20	15	-4.589	0.000	20	18	-1.730	0.001	-2.860	0.000	0.000
50th – 74th	38	19	15	-3.386	0.000	22	21	-1.335	0.249	-2.050	0.126	0.091
Below 50th	17	20	14	-5.326	0.004	20	20	-0.042	0.985	-5.284	0.086	0.132
Option Volume Percentiles												
98th+	49	28	21	-6.752	0.000	30	27	-2.698	0.024	-4.054	0.015	0.005
95th – 97th	77	21	16	-5.214	0.000	22	20	-1.519	0.033	-3.696	0.000	0.000
90th – 94th	73	20	15	-4.956	0.000	17	16	-0.917	0.157	-4.040	0.000	0.000
Below 90th	48	17	14	-3.391	0.000	18	17	-1.577	0.086	-1.814	0.067	0.089

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

Appendix F

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Constrained Matching

Average Daily Volume (Contracts)

		Switching				Non-Switching				Difference-in-Differences		
	N	Pre	Post	Average Change	P-Value	Pre	Post	Average Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods												
All	247	16,905	17,519	0.133	0.012	10,860	8,700	-0.185	0.000	0.318	0.000	0.000
2007 – 2009	85	30,563	31,919	0.134	0.128	20,368	16,883	-0.169	0.001	0.303	0.001	0.000
2010 – 2011	146	7,171	6,672	0.106	0.102	5,378	4,077	-0.209	0.000	0.315	0.000	0.000
2012 – 2015	16	33,171	39,994	0.375	0.263	10,369	7,412	-0.052	0.743	0.426	0.198	0.159
Market Capitalization Percentiles												
95^{th} +	69	30,296	29,461	-0.050	0.270	17,576	14,750	-0.151	0.007	0.101	0.137	0.018
75^{th} – 94^{th}	123	12,438	14,653	0.292	0.001	8,679	6,819	-0.207	0.000	0.500	0.000	0.000
50^{th} – 74^{th}	38	10,907	10,427	0.085	0.457	8,203	5,607	-0.179	0.090	0.264	0.068	0.011
Below 50^{th}	17	8,279	5,638	-0.171	0.439	5,322	4,670	-0.178	0.353	0.007	0.982	0.712
Option Volume Percentiles												
98^{th}+	49	48,674	50,817	0.038	0.615	26,923	22,474	-0.139	0.051	0.177	0.085	0.030
95^{th} – 97^{th}	77	15,290	14,600	-0.033	0.663	10,736	8,059	-0.230	0.000	0.197	0.024	0.001
90^{th} – 94^{th}	73	6,691	7,449	0.182	0.137	5,706	4,559	-0.154	0.039	0.335	0.017	0.003
Below 90^{th}	48	2,600	3,525	0.422	0.002	2,499	1,965	-0.208	0.003	0.630	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For "constrained" matching, the non-switching class must be outside of the Pilot. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

Appendix F

Univariate Statistics Reported by Addition Date

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread ($)						
1/26/2007	9	0.078	0.052	-0.026	0.000	0.104	0.095	-0.009	0.032	-0.017	0.000	0.004
9/28/2007	15	0.147	0.100	-0.047	0.000	0.167	0.142	-0.025	0.003	-0.022	0.015	0.018
3/28/2008	20	0.108	0.072	-0.036	0.000	0.137	0.133	-0.004	0.337	-0.032	0.000	0.000
11/2/2009	41	0.102	0.055	-0.047	0.000	0.109	0.102	-0.007	0.025	-0.039	0.000	0.000
2/1/2010	50	0.089	0.053	-0.036	0.000	0.108	0.108	-0.001	0.838	-0.035	0.000	0.000
5/3/2010	46	0.107	0.066	-0.042	0.000	0.119	0.122	0.002	0.605	-0.044	0.000	0.000
8/2/2010	46	0.097	0.065	-0.032	0.000	0.122	0.123	0.001	0.830	-0.033	0.000	0.000
1/4/2011	1	0.076	0.039	-0.036	–	0.081	0.077	-0.004	–	-0.032	–	–
7/6/2011	3	0.125	0.102	-0.022	–	0.294	0.353	0.060	–	-0.082	–	–
1/4/2012	1	0.134	0.141	0.007	–	0.092	0.078	-0.014	–	0.021	–	–
7/3/2012	2	0.084	0.054	-0.030	–	0.090	0.078	-0.012	–	-0.018	–	–
1/3/2013	5	0.100	0.090	-0.010	–	0.149	0.151	0.002	–	-0.012	–	–
7/3/2013	1	0.254	0.245	-0.009	–	0.085	0.085	0.000	–	-0.008	–	–
1/3/2014	3	0.188	0.179	-0.008	–	0.108	0.114	0.006	–	-0.015	–	–
7/3/2014	1	0.133	0.092	-0.041	–	0.225	0.149	-0.076	–	0.035	–	–
1/5/2015	1	0.176	0.120	-0.056	–	0.205	0.191	-0.015	–	-0.042	–	–
7/6/2015	2	0.186	0.183	-0.002	–	0.108	0.107	-0.001	–	-0.001	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Appendix F

Univariate Statistics Reported by Addition Date

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread (%)						
1/26/2007	9	0.171	0.107	-0.064	0.001	0.153	0.149	-0.004	0.814	-0.059	0.063	0.027
9/28/2007	15	0.136	0.071	-0.065	0.000	0.129	0.120	-0.009	0.108	-0.056	0.000	0.000
3/28/2008	20	0.140	0.085	-0.055	0.000	0.125	0.130	0.005	0.392	-0.060	0.000	0.000
11/2/2009	41	0.134	0.085	-0.049	0.000	0.118	0.132	0.013	0.002	-0.062	0.000	0.000
2/1/2010	50	0.126	0.071	-0.055	0.000	0.121	0.127	0.006	0.061	-0.061	0.000	0.000
5/3/2010	46	0.124	0.100	-0.024	0.000	0.127	0.180	0.053	0.023	-0.077	0.001	0.000
8/2/2010	46	0.143	0.086	-0.056	0.000	0.132	0.144	0.011	0.277	-0.068	0.000	0.000
1/4/2011	1	0.387	0.213	-0.173	–	0.222	0.240	0.018	–	-0.192	–	–
7/6/2011	3	0.129	0.124	-0.006	–	0.105	0.108	0.003	–	-0.009	–	–
1/4/2012	1	0.145	0.086	-0.058	–	0.216	0.174	-0.041	–	-0.017	–	–
7/3/2012	2	0.245	0.168	-0.077	–	0.141	0.141	0.000	–	-0.077	–	–
1/3/2013	5	0.219	0.167	-0.052	–	0.161	0.155	-0.006	–	-0.046	–	–
7/3/2013	1	0.105	0.103	-0.002	–	0.118	0.104	-0.014	–	0.012	–	–
1/3/2014	3	0.140	0.113	-0.027	–	0.157	0.137	-0.020	–	-0.007	–	–
7/3/2014	1	0.135	0.096	-0.039	–	0.245	0.167	-0.078	–	0.039	–	–
1/5/2015	1	0.201	0.159	-0.041	–	0.152	0.148	-0.005	–	-0.036	–	–
7/6/2015	2	0.134	0.123	-0.012	–	0.180	0.222	0.042	–	-0.054	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Appendix F

Univariate Statistics Reported by Addition Date

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread ($)						
1/26/2007	9	0.089	0.058	-0.031	0.000	0.115	0.106	-0.009	0.033	-0.022	0.000	0.004
9/28/2007	15	0.168	0.110	-0.058	0.000	0.196	0.164	-0.032	0.002	-0.026	0.014	0.030
3/28/2008	20	0.123	0.081	-0.042	0.000	0.157	0.155	-0.001	0.711	-0.041	0.000	0.000
11/2/2009	41	0.140	0.073	-0.068	0.000	0.146	0.140	-0.005	0.165	-0.063	0.000	0.000
2/1/2010	50	0.125	0.070	-0.055	0.000	0.147	0.148	0.001	0.751	-0.056	0.000	0.000
5/3/2010	46	0.146	0.085	-0.061	0.000	0.161	0.158	-0.003	0.666	-0.058	0.000	0.000
8/2/2010	46	0.122	0.083	-0.039	0.000	0.154	0.160	0.006	0.444	-0.045	0.000	0.000
1/4/2011	1	0.097	0.050	-0.048	–	0.107	0.107	-0.001	–	-0.047	–	–
7/6/2011	3	0.161	0.132	-0.028	–	0.386	0.471	0.085	–	-0.113	–	–
1/4/2012	1	0.197	0.198	0.001	–	0.125	0.106	-0.019	–	0.020	–	–
7/3/2012	2	0.130	0.079	-0.051	–	0.142	0.119	-0.023	–	-0.028	–	–
1/3/2013	5	0.158	0.133	-0.025	–	0.234	0.228	-0.006	–	-0.019	–	–
7/3/2013	1	0.389	0.366	-0.023	–	0.112	0.120	0.008	–	-0.031	–	–
1/3/2014	3	0.297	0.252	-0.046	–	0.187	0.187	0.000	–	-0.046	–	–
7/3/2014	1	0.208	0.129	-0.078	–	0.314	0.236	-0.078	–	0.000	–	–
1/5/2015	1	0.279	0.186	-0.093	–	0.321	0.295	-0.026	–	-0.066	–	–
7/6/2015	2	0.331	0.262	-0.069	–	0.195	0.195	0.000	–	-0.068	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Appendix F

Univariate Statistics Reported by Addition Date

Constrained Matching

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread (%)						
1/26/2007	9	0.188	0.115	-0.073	0.000	0.169	0.162	-0.008	0.663	-0.066	0.036	0.020
9/28/2007	15	0.152	0.077	-0.075	0.000	0.146	0.137	-0.009	0.130	-0.066	0.000	0.000
3/28/2008	20	0.153	0.088	-0.065	0.000	0.136	0.143	0.008	0.203	-0.072	0.000	0.000
11/2/2009	41	0.170	0.103	-0.067	0.000	0.154	0.170	0.017	0.001	-0.084	0.000	0.000
2/1/2010	50	0.168	0.085	-0.082	0.000	0.159	0.166	0.007	0.093	-0.089	0.000	0.000
5/3/2010	46	0.159	0.120	-0.040	0.000	0.165	0.217	0.052	0.025	-0.091	0.000	0.000
8/2/2010	46	0.173	0.101	-0.072	0.000	0.159	0.177	0.019	0.121	-0.091	0.000	0.000
1/4/2011	1	0.476	0.254	-0.221	–	0.291	0.325	0.034	–	-0.255	–	–
7/6/2011	3	0.154	0.145	-0.009	–	0.132	0.142	0.010	–	-0.019	–	–
1/4/2012	1	0.191	0.111	-0.080	–	0.293	0.233	-0.060	–	-0.020	–	–
7/3/2012	2	0.305	0.223	-0.083	–	0.197	0.180	-0.017	–	-0.065	–	–
1/3/2013	5	0.284	0.214	-0.069	–	0.222	0.214	-0.008	–	-0.062	–	–
7/3/2013	1	0.154	0.145	-0.010	–	0.147	0.148	0.001	–	-0.011	–	–
1/3/2014	3	0.223	0.155	-0.067	–	0.246	0.217	-0.028	–	-0.039	–	–
7/3/2014	1	0.208	0.122	-0.086	–	0.340	0.285	-0.055	–	-0.031	–	–
1/5/2015	1	0.338	0.214	-0.124	–	0.243	0.257	0.014	–	-0.138	–	–
7/6/2015	2	0.253	0.177	-0.076	–	0.334	0.404	0.070	–	-0.146	–	–
1/5/2016	–	–	–	–	–	–	–	–	–	–	–	–

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. P-values are not reported for sample sizes smaller than six.

Appendix G

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Constrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Dates	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
All	53	0.115	0.077	-0.037	0.000	0.122	0.130	0.008	0.175	-0.046	0.000	0.000
2007 – 2009	27	0.123	0.073	-0.050	0.000	0.121	0.126	0.005	0.518	-0.055	0.000	0.000
2010 – 2011	19	0.105	0.061	-0.043	0.000	0.114	0.130	0.016	0.190	-0.059	0.000	0.000
2012 – 2015	7	0.111	0.138	0.027	0.455	0.146	0.146	0.000	0.998	0.027	0.435	0.813
Effective Spread (%)												
All	53	0.136	0.099	-0.037	0.000	0.136	0.154	0.019	0.000	-0.056	0.000	0.000
2007 – 2009	27	0.120	0.088	-0.032	0.000	0.130	0.148	0.019	0.003	-0.050	0.000	0.000
2010 – 2011	19	0.146	0.101	-0.045	0.000	0.130	0.147	0.017	0.027	-0.062	0.000	0.000
2012 – 2015	7	0.175	0.138	-0.037	0.000	0.174	0.198	0.024	0.142	-0.061	0.002	0.016
Quoted Spread ($)												
All	53	0.154	0.102	-0.052	0.000	0.165	0.173	0.008	0.277	-0.060	0.000	0.000
2007 – 2009	27	0.156	0.092	-0.064	0.000	0.154	0.162	0.008	0.387	-0.072	0.000	0.000
2010 – 2011	19	0.140	0.078	-0.062	0.000	0.155	0.173	0.017	0.245	-0.080	0.000	0.000
2012 – 2015	7	0.183	0.204	0.022	0.684	0.234	0.217	-0.017	0.406	0.039	0.437	0.688
Quoted Spread (%)												
All	53	0.183	0.125	-0.058	0.000	0.186	0.204	0.018	0.001	-0.077	0.000	0.000
2007 – 2009	27	0.151	0.104	-0.046	0.000	0.166	0.186	0.020	0.004	-0.067	0.000	0.000
2010 – 2011	19	0.192	0.126	-0.067	0.000	0.181	0.196	0.015	0.110	-0.082	0.000	0.000
2012 – 2015	7	0.281	0.201	-0.080	0.000	0.275	0.295	0.019	0.282	-0.100	0.001	0.016

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period.

Appendix G

Univariate Statistics Reported by Underlying Market Capitalization

Constrained Matching

Option Classes on ETFs

Market Cap Percentile	N	Switching				Non-Switching				Difference-in-Differences		
		Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
75th+	14	0.125	0.077	-0.049	0.028	0.123	0.121	-0.003	0.613	-0.046	0.039	0.004
50th – 74th	17	0.102	0.061	-0.042	0.000	0.117	0.129	0.013	0.314	-0.054	0.002	0.000
Below 50th	22	0.118	0.091	-0.027	0.070	0.125	0.137	0.012	0.278	-0.039	0.030	0.003
Effective Spread (%)												
75th+	14	0.126	0.086	-0.040	0.000	0.131	0.155	0.024	0.005	-0.064	0.000	0.000
50th – 74th	17	0.128	0.095	-0.033	0.000	0.128	0.146	0.019	0.018	-0.052	0.000	0.000
Below 50th	22	0.149	0.110	-0.039	0.000	0.145	0.160	0.015	0.048	-0.054	0.000	0.000
Quoted Spread ($)												
75th+	14	0.158	0.096	-0.062	0.009	0.160	0.158	-0.003	0.659	-0.060	0.014	0.001
50th – 74th	17	0.135	0.078	-0.057	0.000	0.154	0.169	0.015	0.354	-0.072	0.001	0.000
Below 50th	22	0.166	0.124	-0.042	0.040	0.176	0.186	0.010	0.452	-0.052	0.031	0.003
Quoted Spread (%)												
75th+	14	0.165	0.107	-0.057	0.000	0.173	0.201	0.028	0.006	-0.085	0.000	0.000
50th – 74th	17	0.168	0.115	-0.053	0.000	0.171	0.189	0.018	0.038	-0.071	0.000	0.000
Below 50th	22	0.206	0.144	-0.063	0.000	0.205	0.218	0.013	0.167	-0.076	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE.

Appendix G

Univariate Statistics Reported by Option Class Volume

Constrained Matching

Option Classes on ETFs

Option Volume Percentile	N	Switching				Non-Switching				Difference-in-Differences		
		Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Effective Spread ($)												
95th+	15	0.128	0.091	-0.036	0.173	0.122	0.140	0.017	0.200	-0.054	0.085	0.010
90th – 94th	19	0.114	0.079	-0.035	0.001	0.121	0.119	-0.003	0.649	-0.032	0.003	0.001
Below 90th	19	0.106	0.065	-0.041	0.000	0.122	0.135	0.013	0.321	-0.054	0.000	0.000
Effective Spread (%)												
95th+	15	0.115	0.078	-0.037	0.000	0.118	0.138	0.019	0.031	-0.056	0.000	0.000
90th – 94th	19	0.141	0.111	-0.030	0.000	0.150	0.172	0.022	0.005	-0.052	0.000	0.000
Below 90th	19	0.149	0.103	-0.046	0.000	0.135	0.150	0.015	0.058	-0.060	0.000	0.000
Quoted Spread ($)												
95th+	15	0.159	0.119	-0.040	0.215	0.154	0.174	0.020	0.230	-0.061	0.108	0.015
90th – 94th	19	0.162	0.108	-0.055	0.000	0.175	0.167	-0.008	0.311	-0.047	0.002	0.001
Below 90th	19	0.141	0.083	-0.059	0.000	0.164	0.179	0.015	0.316	-0.074	0.000	0.000
Quoted Spread (%)												
95th+	15	0.148	0.097	-0.051	0.000	0.155	0.173	0.018	0.032	-0.069	0.000	0.000
90th – 94th	19	0.197	0.143	-0.054	0.000	0.210	0.233	0.022	0.025	-0.077	0.000	0.000
Below 90th	19	0.196	0.128	-0.067	0.000	0.185	0.200	0.015	0.122	-0.082	0.000	0.000

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

Univariate Statistics Reported by Penny Pilot Addition Date Periods

Constrained Matching

Option Classes on ETFs

Average Daily Volume (Contracts)

		Switching				Non-Switching				Difference-in-Differences		
	N	Pre	Post	Average Change	P-Value	Pre	Post	Average Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
Addition Date Periods												
All	53	39,892	42,336	0.043	0.498	35,388	35,538	-0.216	0.001	0.260	0.003	0.001
2007 – 2009	27	70,848	75,242	-0.032	0.717	64,251	65,710	-0.216	0.015	0.184	0.150	0.209
2010 – 2011	19	5,950	6,113	0.098	0.394	4,196	2,542	-0.313	0.000	0.411	0.004	0.002
2012 – 2015	7	12,617	13,736	0.186	0.302	8,724	8,720	0.045	0.859	0.141	0.531	0.578
Market Capitalization Percentiles												
75^{th}+	14	103,612	121,414	0.169	0.167	115,007	117,963	-0.137	0.337	0.307	0.099	0.135
50^{th} – 74^{th}	17	24,294	19,023	-0.022	0.854	5,965	4,889	-0.283	0.010	0.261	0.055	0.098
Below 50^{th}	22	11,396	10,029	0.013	0.898	7,458	6,768	-0.215	0.023	0.229	0.115	0.033
Option Volume Percentiles												
95^{th}+	15	110,877	123,701	0.125	0.313	110,426	112,718	-0.129	0.241	0.254	0.130	0.169
90^{th} – 94^{th}	19	18,709	14,227	-0.164	0.084	7,790	7,812	-0.171	0.172	0.008	0.949	0.418
Below 90^{th}	19	5,034	6,210	0.186	0.106	3,746	2,331	-0.331	0.000	0.517	0.001	0.001

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For "constrained" matching, the non-switching class must be outside of the Pilot. Pilot addition dates 1/26/07, 9/28/07, 3/28/08, and 11/2/09 are included in the 2007 – 2009 addition date period; Pilot addition dates 2/1/10, 5/3/10, 8/2/10, 1/4/11, and 7/6/11 are included in the 2010 – 2011 period; and Pilot addition dates 1/4/12, 7/3/12, 1/3/13, 7/3/13, 1/3/14, 7/3/14, 1/5/15, and 7/6/15 are included in the 2012 – 2015 period. Matched pairs of switching and non-switching option classes are categorized into market capitalization percentiles using the underlying market capitalization of the switching option class at the end of the month prior to the addition date. Market capitalization percentiles are defined using the stocks listed on the NYSE. Matched pairs of switching and non-switching option classes are categorized into option class volume percentiles using the option class volume of the switching option class during the month prior to the addition date. Option class percentiles are defined using the universe of option classes on common stock in the LiveVol data.

Appendix G

Univariate Statistics Reported by Addition Date

Constrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread ($)						
1/26/2007	3	0.076	0.049	-0.028	–	0.114	0.099	-0.015	–	-0.012	–	–
9/28/2007	4	0.138	0.076	-0.062	–	0.198	0.257	0.060	–	-0.122	–	–
3/28/2008	1	0.422	0.130	-0.292	–	0.040	0.043	0.003	–	-0.295	–	–
11/2/2009	19	0.112	0.073	-0.038	0.000	0.111	0.108	-0.003	0.516	-0.035	0.000	0.000
2/1/2010	6	0.086	0.056	-0.030	0.011	0.102	0.104	0.002	0.707	-0.031	0.029	0.063
5/3/2010	7	0.073	0.047	-0.026	0.000	0.101	0.153	0.052	0.069	-0.078	0.015	0.016
8/2/2010	6	0.159	0.083	-0.077	0.002	0.141	0.130	-0.011	0.591	-0.066	0.024	0.063
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.152	0.111	-0.041	–	0.151	0.114	-0.037	–	-0.004	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.101	0.192	0.091	–	0.089	0.087	-0.002	–	0.093	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.082	0.116	0.034	–	0.129	0.158	0.029	–	0.005	–	–
1/5/2016	1	0.173	0.123	-0.050	–	0.306	0.259	-0.046	–	-0.004	–	–

Appendix G

Univariate Statistics Reported by Addition Date

Constrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Effective Spread (%)						
1/26/2007	3	0.126	0.082	-0.044	–	0.102	0.111	0.009	–	-0.052	–	–
9/28/2007	4	0.091	0.054	-0.037	–	0.093	0.088	-0.005	–	-0.032	–	–
3/28/2008	1	0.102	0.076	-0.026	–	0.108	0.099	-0.009	–	-0.017	–	–
11/2/2009	19	0.125	0.096	-0.029	0.000	0.143	0.169	0.027	0.001	-0.056	0.000	0.000
2/1/2010	6	0.157	0.107	-0.050	0.010	0.110	0.117	0.007	0.490	-0.057	0.017	0.031
5/3/2010	7	0.143	0.101	-0.042	0.015	0.130	0.167	0.037	0.014	-0.079	0.004	0.016
8/2/2010	6	0.137	0.094	-0.044	0.012	0.152	0.155	0.003	0.803	-0.047	0.012	0.063
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.130	0.071	-0.060	–	0.149	0.121	-0.028	–	-0.032	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.128	0.098	-0.030	–	0.172	0.203	0.032	–	-0.062	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.192	0.160	-0.032	–	0.149	0.203	0.054	–	-0.087	–	–
1/5/2016	1	0.263	0.221	-0.043	–	0.277	0.248	-0.029	–	-0.014	–	–

Appendix G

Univariate Statistics Reported by Addition Date

Constrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread ($)						
1/26/2007	3	0.089	0.054	-0.035	–	0.132	0.115	-0.017	–	-0.018	–	–
9/28/2007	4	0.163	0.089	-0.074	–	0.232	0.305	0.073	–	-0.147	–	–
3/28/2008	1	0.447	0.141	-0.306	–	0.043	0.047	0.004	–	-0.310	–	–
11/2/2009	19	0.150	0.096	-0.054	0.000	0.147	0.145	-0.001	0.814	-0.053	0.000	0.000
2/1/2010	6	0.122	0.072	-0.050	0.004	0.144	0.140	-0.004	0.514	-0.046	0.031	0.063
5/3/2010	7	0.102	0.058	-0.044	0.000	0.139	0.198	0.059	0.084	-0.102	0.011	0.016
8/2/2010	6	0.203	0.107	-0.096	0.002	0.185	0.176	-0.009	0.720	-0.087	0.021	0.063
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.256	0.172	-0.083	–	0.244	0.166	-0.077	–	-0.006	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.166	0.285	0.119	–	0.119	0.129	0.010	–	0.109	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.144	0.161	0.017	–	0.236	0.242	0.006	–	0.011	–	–
1/5/2016	1	0.261	0.206	-0.054	–	0.448	0.371	-0.078	–	0.024	–	–

Appendix G

Univariate Statistics Reported by Addition Date

Constrained Matching

Option Classes on ETFs

		Switching				Non-Switching				Difference-in-Differences		
Addition Date	N	Pre	Post	Change	P-Value	Pre	Post	Change	P-Value	Diff-in-Diff	T-Test	Wilcoxon Signed-Rank
						Quoted Spread (%)						
1/26/2007	3	0.146	0.089	-0.057	–	0.117	0.128	0.010	–	-0.067	–	–
9/28/2007	4	0.106	0.060	-0.045	–	0.107	0.104	-0.003	–	-0.042	–	–
3/28/2008	1	0.110	0.080	-0.030	–	0.110	0.097	-0.013	–	-0.017	–	–
11/2/2009	19	0.163	0.117	-0.046	0.000	0.189	0.217	0.029	0.003	-0.074	0.000	0.000
2/1/2010	6	0.206	0.133	-0.073	0.004	0.160	0.162	0.002	0.920	-0.075	0.029	0.031
5/3/2010	7	0.194	0.123	-0.071	0.001	0.180	0.212	0.032	0.053	-0.103	0.001	0.016
8/2/2010	6	0.177	0.122	-0.056	0.016	0.202	0.211	0.008	0.622	-0.064	0.015	0.063
1/4/2011	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2011	0	–	–	–	–	–	–	–	–	–	–	–
1/4/2012	0	–	–	–	–	–	–	–	–	–	–	–
7/3/2012	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2013	1	0.188	0.095	-0.094	–	0.218	0.173	-0.045	–	-0.049	–	–
7/3/2013	0	–	–	–	–	–	–	–	–	–	–	–
1/3/2014	2	0.215	0.141	-0.073	–	0.234	0.286	0.051	–	-0.125	–	–
7/3/2014	0	–	–	–	–	–	–	–	–	–	–	–
1/5/2015	0	–	–	–	–	–	–	–	–	–	–	–
7/6/2015	3	0.325	0.237	-0.088	–	0.278	0.316	0.037	–	-0.126	–	–
1/5/2016	1	0.375	0.318	-0.056	–	0.405	0.371	-0.034	–	-0.022	–	–

Source: LiveVol; OptionMetrics; CRSP.

Note: Each switching option class is matched with a non-switching option class based on underlying market capitalization and option volume. For “constrained” matching, the non-switching class must be outside of the Pilot. P-values are not reported for sample sizes smaller than six.