Reassessing the Impact of Option Introductions on Market Quality: A Less Restrictive Test for Event-Date Effects

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Abstract

Prior research concludes that option introductions improve the average liquidity of the underlying stocks. We develop an improved, generalizable test to assess whether market quality changes occur on or near an event date. Applying this method to option listing events, we conclude that options do not systematically improve the market quality of the underlying security; rather, the market quality for the underlying security improves before the listing decision. Hazard model tests indicate that improving liquidity is a selection criterion in the option listing decision. Moreover, these tests suggest that the size of a stock's bid-ask spread is the single most important option-listing determinant.

I. Introduction

This study reexamines the impact of equity option introductions on stock market liquidity. Previous studies find an improvement in market quality characteristics after option introductions and conclude that options improve the quality of the underlying market.[1] In this paper, we make several new contributions. First, we present and adopt a more flexible empirical tool for identifying regime shifts when event selection may be endogenously determined. Second, using this method, we reverse two major findings of the existing literature, that option introductions reduce spreads and increase volume. Finally, we find that the bid-ask spread is an important, and perhaps the most important, determinant of the option listing decision. Stocks that experience declines in the bid-ask spread are much more likely to be selected for option listing.

Our empirical findings are consistent with anecdotal evidence derived from conversations with options exchange personnel who suggest that exchanges focus attention on stocks that have seen recent improvements in market quality. Reflecting on these insights, we track changes in stock characteristics on a daily basis to determine whether shifts in market microstructure measures occur on or near the option introduction date. We discover that many of the previously documented changes in stock trading characteristics do not result from the option listing. Instead, these characteristics are already changing before exchanges list options on these securities. Earlier research has mistakenly interpreted the ex-ante improvements in market quality as ex-post option listing effects.

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[1] Kumar, Sarin, and Shastri (1998) examine the market microstructure impacts of options. Figlewski and Webb (1993), Sorescu (2000), and Danielsen and Sorescu (2001) discuss the impact of options on short sale constraints.

We design a less rigid, highly generalizable structure to accommodate parameter drift as well as potential event-date parameter shifts. Using this approach, we find that implied regime shifts in market microstructure variables, to the extent they exist, generally occur during the prior month, and occasionally the implied optimal shift date occurs more than 35 trading days before the listing. In fact, the data usually rule out a shift near the listing date with high statistical significance, preferring pre-listing dates as more likely dates for structural changes to have occurred.

Previous work, namely that of Mayhew and Mihov (2004), finds that volume and volatility are determinants of the option listing decision. While our tests largely confirm the Mayhew-Mihov results with respect to volatility, we discover that the percentage bid-ask spread is an even more important listing determinant than volume or volatility. This finding is consistent with option exchanges selecting highly liquid stocks for listing as liquidity is essential for option traders who wish to engage in dynamic hedging.

Our paper proceeds as follows: Section II provides a review of the literature. Section III presents the data and empirical method. Section IV presents time-series tests for whether liquidity changes are caused by option listing. Section V examines the determinants of option listing in cross-section, and Section VI summarizes and concludes.

II. Review of Related Literature

Black and Scholes (1973) model options as redundant securities, where the trading characteristics of the underlying stock influence the value of the option. However, Ross (1976) and Hakansson (1982) argue that it seems naïve to assume that stock characteristics govern option prices, but the reverse cannot hold. Instead, if optionless markets are incomplete, improved trading efficiencies could result from option introductions. Conrad (1989) finds that the price of the underlying security rises on the date of option listing. Sorescu (2000) discovers that Conrad's observed positive abnormal returns arise from option listings in the 1970's. After the early 1980's, option introductions are associated with declines in the price of the underlying stocks.

Other potential impacts of option listing are considered by Skinner (1989) and Conrad (1989) who observe a decline in post-option-listing volatility. Kumar, Sarin, and Shastri (1998) extend the analysis to a wide array of microstructure characteristics, and they conclude that "option listings improve the quality of the underlying stocks" [p.717 abstract] because bid-ask spreads and volatility decrease, and volume and transaction sizes increase after options are introduced.

A selection bias may exist in the optioned stocks if the variable of interest is correlated with characteristics of a stock that make it a good candidate for options trading. This possibility of an endogenous relation between changes in stock trading characteristics and option exchanges' listing decisions is raised by Conrad (1989), Skinner (1989), Figlewski and Webb (1993), Kumar, Sarin, and Shastri (1998) and Sorescu (2000). To our knowledge, little research has attempted to differentiate between whether option listings produce stock trading changes or whether changes in stock trading behaviors produce option listings. An exception is Mayhew and Mihov (2004) who find that exchanges appear to treat increased volatility as a selection criterion. They conclude that the declines in volatility observed by previous authors are endogenous to the selection process and are not an outcome of the listing event.

Given that decreased volatility has been the longest-recognized change previously attributed as an "option listing effect," other presumed listing effects should be reexamined to determine whether options cause changes in the underlying market quality or merely flag firms for which changes are already underway. Market quality, however, has many dimensions, and proxies for market quality vary from study to study. We study trading volume (and its components: trade size and number of trades), volatility, and transaction costs (as measured by bid-ask spreads). We reexamine the impact of option listings on these proxies and find that previous studies erred in concluding that market quality changes are a result of the option listing, rather than a determinant of the listing.

III. Data and Method

In addition to data on options listings from 1993 to 2002, our study uses TAQ microstructure data to estimate several measures of stock liquidity around the options introduction date. These measures are the quoted bid-ask spread, the percentage spread, the percentage effective spread, the trading volume, and the standard deviation of the quote midpoint. Because we wish to track the microstructure characteristics over a period both before and after the option introduction, we require that microstructure data be available for the security for 125 trading days on either side of the event date. This produces a 251-day window of trade and quote data, centered on the introduction date, and is the same window used by Kumar, Sarin, and Shastri (1998).

Between 1993 and 2002, several market changes and reforms took place on both the NYSE and NASDAQ.[2] Bessembinder (2003), and Chung, Van Ness, and Van Ness (2004)

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[2] The minimum tick sizes for NYSE stocks changed on June 24, 1997 and January 29, 2001. The NASDAQ moved to 16ths on June 27, 1997 and phased in decimal trading over the interval of March 12, 2001 to April 9, 2001. The NASDAQ stocks subject to the SEC's Order Handling Rules were phased in from January 20, 1997 to October 13, 1997. A pilot decimalization program of 159 NYSE and AMEX stocks started in August 2000. However, none of these stocks had options introduced within 125 days of the program’s effective date.

report that these market changes had a significant impact on market quality metrics, including a narrowing of spreads. To avoid confusing the impact of option introductions with market-wide changes in the stock trading process, we exclude all firms for which the previously described 251-day window includes a significant rule change or a tick reduction.

To minimize data errors, we precondition the TAQ data in several ways. We omit trades and quotes if they are flagged as out of time sequence or involve either an error or a correction. We omit quotes if either the ask or bid price is zero or less, and we omit trades if the price or volume is not greater than zero. In addition, as in Huang and Stoll (1996), we omit the following to further minimize data errors: (1) quotes when the spread is greater than \$4 or less than zero; (2) before-the-open and after-the-close trades and quotes; (3) trade price, p_t, when $|(p_t - p_{t-1})/p_{t-1}| > 0.10$; (4) ask quote, a_t, when $|(a_t - a_{t-1})/a_{t-1}| > 0.10$; and (5) bid quote, b_t, when $|(b_t - b_{t-1})/b_{t-1}| > 0.10$. Because liquidity metrics differ across exchanges, we exclude all firms that moved from NASDAQ to the NYSE during the 251-day window. We also exclude any stocks that had stock splits during the window.

For the purposes of this portion of the analysis, the quoted bid-ask spread, spread_i, is defined as the difference in the ask price and the bid price, for each firm i:

$$\text{Spread}_i = \left(\text{Ask Price}_i - \text{Bid Price}_i\right). \tag{1}$$

The midpoint of the spread is defined as the mean of the ask price and the bid price, for each firm i:

$$\text{Midpoint}_i = \frac{\left(\text{Ask Price}_i + \text{Bid Price}_i\right)}{2}. \tag{2}$$

The percentage spread_i, is the spread divided the midpoint of the spread:

$$\text{Percentage Spread}_i = \frac{\text{Spread}_i}{\text{Midpoint}_i}. \tag{3}$$

To measure trading costs when trades occur at prices inside the posted bid and ask quotes, we use the effective spread_i, which is defined as:

$$\text{Effective Spread}_i = 2D_i(\text{Trade Price}_i - \text{Midpoint}_i), \qquad (4)$$

where trade price_i is the transaction price for security i, midpoint_i is the midpoint of the most recently posted bid and ask quotes for security i, and D_i is a binary variable, which equals +1 for a customer buy order and -1 for a customer sell order as in Lee and Ready (1991).

Table 1 presents means and standard deviations of key variables in our basic data set. The impact of the screens we impose is clearly visible in the reduced number of observations in 1997 and the lack of observations in 2001. Percentage spread and volume are the mean daily values of these variables in the period 40 days to 20 days before the option listing. Volatility is the standard deviation of returns over the same 40 to 20 day window, and market value and price are as of the listing date. The cross-sectional standard deviation for each variable is presented in brackets below the mean values.

For each variable, in each year, we report the ratio of the listed-firm mean value to eligible-but-not-listed firm mean value for that year. In all years the pre-listing percentage spreads are lower for listed firms than non-listed firms, and the magnitude of the spread for listed firms declines over the study period. Listed firms also tend to have higher pre-listing trading volume than non-listed firms.

The pre-listing volatility of listed firms is not statistically different from other firms during 1993, 1994, and 1995, but the pre-listing volatility of listed firms rises to twice that of non-listed firms by 2000. During the early years of the sample, listed firms have higher market value than non-listed firms, but in later years the exchanges are listing options on firms with lower-than-average market values. Taken together, we infer that options exchanges listed relatively larger and less volatile firms in the early years of the sample relative to those selected in the later years.

IV. Does Liquidity Change Around Option Introductions?

A. Simple Means Tests

Using a sample of 174 option introductions between 1983 and 1989, Kumar, Sarin, and Shastri (1998) find that option introductions are associated with an overall improvement in market liquidity. In Table 2 we follow their method and examine the means of spreads, volume, and trading activity before and after the option introduction.[3] For spread, percentage spread, and percentage effective spread there is a statistically significant decline following the introduction. For volume and the number of trades, there is a significant increase. The change in average trade size is not consistent between the NYSE and the NASDAQ samples. NYSE trade size increases after the option listing, but NASDAQ trade size decreases.

Instead of the daily volatility metric used by Kumar, Sarin, and Shastri (1998), we examine the intraday volatility using the standard deviation of the quote midpoint. This intraday volatility declines after the option listing, consistent with the decline in inter-day volatility observed by Kumar, Sarin, and Shastri.[4] In summary, these tests provide evidence of multi-dimensional improvements in market liquidity after options are introduced, consistent with the results described by Kumar, Sarin, and Shastri.

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[3] We divide the sample into NYSE/AMEX and NASDAQ stocks, and apply the label "NYSE" to the union of NYSE and AMEX listings.

[4] In unreported tests, we observe that inter-day volatility for our sample of firms, as calculated using the Kumar, Sarin, and Shastri method, is lower after option listings also.

B. A Less Restrictive Model

The key shortcoming of the difference-in-means tests performed in Table 2 is that these tests explicitly assume a shift in the means around the option listing date and stationarity at all other times. An alternative explanation is that the liquidity measures improve gradually over time. In other words, liquidity changes “drift through” rather than “shift on” the event date. If so, improving liquidity is more consistent with option exchanges deciding to introduce options on stocks with improved liquidity than with the previous conclusion that options improve market quality. It is also plausible that there is both a drift in the trading characteristics and a shift in those characteristics due to the option listing. In other words, the presence of an ex-ante drift does not preclude the possibility of a listing-induced shift.

Taking this more agnostic approach, we consider a model that allows for both a drift and a shift in the data. Moreover, we allow the data to select an optimal regime change date instead of imposing an assumption that any observed structural change must occur on the option introduction date.

According to options exchange personnel, listing decisions for stock options are usually made a week to a month before the option is introduced. If this is the case, and if improved liquidity impacts the listing decision, improving liquidity will be observed during the pre-listing period that is analyzed by the exchanges’ new product development groups. Subsequent data may reveal continued high liquidity, but further abnormal improvements in liquidity are not expected, because ex-post improvement is not, and cannot be a selection criterion. Only observable ex-ante characteristics can result in a selection bias.

For expositional clarity, consider a simple model (Figure 1) with binomial liquidity changes in each of three periods. After two periods, a random subset of firms shows liquidity improvements in both the first and second periods. At t=2, these firms are selected for observation and all others are not. In the third period, liquidity innovations continue along binomial paths. Under this scenario, the selection bias will create an observed regime shift at t=2, because the pre-selection path of selected firms gives rise to inclusion in the sample, but the post-selection path for these firms remains random.

To search for the presence of such a path (the bold line in Figure 1) we employ an iterative switching regression model. We fit the model to the data, iteratively moving through the range of potential switch dates. For each of these switching regressions we record the log-likelihood ratio. We make no prior assumption as to which is the most likely switch date, and we rely solely on the highest log likelihood ratio to indicate the best fitting of all of the alternative switching regressions.

In more detail, our approach is as follows. First, for each option listing, we collect data for the 251-day window centered on the option listing date. Thus, we have data for the 125 days before and after the option listing. Second, we label all the dates relative to the listing date, which is labeled t=0. Our dates range from t_L-125 to t_L+125, where t_L is the list date.

Quandt (1958) observes that the power of a test to detect regime changes declines as the true switching point approaches either endpoint of a series. Therefore, we confine our tests for alternative switch dates to a 201-day range between day -100 and day +100, although each test uses all data from the entire 251-day range. Accordingly, we estimate 201 switching regression models, each time using a different switch date, starting with day -100 and incrementing forward one day at a time until we reach day +100. Each switching regression model is simply two straight lines combined so that one is parameterized before the switch date, while the other is parameterized after the switch date.

The following model is run 201 times on the full sample of option listings:

$$\text{liquidity variable}_i = [\alpha_0 + \alpha_1 \text{DAY}] \times \text{PRE} + [\beta_0 + \beta_1 \text{DAY}] \times \text{POST} + \varepsilon_i \tag{5}$$

The first two parameters (α_0, α_1) cross-sectionally fit data prior to the hypothesized switch date, and the second two parameters (β_0, β_1) fit the data after the hypothesized regime-switch date. The independent variable in the regression is DAY, which takes the value of -125 through +125, with DAY=0 being the date of the option listing. Equation 5 is estimated 201 times for each liquidity variable; after each iteration the hypothesized switch date is moved forward an additional day, starting at day -100. PRE = 1 if DAY is less than or equal to the hypothesized switch day, and zero otherwise. Likewise, POST = 1 if DAY is greater than the hypothesized switch date, and zero otherwise.

In the first iteration of the 201 alternative regressions, where the switch date is presumed to occur on DAY = -100, PRE and POST take the following values:

PRE = 1, POST = 0 if ($-125 \leq \text{DAY} \leq -100$)
PRE = 0, POST = 1 if ($-100 > \text{DAY} \leq +125$)

In the second iteration of the 201 alternative regressions, the switch date is presumed to occur on DAY = -99. Thus,

PRE = 1, POST = 0 if ($-125 \leq \text{DAY} \leq -99$)
PRE = 0, POST = 1 if ($-99 > \text{DAY} \leq +125$)

In the final regression, after 198 additional intervening iterations, the switch is presumed to occur on DAY = +100,

PRE = 1, POST = 0 if ($-125 \leq \text{DAY} \leq +100$)
PRE = 0, POST = 1 if ($+100 > \text{DAY} \leq +125$)

In order to determine the most likely date for a regime change to have occurred, we consider each of the possible switch dates between t_L-100 and t_L+100, where t_L is the list date.

We then compare the goodness-of-fit across these 201 regression outputs. The regime-change date that results in the highest log-likelihood ratio denotes the optimal switch date.

The foregoing test implicitly assumes that an optimal switch date exists. Therefore, we also consider the possibility that no regime shift occurs at all. Constraining the coefficients β_0 and β_1 in Equation 5 to be zero, and setting the hypothesized switch date to t_L+125, the model fits the data without allowing for the possibility of a regime change. Using a test described by Quandt (1958), the likelihood ratio for the hypothesized optimal-switch-date model can be compared to that of the restricted one-regime model. We apply this test to our data and find that, for each variable we consider, the preferred specification is the optimized two-regime model, rather than the alternative constrained one-regime model.

Having rejected the alternative that no regime change occurs, we next test whether the optimal switch date is statistically different from the option listing date using the following statistic: $2(LR_{\text{switch date}} - LR_{\text{list date}}) \sim \chi^2(1\text{ df})$, where LR is the log of the likelihood ratio on the optimal switch date or the listing date. The upper and lower bounds of the confidence interval around the optimal switch-date, T*, are based on $2(LR_{T*} - LR_{\text{lower date}}) \sim \chi^2(1\text{ df})$ and $2(LR_{T*} - LR_{\text{upper date}}) \sim \chi^2(1\text{ df})$. These bounds denote the earliest and latest dates that cannot be distinguished from the optimal switch date with statistical significance. However, some dates within the confidence interval can occasionally be statistically differentiated from the optimal shift-date.

In Panel A of Table 3, we apply our regime-change tests to all option listings ("Combined") as well as to the NYSE and NASDAQ groups separately. None of the optimal switch dates suggest a switch on the listing date for the Combined set of firms or for the separate NASDAQ stocks, which comprise approximately three quarters of the Combined sample. The

χ^2 test rules out the list date as a switch date in each case. Except for trade size, which identifies a preferred regime change after the listing date, each measure identifies the optimal shift as occurring before the listing date with 95% significance.

For the smaller subset of NYSE firms, we observe three exceptions to the general finding outlined above. The trade size variable exhibits an optimal switch date 75 days before the listing, but the 95% confidence interval includes the listing date. In addition, the percentage quoted spread and the percentage effective spread have optimal switch dates near the listing, and these switch dates cannot be distinguished statistically from the listing date.

The percentage spread variables in Panel A reflect not only the dollar spread, but also the daily share price, which previous researchers have found changes fairly sharply around the listing date. In order to isolate the effect of the change in the spread (the numerator) from the scaling metric (the denominator), we also consider whether an option-listing price effect might induce a change in the percentage spread at the time of listing. In Panel B, we calculate the percentage spread variables using the listing day price for each stock, so any change in the percentage spread is a result of the dollar spread, and not the share price. Using these revised variable definitions, the optimal switch date for the percentage quoted spread is, unambiguously, prior to the listing date for both the NYSE and NASDAQ stocks, although the percentage effective spread results continue to mirror those in Panel A.

The NASDAQ optimal switch precedes and can be statistically distinguished from the listing date, but for the NYSE percentage effective spread, the optimal switch date, while predating listing, cannot be statistically distinguished from the listing date. We also note that the confidence interval for NYSE percentage effective spread in Panel B covers 113 days. Thus, while the model cannot distinguish between the optimal regime-change date and the option-listing date, it also cannot distinguish the optimal regime shift date from a large fraction of the 201 alternative regime-shift dates.

Taken as a whole, the change-date tests for the market liquidity measures suggest that improvements in liquidity do not generally result from option listings, but rather precede option listings.

For robustness, we also examine the cross-sectional median values of each liquidity measure (not tabulated). For 18 of the 21 liquidity measures reported in Table 3, Panel A, the optimal-switch-date estimates precede the option introduction date. The exceptions are the NYSE percentage effective spread, NASDAQ trade size, and Combined trade size variables, which report optimal switch dates using median values that are several weeks after the introduction date.

C. Visual Depictions and Further Discussions of the Results

To give the reader a better understanding of the data time series, Figure 2 presents several graphs using the fitted values for the “optimal” switch day regression results shown in Table 3. The confidence interval is identified on each graph using two solid vertical lines. A dotted line marks the listing date on each graph. In addition to the fitted values, each figure shows the mean value of the variable observed on each day.

The first two graphs show the percentage spread for NYSE and NASDAQ stocks, respectively. The results here are relatively clear. Although the option listing cannot be distinguished from the optimal switch-date for the NYSE firms, spreads for both NASDAQ and NYSE firms are declining before the option introduction, and the listing does not cause spreads to fall in any obvious manner. Likewise, in the third and fourth graphs, daily trading volume peaks before options are introduced. While average volume is higher after the option is introduced, it should be clear that increasing volume *precedes* the listing rather than *results from* the listing.

NASDAQ volatility (the last graph) is the single microstructure measure where a true regime shift seems to occur near the listing date. Recall that the optimal shift date for this variable is four days before the listing date. Mayhew and Mihov (2004) observe that volatility is a selection criterion for the exchanges, and we clearly observe increased volatility for NASDAQ firms shortly before the option listing. Nevertheless, we also observe a substantial break in the data points in the week prior to the option listing. In the next subsection, we will show that this break apparently coincides with the option announcement date, suggesting that the announcement has an impact on NASDAQ volatility.

D. Announcement Date Effects

One might speculate that our tests reflect some type of announcement date effect, but this seems unlikely. Announcement effects in returns, as opposed to the microstructure variables studied here, are understood to exist because traders incorporate new information into security prices. If the price did not immediately respond to announcements of future wealth-generating events, arbitrage opportunities would exist. It is not clear how announcement date effects should be manifested in liquidity variables prior to the actual listing, because no obvious arbitrage opportunity exists for liquidity measures. Nevertheless, in Table 4, we search for possible announcement effects by examining the subset of listings for which we have determined the announcement date for the option listing. These tests are identical to those in Table 3, except that all variables are reordered and expressed in “announcement time,” rather than “listing time.”

Using Lexis/Nexis, we search for announcement dates for each of the 1062 option listings. We find announcement dates for 764 of these events, of which 195 are NYSE stock listings and 569 are NASDAQ stock listings. The firms for which we find announcements are not a random subset of the listed firms, as they have lower average spreads and higher average volatility over the t_L-40 to t_L-20 window. The fact that exchanges publicize the introduction of options on more volatile, lower bid-ask spread firms is consistent with these variables being viewed as important selection criteria by these exchanges.[5]

For each observation, we capture a 251-day time series of data around the announcement date, t_A. The mean number of days between the announcement and the listing day is 4.73 calendar days, or 3.06 trading days. The median number of days between announcement and listing is 5 calendar days (3 trading days).

The first two columns in Table 4 report optimal switch dates and the 95% confidence intervals found in the data relative to the announcement dates. Generally, the results are consistent with those in Table 3, as for most variables the optimal switch-date precedes the announcement date with high levels of statistical significance. Two variables present exceptions to this general characterization. For NYSE percentage effective spreads, the optimal switch date is eleven days before the announcement, but this optimal date cannot be statistically distinguished from the announcement date. Moreover, the 95% confidence interval around this optimal switch-date extends from t_A-16 to t_A+37. The second and more interesting exception to the general rule that regime shifts occur before the announcement date arises for volatility. The

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[5] We find that a one standard deviation decrease in the bid-ask spread produces a 52% greater probability that we find an announcement in the Lexis/Nexis database. A one standard deviation increase in the intraday volatility produces a 40% increase in the probability of finding an announcement. Volume, share price, and market value do not appear to impact the odds of an announcement being released. These findings are obtained using a logit analysis of announced versus unannounced listings.

optimal switch date for NASDAQ and Combined midpoint volatility is on the announcement date itself, and the 95% confidence interval spans only two days.[6] This is strong evidence that option listing announcements have an impact on the time-series of intraday volatility for NASDAQ firms. We are surprised by this result, and we observe that no such result is evident for the NYSE stocks.[7]

The trade size results in Table 4 are rather weak, as evidenced by the large confidence intervals for both the NASDAQ and Combined samples. The NASDAQ trade size confidence interval, in particular, requires comment. The NASDAQ data selects t_A+94 as the optimal switch date, with a confidence interval from t_A-97 to t_A+100 and actually includes the announcement day. This seemingly contradictory result is due to our method of measuring the confidence interval as ranging from the first and last date that can be distinguished from the switch date, even though dates in the interval may also be distinguished from the switch date. A similar issue occurs for the Combined sample trade size test, where the selected shift date of t_A-94 is bounded by a confidence interval stretching from t_A-99 to t_A+18. Within this interval, only the dates between t_A-99 and t_A-85 and the date t_A+18 cannot be statistically distinguished from t_A-94.

The last two columns of Table 4 present the optimal shift dates in list-date time, as opposed to announcement-date time. Because the announcement date precedes the list date by a mean of 3.06 trading days (median 3), the optimal switch date that we expect to observe in list-date time should precede the switch in announcement-time by approximately 3 trading days.

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[6] Given that more volatile firms have option introductions announced, we speculate that the tighter confidence intervals associated with both the NASDAQ and the Combined volatility in Table 4, relative to Table 3, may be related to this announcement selection bias.

[7] We consider the possibility that reduced NASDAQ volatility at the announcement might be related to the arrival of additional market makers in the stock who are attracted to the security by the option announcement. In fact, the number of market makers in the stock increases from less than 15 to more than 19 over the 251-day window, but no spike is observed on or near the listing or the announcement. We remain puzzled concerning the reason for the drop in NASDAQ volatility on the announcement date.

Since there is cross-sectional variation in the number of days between announcement and listing, the announcement-date-centered results and listing-date-centered results are not simply shifted by exactly 3 days, but instead are slightly shifted and shuffled. As a general rule, the list-date centered results conform to the announcement-time results in Table 4 and also to the list-date results in Table 3.

In summary, with the exception of NASDAQ volatility, all of the optimal-switch-date analyses suggest that neither the announcement, nor the listing has an observable impact on measured liquidity. Instead, a selection bias by the exchanges offers a better potential explanation for the observed patterns. In the next section we examine whether the observed ex-ante improvements in liquidity influence the likelihood that an exchange lists options on a security.

V. Revisiting the Determinants of Option Listing

Having determined that various liquidity metrics decline prior to both the option announcement and listing dates, it seems reasonable to suspect that exchanges may use liquidity metrics as listing decision variables.

Mayhew and Mihov (2004) set forth a method for examining the relative importance of factors influencing exchanges' listing decisions. They model the option listing decision in a logit framework in which the decision to list is a binary variable, and the listing determinants are the regressors. Under this approach, the data set is comprised of the dates on which options can be listed. On each of these dates, an option listing dummy variable is created and coded 1 for the firms that are listed, while the other non-listed, but eligible firms are coded 0. This approach, termed the “static model” by Shumway (2001), ignores information contained in the days on which there were no options listed, yet firms were eligible and suitable candidates for optioning.

An alternative approach that attempts to use the full time series of data, including those dates on which no listing event actually happens, is to create a data set in which every trading day is included regardless of whether an option is listed. For days on which no options are listed, the dependent binary variable is zero for every firm in the data set. This approach has been used by other authors (see for example: Pagano, Panetta, and Zingales (1998) who model the IPO decision using a probit model, and Denis, Denis, and Sarin (1997) who model executive turnover using a logit model). In these applications the data set is not a traditional panel data set but more correctly termed an event-history data set, which reduces in observations each time a firm is optioned and thus exits from the data set.

While the use of the full time series event history data set is an improvement over the static model, the use of logit regressions will produce incorrect test statistics because of the flawed assumption that all the observations for a firm are independent. At the simplest level, if a firm is optioned on day t, it cannot be optioned on day t-1. Therefore the observations on day t and t-1 are not independent.

Shumway (2001) discusses these issues in detail and notes that adjusting the sample size of the logit estimation can account for the non-independence of observations. Alternatively, we can directly estimate a Cox proportional hazard model. Hazard models, commonly used in medical research, model a failure event (in this case failure means being listed by an options exchange) as a function of the determinants of the failure.[8] Some types of hazard model also

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[8] Hazard models are used periodically in finance, in addition to those cited, see also Johnson (2004), Ongena and Smith (2001), McQueen and Thorley (1994), and Deshmukh (2003).

model the failure event as an independent function of elapsed time. However, the Cox proportional hazard model is a semi-parametric model in which the likelihood of failure is not related to elapsed time, an assumption that seems reasonable in our context. The hazard model approach takes into account the evolution of a firm's characteristics and computes a hazard (or likelihood) ratio of the firm being optioned, whether or not the firm is actually listed. The parameter estimates of the hazard model should be similar to those of the logit model (using a full event-history data set), but the hazard model accounts for the lack of independence between observations and produces superior test statistics.[9]

We therefore estimate the following hazard model in which the option listing decision is a function of various observable stock characteristics:

$$\begin{aligned} LIST_{it} &= \alpha_0 + \alpha_1 SPREAD40\text{-}20_{it} + \alpha_2 ABSPREAD_{it} + \alpha_3 SDRET40\text{-}20_{it} \\ &+ \alpha_4 ABSTD_{it} + \alpha_5 VOLUME40\text{-}20_{it} + \alpha_6 ABVOL_{it} + \alpha_7 PRC_{it} + \alpha_8 MV_{it} + \varepsilon \qquad (6) \end{aligned}$$

The subscript *i* represents each firm in the data set that is eligible to be optioned on the day t, where t covers every trading day from January 1994 to March 2001.[10] The dependent variable, $LIST_{it}$, is binary. If firm *i* is initially listed by an options exchange on a day t, LIST =1. If firm *i* does not already have options listed, and options are not listed on day t, LIST = 0. Firms with outstanding options cannot have initial listings, and these firms are excluded from the analysis. Finally, once a firm is listed, it drops out of the data set.

The independent variables are all measured prior to the option listing date. Ideally, we would consider the value of various variables prior to the date of the listing decision, as opposed to the actual listing, but the decision date is unobserved. Therefore, to be confident that the

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[9] Our results are qualitatively similar if we estimate a logit model on either a static or an event-history data set.

[10] Our sample begins in 1994, because we need one prior year of TAQ data to generate variables and ends in 2001, prior to the tick size change in April 2001.

variables of interest are in the exchanges' information set, we measure the variables over the 20 to 40 days preceding the option listing date.[11] While the t_L-40 to t_L-20 day window represents the most recent level of the variable in question, we also create change variables to compare the recent level with a longer run historical level, which we measure over days t_L-250 to t_L-125. The change, or abnormal variable, is computed as the ratio of the t_L-40 to t_L-20 variable to the t_L-250 to t_L-125 variable.

The specific variables we consider are as follows: SPREAD40-20$_{it}$ is the mean percentage bid-ask spread for firm *i* over the t_L-40 to t_L-20 trading day window. ABSPREAD$_{it}$ is the ratio of SPREAD40-20$_{it}$ to the 125-day average percentage bid-ask spread for the period from t_L-250 to t_L-125 prior to the listing. Thus, SPREAD40-20$_{it}$ captures the spread level shortly before the listing decision is announced, and ABSPREAD$_{it}$ captures the change in the spread during the several months prior to the listing decision. Using the same naming convention, SDRET40-20$_{it}$ (VOLUME40-20$_{it}$) is the prior mean daily volatility (volume) over the t_L-40 to t_L-20 trading day window prior to the listing date. ABSDRET$_{it}$ (ABVOL$_{it}$) is the ratio of SDRET40-20$_{it}$ (VOLUME40-20$_{it}$) to the t_L-250 to t_L-125 day average volatility (volume) prior to the listing. MV$_{it}$ is the market value of the firm on day t_L-20 prior to listing, and PRC$_{it}$ is the price of the stock also recorded on day t_L-20.

Our measures of abnormal volume and volatility differ slightly from those utilized by Mayhew and Mihov (2004). Mayhew and Mihov use the average daily values for variables over

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[11] Our decision to present results using a baseline period of t_L-40 to t_L-20 for all variables is somewhat ad hoc. The results are fundamentally unchanged when several alternative baseline periods are considered. For example, we test using base-level mean metrics calculated from t_L-60 to t_L-40. Alternatively, we examine results for tests with heterogeneous base periods for each variable. As an example, t_L-39 to t_L-19 for percentage spread, t_L-59 to t_L-39 for volatility, and t_L-58 to t_L-38 for volume. These base periods immediately precede the earliest date for the 95% confidence interval in Table 3. Results do not change substantially for any of these alternatives.

the 250 days prior to the 15th of each listing month as baseline values. We have chosen as a baseline the average daily values 40 days to 20 days prior to the listing day. Not only are our baseline values more recent when a listing decision is being considered, but by eliminating the data from the last 20 trading days prior to the listing, it seems likely that all of the data we use were actually available to the decision makers at the decision time. Our abnormal volume and volatility metrics also differ from those used in the Mayhew-Mihov model. Mayhew and Mihov construct these variables as the ratios of 30-day to 250-day prior trading volume and standard deviation. Our abnormal volatility and volume metrics are constructed so that the time periods used for the numerator and the denominator of the ratio do not overlap.

The first model in Table 5 presents results for the hazard model in equation 6. Coefficients and p-values demonstrate that both the average ex-ante bid-ask spread, and the abnormal ex-ante spread are important determinants of option listing. If a firm has a low spread, and if the spread has declined prior to the potential event selection date, the firm is more likely to be selected for option listing. The positive coefficient on SDRET40-20 demonstrates that high volatility increases the odds that exchanges will list options on a stock. ABSDRET is positive, indicating that stocks with increasing volatility are also more likely to be optioned.

Mayhew and Mihov (2004) report that high trading volume appears to be a determinative listing variable, although during one sub-period they find that the volume effect is not significant. In Model 1, we find that VOLUME40-20 is weakly negatively correlated with the listing probability, while ABVOL has a positive relation with the likelihood of optioning. Neither volume variable is statistically significant.

The market value of equity has a negative relation with the likelihood of listing, consistent with smaller stocks being favored as option candidates. In this specification we find no relation between the share price and the probability of listing.

Interpreting the economic significance of the coefficients requires estimating the increase in the likelihood of the option listing given a change in the independent variable of interest. Commonly, standardized hazard ratios are computed by calculating the effect of a one standard deviation shift for each independent variable. However, several of the variables in our study are right-tail skewed, and consequently they have large standard deviations, which may make cross-sectional comparisons misleading. As an alternative, we consider a change in each right-hand-side variable equal to 10% of the variable’s mean value, but our results are qualitatively similar using 10% of medians. We refer to this measure as a 10%-of-mean-standardized hazard ratio to avoid confusion with a ratio based on standard deviations. Because hazard ratios are easier to interpret when the coefficient estimates are positive, we use the absolute value of each coefficient to estimate our 10%-of-mean-standardized hazard ratio. The 10%-of-mean-standardized hazard ratio is computed as $e^{\left|coef\right| \times 0.1 \times mean}$.

For Model 1 in Table 5, consider 10%-of-mean-standardized hazard ratio for SPREAD40-20, which equals 1.0863. For a 10% decrease in SPREAD40-20 (which equates to about 4.5 cents for the average stock over this time period), the odds of the security having an option listing are increased by 8.63% (108.63%-100%). Likewise, in cross-section, a firm with a 10% lower ABSPREAD is 21.05% more likely to have options listed in the next month.

The effect of volatility on the probability of listing is captured by the 10%-of-mean-standardized hazard ratio on SDRET40-20 and ABSDRET. The listing probability increases by 1.51% for a 10% increase from the mean of SDRET40-20, which equates to about a 0.3% point increase in cross-sectional volatility between days t_L-40 and t_L-20, and by 0.53% for a 10% increase in ABSDRET. The hazard ratios for VOLUME40-20 and ABVOL are not significantly different from unity, implying that in this specification, volume of the underlying stock has little impact on the listing decision. We will revisit the impact of volume in model 3.

The 10%-of-mean hazard ratios highlight the relative importance of the spread variables as determinants of listing. These findings are consistent with the hypothesis that exchanges prefer to list highly liquid stocks as liquidity mitigates the costs of dynamic trading strategies.

In Model 2, we drop the spread variables from Model 1 to create a model that closely resembles Mayhew and Mihov's model. We find some differences between our results and their post 1991-1996 results (which most closely overlaps our sample period). The coefficients on SDRET40-20 are not materially impacted in this specification. However ABSDRET becomes insignificant, VOLUME40-20 remains insignificant, although ABVOL becomes positive and significant. The sign on market value becomes positive and significant and the price variable becomes positive and highly significant. The sign and significance of the coefficients on ln(MV), PRICE and ABVOL, should not be surprising. Percentage spreads are lower for large, high-priced firms with high trading volume. Deleting the spread variables from the regression forces other variables with positive correlations to the spread variables to serve as proxies for the missing variable.

Model 3 in Table 5 replaces the volume variables (VOLUME40-20 and ABVOL) with variables constructed from components of volume. Volume is equal to the number of trades multiplied by the average trade size. TSIZE40-20 is the mean daily trade size over t_L-40 to t_L-20. ABTSIZE is the ratio of TSIZE40-20 to the average trade size over t_L-250 to t_L-125.

NUMTRD40-20 is the average number of daily trades over t_L-40 to t_L-20. ABNUMTRD is the ratio of NUMTRD40-20 to the average number of trades over t_L-250 to t_L-125.

Using this decomposition of volume, we discover that TSIZE40-20 and NUMTRD40-20 are significant at the 10% level, suggesting that large trades by a limited number of traders are more likely to result in option listing. This result seems reasonable in that larger, more sophisticated traders seem more likely to trade in the options markets.

The 10%-of-mean hazard ratios are also presented for Model 3. The spread variables remain very important determinants of listings and have been joined by market value. Spreads apparently play a critical, but previously unrecognized, role in the options listing decision.

Table 6 presents sub-period results for Models 1 and 3 from Table 5. Minimum tick sizes were reduced from eighths of a dollar to sixteenths of a dollar during June of 1997. We use this date to bifurcate the sample (note that the second sub-sample starts for option listings from June 1998 because of the data requirements for the abnormal variables). The sub-period results are broadly consistent with the full-sample results reported in Table 5, and the results are qualitatively similar in both subperiods. Careful scrutiny suggests that SDRET40-20 has slightly greater predictive power in the earlier period, because the 10%-of-mean hazard ratio is slightly above 1.05 for both specifications in the early period and only slightly above 1.02 in both specifications for the later subperiod. Also, the sign on ln(MV) reverses between the subperiods. However, all of the fundamental results are robust to our subperiod analysis.

VI. Conclusion

This paper re-examines the impact of option introductions on the market quality of the underlying stocks. We find that the post-option market quality, measured by spreads, volatility and volume shows an improvement over the pre-option market quality. However, we conclude that this improvement is not due to the option introduction. Our findings indicate that previous studies have misinterpreted ex-ante changes as option introduction effects. In most cases, market quality, as measured by spreads, trading volume, and volatility peaks before the option listing date. We can usually rule out the listing date and announcement dates as the optimal regime shift date at high levels of statistical significance.

Not only are changes in liquidity endogenous to the option listing decision, but we find that the level of the spread prior to the option listing may be the most important determinant of the listing decision, although volatility clearly plays an important role. The importance of liquidity, particularly as measured by spreads, in the option listing decision is a new result, but one that makes intuitive sense. If traders or option market makers engage in dynamic hedging in the spot market, the liquidity of the spot asset will greatly impact the costs of hedging. Our observation that low-spread, high-volatility firms are more likely to have listing announcements is also consistent with exchanges focusing on these variables when making listing decisions.

Apart from providing a more complete picture of market quality changes around option listings, the more general contribution of our analysis is that we provide a new technique that can accommodate drift in the estimation parameters as well as identify the parameters' optimal shift date with a confidence interval. The model's optimal shift date, obtained as the highest log-likelihood from a switching regression model, can be compared to the event date, or any other date of interest. While we use this method to search for option listing effects in microstructure data, the method is generalizable to other events and/or variables of interest.

References

Bessembinder, H. “Trade Execution Costs and Market Quality after Decimalization.” *Journal of Financial and Quantitative Analysis,* 38 (2003), 747-777.

Black, F. and M. S. Scholes. “The Pricing of Options and Corporate Liabilities.” *Journal of Political Economy*, 81 (1973), 637-654.

Chung, K., B. Van Ness, and R. Van Ness. “Trading Costs and Quote Clustering on the NYSE and NASDAQ After Decimalization.” *Journal of Financial Research,* 27 (2004), 309-328.

Conrad, J. “The Price Effect of Option Introductions.” *Journal of Finance*, 44 (1989), 487-499.

Danielsen, B. R. and S. M. Sorescu. “Why do Option Introductions Depress Stock Prices? A Study of Diminishing Short-Sale Constraints.” *Journal of Financial and Quantitative Analysis*, 36 (2001), 451-484.

Deshmukh, S. “Dividend Initiations and Asymmetric Information: A Hazard Model.” *Financial Review,* 38 (2003), 351-368.

Denis, D. J., D. K. Denis and A. Sarin. “Agency Problems, Equity Ownership, and Corporate Diversification.” *Journal of Finance,* 52 (1997), 135-160.

Figlewski, S. and G.P. Webb. “Options, Short Sales, and Market Completeness.” *Journal of Finance,* 48 (1993), 761-777.

Hakansson, N. H. "Changes in the Financial Market: Welfare and Price Effects and the Basic Theorems of Value Conservation." *Journal of Finance,* 37 (1982), 977-1004.

Huang, R. and H. Stoll. "Dealer Versus Auction Markets: A Paired Comparison of Execution Costs on NASDAQ and the NYSE." *Journal of Financial Economics,* 41 (1996), 313-357.

Johnson, T. C. "Forecast Dispersion and the Cross Section of Expected Returns." *Journal of Finance*, 59 (2004), 1957-1978.

Kumar, R., A. Sarin and K. Shastri. "The Impact of Options Trading on the Market Quality of the Underlying Security: An Empirical Analysis." *Journal of Finance,* 53 (1998), 717-732.

Lee, C. M. C., and M. A. Ready. "Inferring Trade Direction From Intraday Data." *Journal of Finance,* 46 (1991), 733-746.

Mayhew, S., and V. Mihov. "How Do Exchanges Select Stocks for Option Listing?" *Journal of Finance*, 59 (2004), 447-472.

McQueen, G. and S. Thorley. **"**Bubbles, Stock Returns, and Duration Dependence." *Journal of Financial and Quantitative Analysis,* 29 (1994), 379-401.

Onega S. and D. Smith. "The Duration of Bank Relationships." *Journal of Financial Economics,* 61 (2001), 449-475.

Pagano, M., F. Panetta and L. Zingales. “Why Do Companies Go Public? An Empirical Analysis.” *Journal of Finance*, 53 (1998), 27-64.

Quandt, R. E. “The Estimation of the Parameters of a Linear Regression System Obeying Two Separate Regimes.” *Journal of the American Statistical Association*, 53 (1958), 873-880.

Ross, S. A. “Options and Efficiency.” *Quarterly Journal of Economics*, 90 (1976), 75-89.

Shumway, T. **“**Forecasting Bankruptcy More Accurately: A Simple Hazard Model.” *Journal of Business,* 74 (2001), 101-124.

Skinner, D. J. “Options Market and Stock Return Volatility.” *Journal of Financial Economics,* 23 (1989), 61-78.

Sorescu, S. M. “The Effect of Options on Stock Prices: 1973 to 1995.” *Journal of Finance*, 55 (2000), 487-514.

TABLE 1
Summary Statistics of Optioned Stocks Compared to Non-optioned Stocks

		Percent Spread		Volume		Volatility		Market Value		Price	
Year	Obs	Mean [StDev]	Ratio to All Firms	Mean [StDev]	Ratio to All Firms	Mean [StDev]	Ratio to All Firms	Mean [StDev]	Ratio to All Firms	Mean [StDev]	Ratio to All Firms
1993	32	1.46%	0.454***	290,598	4.545	3.12%	1.044	476,259	1.126	21.46	1.162*
		[0.56%]		[894,174]		[2.05%]		[308,040]		[8.54]	
1994	108	1.83%	0.549***	137,144	2.363***	3.10%	1.071	766,464	1.916*	22.05	1.290***
		[0.99%]		[96,044]		[1.45%]		[2,222,659]		[11.19]	
1995	95	1.41%	0.458***	129,701	1.878***	2.68%	0.952	612,316	1.409***	26.82	1.533***
		[0.79%]		[101,529]		[1.34%]		[525,213]		[14.28]	
1996	175	1.78%	0.661***	160,521	1.747***	3.88%	1.342***	505,007	0.924	23.99	1.219***
		[1.02%]		[145,316]		[2.09%]		[572,779]		[12.23]	
1997	21	1.60%	0.858*	144,395	1.177	4.56%	1.424**	392,409	0.529***	18.37	0.833*
		[0.69%]		[134,879]		[2.28%]		[419,265]		[8.41]	
1998	263	1.30%	0.664***	139,226	0.986	3.80%	1.121***	552,518	0.669***	25.00	1.203***
		[0.72%]		[211,067]		[2.18%]		[515,251]		[15.75]	
1999	179	1.12%	0.585***	344,279	1.873***	5.85%	1.650***	708,782	0.678***	29.50	1.531***
		[0.44%]		[510,266]		[3.54%]		[1,014,288]		[31.98]	
2000	136	1.02%	0.563***	677,251	2.446***	9.07%	2.083***	1,185,889	0.836*	42.08	1.988***
		[0.35%]		[1,578,173]		[4.07%]		[1,647,382]		[43.97]	

Table 1 presents annual summary statistics for stocks in the sample. Percent Spread is the average quoted spread as a percentage of the price for the 40 to 20 day window prior to the listing date. Volume is the average volume for the 40 to 20 day window, and Volatility is the standard deviation of returns over the 40 to 20 day window. Market Value and Price are reported for the listing date. For each variable, the standard deviation [StDev] is reported immediately beneath the mean value. The “Ratio to All Firms” columns contain the ratio of the option firm variable to the equivalent variable for all eligible firms that are not optioned in that year. The significance level reported is for a simple two tailed t-test that the mean of the listing firm’s variable is equal to the mean of the non-listed firm’s variable.

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

TABLE 2
Changes in the Means of Variables Around the Options Listing Day

	NYSE			NASDAQ		
	Mean t < 0	Mean t > 0	Difference	Mean t < 0	Mean t > 0	Difference
Spread	0.20149	0.19004	-0.01146***	0.37086	0.30172	-0.06914***
Percent spread	0.00982	0.00944	-0.00038***	0.01758	0.01542	-0.00216***
Effective spread	0.00608	0.00587	-0.00021***	0.01336	0.01168	-0.00168***
Standardized volume	0.00017	0.00018	0.00001**	0.00030	0.00036	0.00006***
Trade size	1780.67	1788.27	7.59664	1274.52	1169.21	-105.310***
Number of trades	43.9932	52.3985	8.4053***	320.741	434.109	113.368***
Standard deviation of quote midpoint	0.08231	0.07939	-0.00292***	0.45781	0.42904	-0.02877***

Table 2 presents tests of the changes in microstructure variables around the option listing day. The variables are measured as the average for all stocks over all days before and after option introduction date. The Spread is the average dollar spread between the bid and the ask quotes. Percent spread standardizes the Spread by dividing by the quote midpoint. The Effective spread is twice the signed difference between the average trade price and the midpoint. Standardized volume is daily share volume divided by total volume for the exchange for that day, i.e. total NASDAQ volume for NASDAQ stocks, total NYSE volume for NYSE stocks. Trade size and Number of trades are daily averages, and the Standard deviation of quote midpoint captures intraday volatility. The window before and after the option listing date is 125 days.

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

TABLE 3
Tests for Most Likely Switch Date for Regimes in Switching Regression Model

Exchange	Variable	Optimal Switch Date(s)	P(Switch Date=List Date)	Lower 95% CI	Upper 95% CI
Panel A: Optimal Switch Dates Relative to the Option Listing Date					
Combined					
	Percentage Quoted Spread	(-10,-6)***	0.0003	-18	-4
	Quoted Spread	-18***	<0.0001	-18	-9
	Percentage Effective Spread	-8***	0.0054	-15	-4
	Std Dev Of Quote Midpoint	-4***	<0.0001	-38	-3
	Volume	-37***	<0.0001	-37	-37
	Number Of Trades	-42***	<0.0001	-49	-33
	Trade Size	13***	0.0045	+6	+31
NASDAQ					
	Percentage Quoted Spread	-12***	<0.0001	-19	-5
	Quoted Spread	-10***	<0.0001	-18	-8
	Percentage Effective Spread	(-11,-10,-9)***	0.0005	-17	-5
	Std Dev Of Quote Midpoint	-4***	<0.0001	-38	-4
	Volume	-37***	<0.0001	-56	-37
	Number Of Trades	-42***	<0.0001	-62	-33
	Trade Size	+83***	0.0001	+75	+100
NYSE					
	Percentage Quoted Spread	-1	0.8026	-31	+21
	Quoted Spread	-31***	<0.0001	-37	-31
	Percentage Effective Spread	-2	0.8026	-16	+25
	Std Dev Of Quote Midpoint	-56***	0.0045	-56	-55
	Volume	-33***	<0.0001	-35	-33
	Number Of Trades	-33***	<0.0001	-35	-28
	Trade Size	-75*	0.0742	-84	+14

TABLE 3
Tests for Most Likely Switch Date for Regimes in Switching Regression Model (continued)

Exchange	Variable	Optimal Switch Date(s)	P(Switch Date=List Date)	Lower 95% CI	Upper 95% CI
Panel B: Optimal Switch Dates Relative to the Listing Date (Scaled by the Listing Day Stock Price)					
Combined					
	Percentage Quoted Spread	-9***	<0.0001	-19	-7
	Percentage Effective Spread	-11***	<0.0001	-17	-7
NASDAQ					
	Percentage Quoted Spread	-9***	<0.0001	-11	-7
	Percentage Effective Spread	-11***	<0.0001	-17	-7
NYSE					
	Percentage Quoted Spread	-31***	0.0082	-36	-17
	Percentage Effective Spread	-30	0.3026	-59	+53

Table 3 presents the optimal switch date estimated as the date that results in the highest log-likelihood ratio from a switching regression model that fits two lines with different slopes and intercepts. The lines are not required to connect at a spline node. The p-value is for the test $2(LR_{T^*} – LR_L)$~X (1df) where T* is the switch date and L is the listing date. The test statistic reveals whether the LR on the identified switch date is significantly different from the LR from a hypothesized switch on the option listing date. The lower and upper confidence interval bounds are based on the tests: $2(LR_{T^*}-LR_{\text{lower date}})$~X (1df) and $2(LR_{T^*}-LR_{\text{upper date}})$~X (1df). Panel A reports optimal switch dates for all variables, Panel B reports optimal switch dates for spread variables that are scaled by the stock price on the listing, rather than the stock price on each day t.

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

TABLE 4
Tests for Optimal Switch Dates for Firms with Announcement data, in Both Announcement-Date and List-Date Time

		Announcement-date Time		List-date Time	
Exchange	Variable	Optimal Switch Day(s)	Con. Interval	Optimal Switch Day(s)	Con. Interval
Combined					
	Percentage Quoted Spread	(-13,-12,-11,-10)***	[-19,-2]	(-16,-15,-14)***	[-22,-5]
	Quoted Spread	-6***	[-7,-3]	-9***	[-11,-8]
	Percentage Effective Spread	-9**	[-18,-1]	-12***	[-22,-5]
	Std Dev Of Quote Midpoint	0	[-1,0]	-4***	[-6,-4]
	Volume	-32***	[-41,-32]	-37***	[-37]
	Number Of Trades	-42***	[-42,+8]	(-49,-48)**	[-49,+42]
	Trade Size	-94***	[-99,+18]	83**	[+6,+100]
NASDAQ					
	Percentage Quoted Spread	(-15,14)***	[-21,-8]	(-17,16)***	[-23,-6]
	Quoted Spread	-6***	[-7,-3]	-10***	[-11,-8]
	Percentage Effective Spread	(-15,-12,-11)***	[-19,-3]	(-14,-13)***	[-22,-6]
	Std Dev Of Quote Midpoint	0	[-1,0]	-4***	[-6,-4]
	Volume	-41***	[-42,-41]	-55***	[-59,-55]
	Number Of Trades	-42***	[-42,+7]	-49**	[-49,-2]
	Trade Size	94***	[-97,+100]	83***	[+63,+100]
NYSE					
	Percentage Quoted Spread	-30*	[-42,+20]	-31	[-43,+21]
	Quoted Spread	-30***	[-38,-28]	-31***	[-43,-22]
	Percentage Effective Spread	-11	[-16,+37]	-2	[-17,+36]
	Std Dev Of Quote Midpoint	-41***	[-54,-37]	-43***	[-56,-41]
	Volume	-25***	[-26,-23]	-33***	[-33,-28]
	Number Of Trades	-25***	[-26,-24]	-28***	[-29,-28]
	Trade Size	-76***	[-77,-75]	-75***	[-83,-75]

Table 4 presents the subset of data with announcement dates organized first in announcement time and then in list time. The optimal switch date estimated as the date that results in the highest log-likelihood ratio from a switching regression model that fits two lines with different slopes and intercepts. The lines are not required to connect at a spline node. The p-value is for the test $2(LR_{T*} – LR_{D})$~X (1df) where T* is the switch date and D is either the announcement date or the listing date depending on whether the data is in announcement time or listing time. The test statistic reveals whether the LR on the identified switch date is significantly different from the LR from a hypothesized switch on the option announcement or listing date. The lower and upper confidence interval bounds are based on the tests: $2(LR_{T*}$-$LR_{\text{lower date}})$~X (1df) and $2(LR_{T*}$-$LR_{\text{upper date}})$~X (1df).
***, **, * indicate significance at the 1%, 5%, and 10% levels respectively.

TABLE 5
Cox Proportional Hazard Model Measuring the Determinants of Option Listing

	Model 1		Model 2		Model 3		
Optioned=1	Coefficient [P>|z|]	10%-of-mean-standardized HR	Coefficient [P>|z|]	10%-of-mean-standardized HR	Coefficient [P>|z|]	10%-of-mean-standardized HR	Variable Mean
PCT SPREAD40-20	-0.0372	1.0863			-0.0350	1.0809	22.2260
[× 1,000]	[<0.001]***				[<0.001]***		
ABSPREAD	-1.9139	1.2105			-1.9525	1.2152	0.9981
	[<0.001]***				[<0.001]***		
SDRET40-20	0.0045	1.0151	0.0042	1.0142	0.0055	1.0185	33.3252
[× 1,000]	[<0.001]***		[<0.001]***		[<0.001]***		
ABSDRET	0.0514	1.0053	0.0057	1.0006	0.0554	1.0057	1.0324
	[0.036]**		[0.909]		[0.018]**		
VOLUME40-20	-0.0819	1.0016	-0.0008	1.0000			0.1997
[/ 1,000,000]	[0.234]		[0.986]				
ABVOL	0.0021	1.0003	0.0038	1.0005			1.3289
	[0.364]		[<0.001]***				
TSIZE40-20					0.0671	1.0104	1.5397
[/ 1,000]					[0.069]*		
ABTSIZE					-0.0889	1.0089	1.0021
					[0.223]		
NUMTRD40-20					-0.0977	1.0017	0.1775
[/ 1,000]					[0.063]*		
ABNUMTRD					-0.0026	1.0004	1.3621
					[0.366]		
ln(MV)	-0.1486	1.2059	0.0659	1.0866	-0.1676	1.2350	12.5976
[/ 1,000,000]	[<0.001]***		[0.024]**		[<0.001]***		
PRICE	-0.0001	1.0002	0.0026	1.0054	0.0015	1.0032	20.9426
	[0.951]		[0.046]**		[0.386]		
Observations	5,375,676		5,375,676		5,375,676		
Log Likelihood	-7,118.61		-7,387.83		-7,114.97		

Table 5 presents Cox proportional hazard regressions on firms eligible for option listing from January 1994 to January 2001. The dependent variable is either 1 for firms that are optioned on a given day or 0 for those firms that are eligible, but are not optioned. PCT SPREAD40-20 is the mean percentage spread for the window t_L-20 to t_L-40, where t_L is the listing date. ABSPREAD is the ratio of PCT SPREAD40-20 to the average percentage spread for the window t_L-125 to t_L-250. The following variables are all calculated in a similar manner, SDRET40-20 is the standard deviation of the firm's returns, ABSDRET is the ratio, VOLUME40-20 is the average volume, ABVOL is the ratio, TSIZE40-20 is the average daily trade size, ABTSIZE is the ratio, NUMTRD40-20 is the average daily number of trades, ABNUMTRD is the ratio. MV is the market value on t_L-20. PRC is the stock price on t_L-20. Some variables have been scaled as described in the table. 10%-of-mean-standardized hazard ratios are the are calculated for the absolute value of the coefficients for each independent variable as: $e^{|coef| \times 0.1 \times mean}$. The mean of each independent variable is presented in the last column of the table. P-values are in brackets.

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

TABLE 6
Cox Proportional Hazard Model Measuring the Determinants of Option Listing Pre and Post 16^{ths}

	Pre 1997/06				Post 1998/06			
Optioned=1	Coefficient [P>|z|]	10%-of-mean-standardized HR	Coefficient [P>|z|]	10%-of-mean-standardized HR	Coefficient [P>|z|]	10%-of-mean-standardized HR	Coefficient [P>|z|]	10%-of-mean-standardized HR
PCT SPREAD40-20	-0.0454	1.1095	-0.0450	1.1086	-0.0583	1.1146	-0.0599	1.1179
[× 1,000]	[<0.001]***		[<0.001]***		[<0.001]***		[<0.001]***	
ABSPREAD	-1.8783	1.1994	-1.7596	1.1857	-1.7070	1.2057	-1.7102	1.2061
	[<0.001]***		[<0.001]***		[<0.001]***		[<0.001]***	
SDRET40-20	0.0194	1.0568	0.0173	1.0505	0.0055	1.0220	0.0062	1.0247
[× 1,000]	[<0.001]***		[<0.001]***		[<0.001]***		[<0.001]***	
ABSDRET	-0.0163	1.0016	-0.0619	1.0061	-0.0117	1.0013	0.0102	1.0011
	[0.887]		[0.619]		[0.815]		[0.792]	
VOLUME40-20	-0.4799	1.0059			0.0270	1.0008		
[/ 1,000,000]	[0.064]*				[0.625]			
ABVOL	0.0052	1.0007			-0.0028	1.0004		
	[0.103]				[0.665]			
TSIZE40-20			0.0103	1.0018			-0.1341	1.0179
[/ 1,000]			[0.836]				[0.150]	
ABTSIZE			0.0249	1.0026			-0.1102	1.0110
			[0.771]				[0.452]	
NUMTRD40-20			-0.8830	1.0063			0.0012	1.0000
[/ 1,000]			[0.040]**				[0.975]	
ABNUMTRD			0.0516	1.0065			-0.0062	1.0009
			[<0.001]				[0.085]*	
ln(MV)	0.0703	1.0917	0.0578	1.0748	-0.3159	1.4929	-0.2947	1.4533
[/ 1,000,000]	[0.309]		[0.403]		[<0.001]***		[<0.001]***	
PRICE	0.0028	1.0057	0.0039	1.0078	0.0019	1.0040	0.0004	1.0009
	[0.440]		[0.282]		[0.387]		[0.863]	
Observations	2,160,696		2,160,696		2,326,600		2,326,600	
Log Likelihood	-2,954.77		-2,948.86		-2,882.21		-2,878.22	

Table 6 presents Cox proportional hazard regressions on firms eligible for option listing for the pre and post 16ths tick size reduction. The dependent variable is either 1 for firms that are optioned on a given day or 0 for those firms that are eligible, but are not optioned. PCT SPREAD40-20 is the mean percentage spread for the window t_L-20 to t_L-40, where t_L is the listing date. ABSPREAD is the ratio of PCT SPREAD40-20 to the average percentage spread for the window t_L-125 to t_L-250. The following variables are all calculated in a similar manner, SDRET40-20 is the standard deviation of the firm's returns, ABSDRET is the ratio, VOLUME40-20 is the average volume, ABVOL is the ratio, TSIZE40-20 is the average daily trade size, ABTSIZE is the ratio, NUMTRD40-20 is the average daily number of trades, ABNUMTRD is the ratio. MV is the market value on t_L-20. PRC is the stock price on t_L-20. Some variables have been scaled as described in the table. 10%-of-mean-standardized hazard ratios are the are calculated for the absolute value of the coefficients for each independent variable as: $e^{|coef| \times 0.1 \times mean}$. The mean of each independent variable is presented in the last column of the table. P-values are in brackets.

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

FIGURE 1
Observed Liquidity with Selection Bias

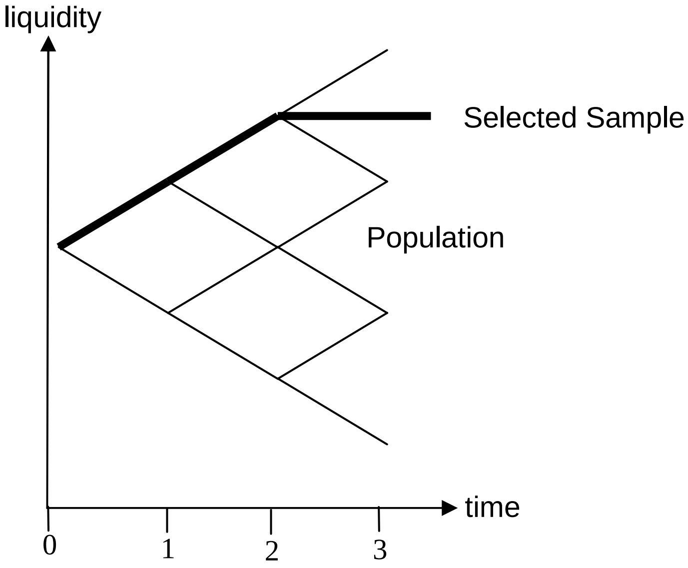
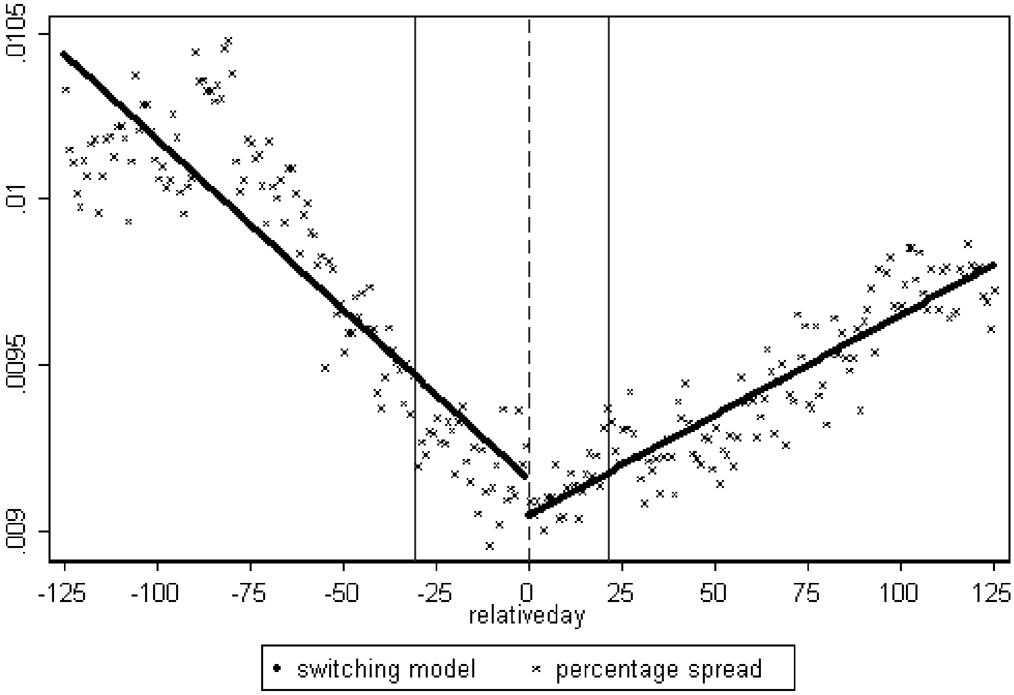
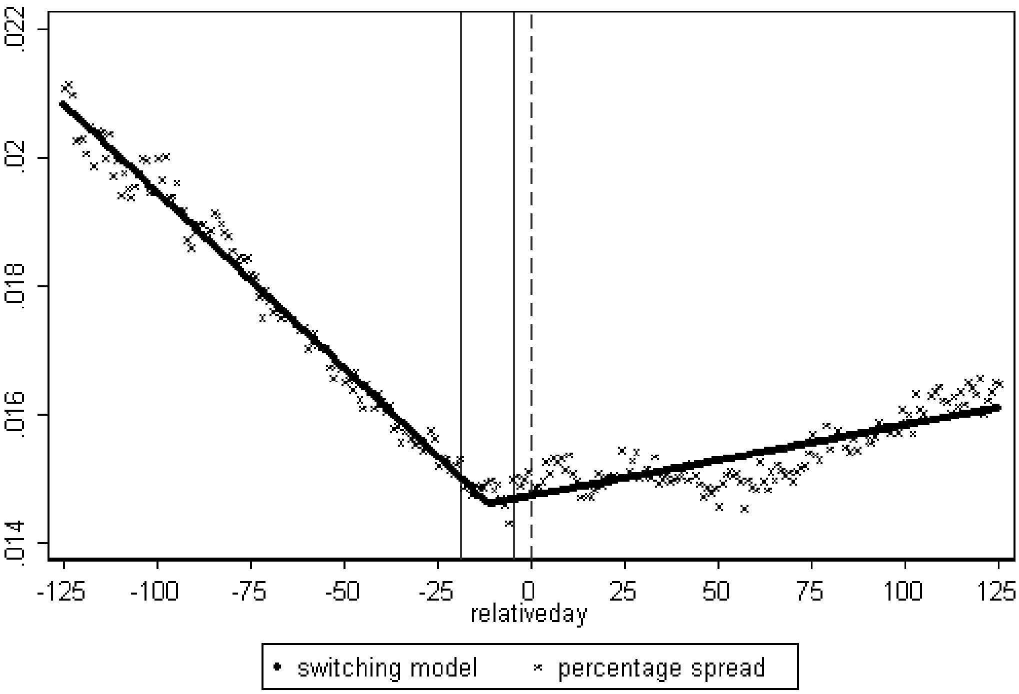


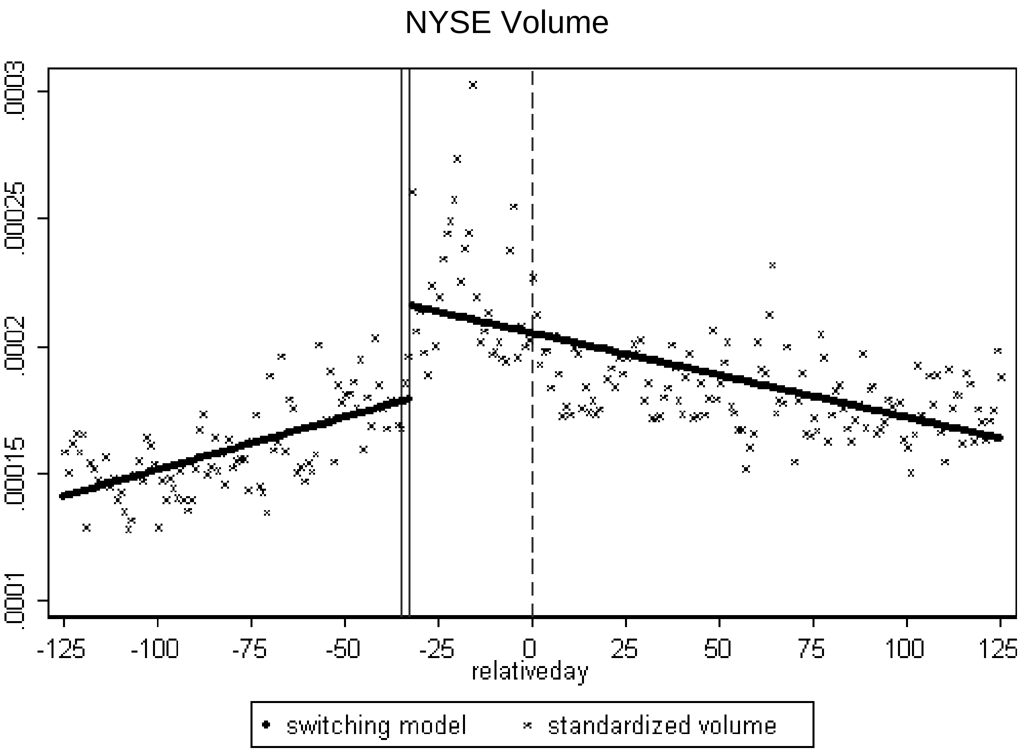
FIGURE 2
Mean daily values around the option introduction

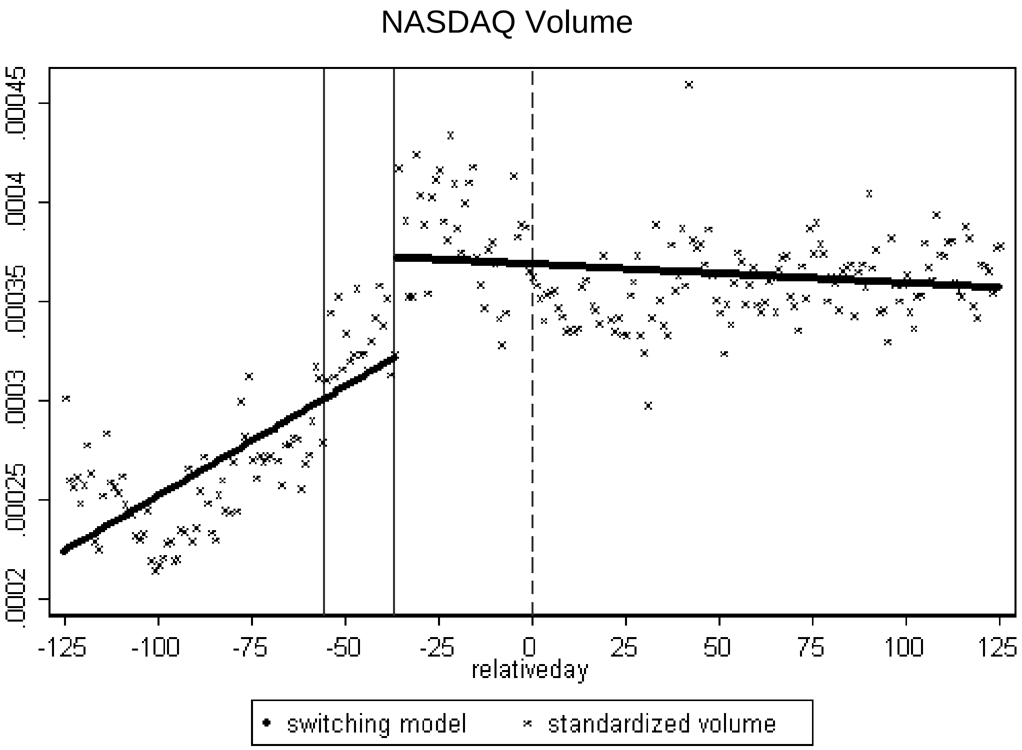
NYSE Percentage spread

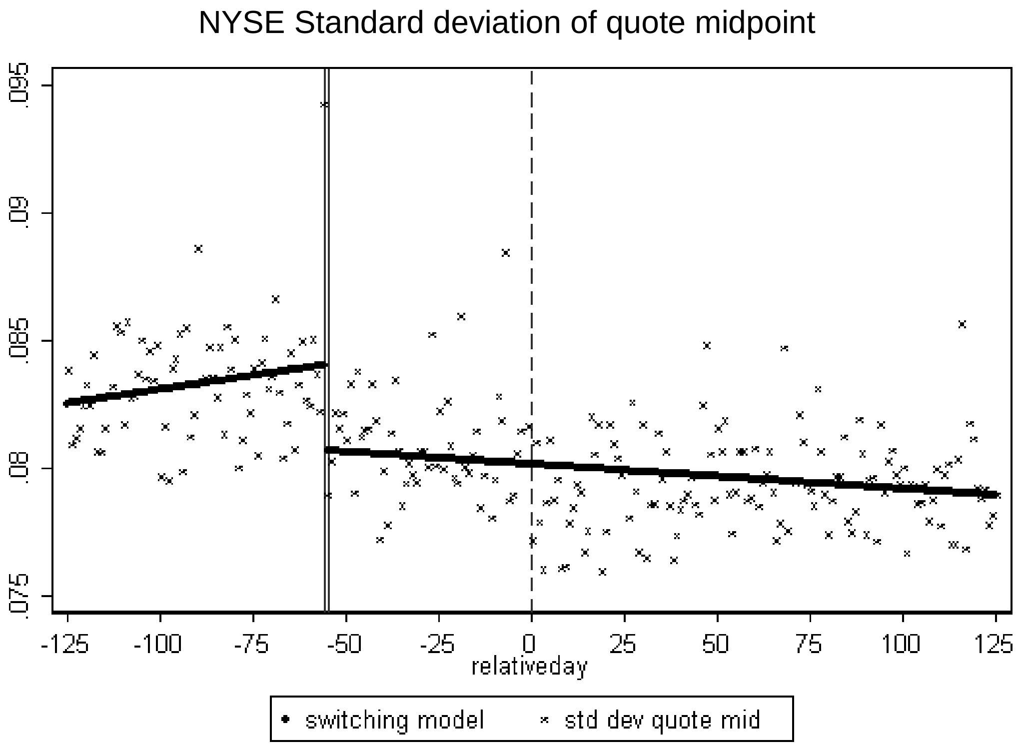


NASDAQ Percentage spread




NYSE Volume
.0001
.00015
.0002
.00025
.0003
-125
-100
-75
-50
-25
0
25
50
75
100
125
relativeday
switching model
standardized volume


NASDAQ Volume
.0002
.00025
.0003
.00035
.0004
.00045
-125
-100
-75
-50
-25
0
25
50
75
100
125
relativeday
switching model
standardized volume



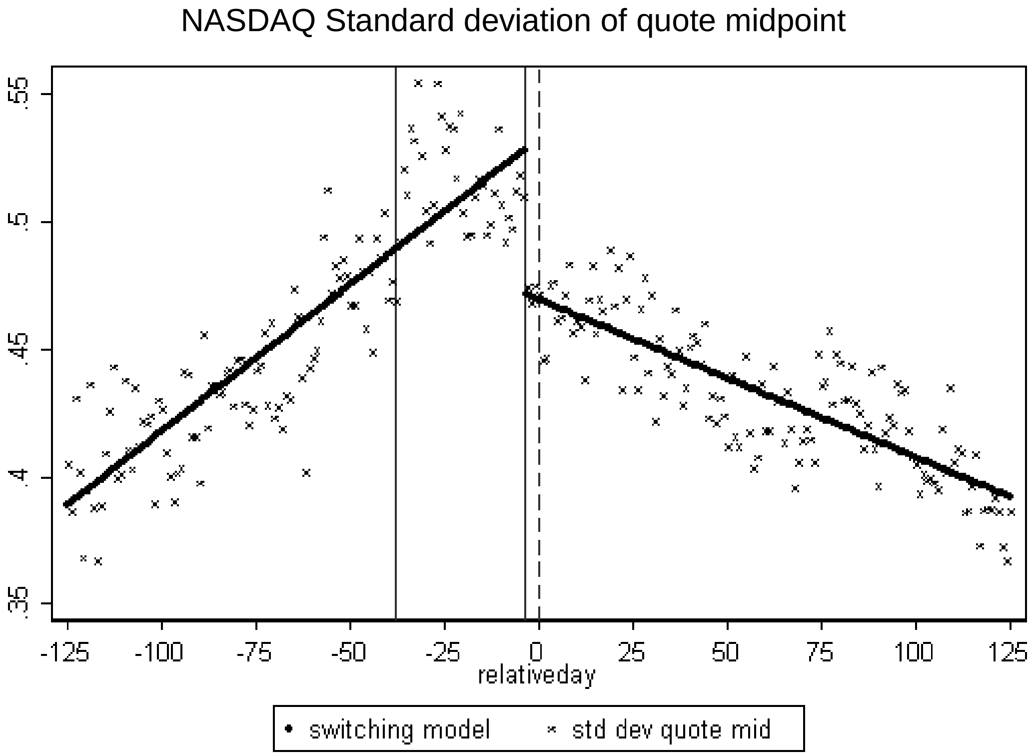


Figure 2 shows fitted lines which represent a switching regime model using the optimal switch date presented in Table 3. The solid vertical lines represent the upper and lower 95% confidence intervals surrounding the estimation of the regime switch date. The vertical dashed line represents relativeday zero, the option introduction date.