Rethinking Decimalization
The Impact of Increased Tick Sizes on Trading Activity and Volatility

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Abstract

In this study, we examine the trading activity and volatility of stocks influenced by the US Securities and Exchange Commission’s pilot program that increased tick sizes for various samples of stocks. The objective of the program is to examine possible improvements to the market quality of small-cap stocks, which have historically been less liquid than larger-cap stocks. Using a difference-in-difference approach, we find that, relative to control stocks, the trading activity of pilot stocks does not appear to be meaningfully affected by the increase in tick sizes. Volatility, however, increases markedly for the pilot stocks vis-à-vis other stocks. These results are robust to the different sets of pilot stocks, various rollout periods, and different control groups.

JEL codes: G10, G14, G18

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1. Introduction

Before June of 1997, the rules of the New York Stock Exchange (NYSE) required all stocks priced above $1 to be quoted on 1/8 of US dollars.[1] Between June 1997 and the beginning of 2001, the minimum tick size (for the large majority of US equities) was reduced to 1/16 of US dollars. Then, in 2001, the tick size was again reduced to one cent ($0.01). A number of studies have examined the quality of financial markets surrounding these types of changes in tick size. While several studies show that bid-ask spreads (the difference between the best bid price and the best ask price) decrease in response to tick size changes (Harris 1994; Ahn, Cao, and Choe 1996; Bacidore 1997; Bessembinder 1997, 2003; Goldstein and Kavajecz 2000; Chung, Van Ness, and Van Ness 2004), other studies note the negative externalities of reducing minimum tick sizes. For instance, Goldstein and Kavajecz (2000) show that while traders submitting small orders are better off in the presence of smaller minimum tick sizes, liquidity worsens for traders submitting larger orders. The authors also find that the depth at the quote decreases in response to the tick size reduction. Bourghelle and Declerck (2004) examine tick size changes on the Paris Bourse and show that reductions in tick sizes do not have a meaningful effect on bid-ask spreads.

Recently, the US Securities and Exchange Commission (SEC) directed the Financial Industry Regulatory Authority (FINRA) and other national securities exchanges to jointly develop

[1] For stocks priced between $0.50 and $1.00, the minimum allowable tick size was 1/16 of a dollar. For stocks priced less than $0.50, the minimum allowable tick size was 1/32 of a dollar.

and implement a pilot program that would widen the quoting and trading increment for certain securities with smaller market capitalization. The SEC would then use the pilot program to assess whether the changes could enhance market quality and benefit investors and equity issuers. The motivation for this pilot program was based on the 2012 Jumpstart Our Business Startups (JOBS) Act, which directed the SEC to conduct a study and report to Congress on how decimalization directly affected the liquidity of smaller capitalization companies.[2] The JOBS Act also allowed the SEC to designate a minimum increment between $0.01 and $0.10 for all quoting and trading for securities of emerging growth companies. FINRA and the national securities exchanges proposed the pilot program on August 25, 2014, and the SEC approved the pilot on May 6, 2015. SEC chairwoman Mary Jo White stated, “The data generated by this important market structure initiative will deepen our understanding of the impact of the tick sizes on market quality and help us consider new policy initiatives that improve trading the securities of smaller-cap issuers” (SEC 2015). As part of this pilot program, which was scheduled to run for two years starting in the latter half of 2016, the SEC created three different treatment groups of stocks.

The first pilot sample of stocks would be quoted at a minimum increment of $0.05 but allowed to trade at $0.01. The second pilot sample of securities was set to be both quoted and traded at a minimum increment of $0.05. The third pilot sample of stocks was subject to the same terms as the second pilot group but was also subject to the so-called trade-at requirement, which restricts the matching of quoted prices at exchanges or other centers that are not displaying the best bid or ask prices. In general, the objective of the trade-at requirement was to remedy the effects of “off-exchange” trading and attempts to prevent exchanges from benefiting from price matching without providing traditional liquidity. Table 1 reports a simple table

[2] Besides focusing on the liquidity of small-cap securities in particular, the JOBS Act was also concerned with the growing decline in the number of publicly traded companies. For more information, see, for example, http://www.finra.org/investors/tick-size-pilot-program.

documenting the differences between the pilot groups. In addition, the SEC put together a group of 1,400 control stocks that would continue to trade on $0.01 increments. Each of the groups was obtained using a stratified sampling technique. Both the NYSE and NASDAQ exchanges provide a detailed description of the securities in the pilot program on each exchange.[3]

Table 1. Pilot Group Restrictions

Group	Minimum increment of quote	Trade allowed in increments of	Other conditions of pilot program
Pilot 1	$0.05	$0.01	N/A
Pilot 2	$0.05	$0.05	N/A
Pilot 3	$0.05	$0.05	Trade-at requirement
Control	$0.01	$0.01	N/A

Source: Authors' calculations.

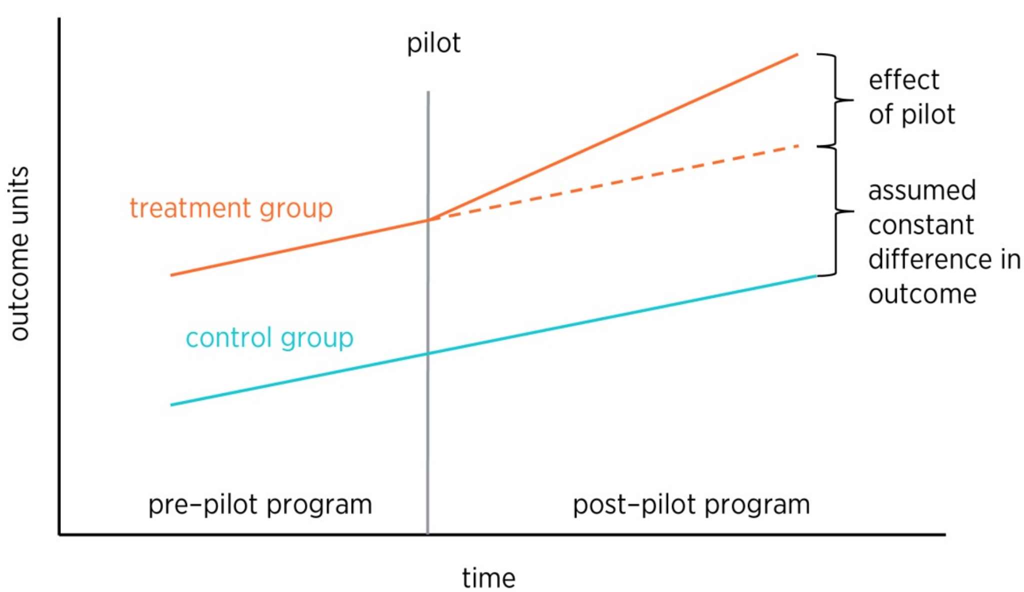
Given that the objective of the pilot program is to determine whether or not the market quality of the different treatment groups of stocks changes compared to the control stocks after the program is rolled out, we seek to examine various measures of market quality before and after the implementation of the tick size change. In recent studies, Griffith and Roseman (2017) and Rindi and Werner (2017) show that both bid-ask spreads and quoted depth (the number of open orders in the limit order book) widen in response to the changes in the minimum tick size increment. These initial results suggest that the increase in tick sizes has both positive and negative effects on market quality. For instance, traders that submit larger orders are likely better off, given that quoted depth increases. However, traders submitting smaller orders pay higher transaction costs because of wider bid-ask spreads. Rindi and Werner (2017) argue that the costs associated with increased tick sizes will most likely affect retail investors. In order to provide additional insight into the effect of the tick size changes, this study examines several other

[3] See, for example, https://www.nyse.com/tick-pilot and http://www.nasdaqtrader.com/Trader.aspx?id=TickPilot.

measures of liquidity, such as Amihud's (2002) measure of price impact and trading volume. However, we also analyze the impact of the pilot program on volatility. The motivation for studying how widening tick sizes influence volatility is based on the idea that prices will change by greater amounts, which will increase volatility.

Examining the last six months of 2016 using daily data for the stocks from the three treatment groups and the control group, we conduct a series of both univariate and multivariate difference-in-difference tests to determine whether these additional measures of market quality are affected by the implementation of the pilot program. We first examine the difference for each group before and after the initiation of the pilot program. We then control for any time trends by subtracting the average of the control group for each measure in each period and then calculating the difference between those differences. Figure 1 illustrates the structure of our analysis.

Figure 1. Difference-in-Difference Structure



Source: Authors' calculations.

Results show that, relative to control stocks, price impact increases and trading volumes decrease after the initiation of the pilot program, suggesting that liquidity worsens in response to the implementation of the pilot program. These results are robust to the different treatment groups, the different rollout periods, the exchange where the stock is listed, and the use of different control groups. Not only are the results statistically significant, but our findings are also economically meaningful. For instance, relative to the stated control group, price impact increases from 18 percent to 24.5 percent and share turnover decreases from 4 percent to 7.8 percent during the postimplementation period for the first treatment group of stocks. Our multivariate tests also reveal that, relative to control stocks, volatility increases for treatment stocks. These results are robust to a range-based measure of volatility (Alizadeh, Brandt, and Diebold 2002) and volatility calculated by fitting daily returns in a Garch(1,1) framework. In economic terms, difference-in-difference tests show that range-based volatility increases from 3 percent to 8 percent while Garch(1,1) volatility increases from 1.05 percent to 2.4 percent during the postimplementation period for the various treatment groups of pilot stocks. Finding that trading activity decreases and price impact increases seems to indicate that the increase in the minimum tick size adversely affects liquidity. The results support the previous research reported in Griffith and Roseman (2017) and Rindi and Werner (2017). The increase in volatility during the postimplementation period also indicates that prices become less stable.

When taking the results of our tests together, this study contributes more broadly to the literature about the effect of tick sizes on certain measures of market quality. More specifically, our results also contribute to the policy debate about the effect of increasing minimum tick sizes on trading activity, volatility, and price impact. Analysis of our market quality measures indicates that the SEC’s pilot program was detrimental to the stability and liquidity of the affected stocks. Instead of increasing liquidity and aiding market stability, increasing the tick size appears to have the opposite effect than hoped for from the pilot program.

The rest of the paper follows: in section 2 we introduce our measures of market quality; in section 3 we discuss the results from our empirical tests, which are reported in the appendix; and in section 4, we restate our conclusions and policy implications.

2. Measures of Market Quality

The quality of different market mechanisms has been studied in a variety of regulatory settings. For example, prior research has examined how changes in limit order handling rules have influenced measures of liquidity and volatility (Bessembinder 1999). Others have explored how rule changes to short-sale restrictions have influenced market quality (Diether, Lee, and Werner 2009; Battalio and Schultz 2011). One dimension of market quality is liquidity, which is often defined as the ability to trade quickly at a fair price. However, even liquidity has multiple dimensions. The liquidity of a stock can be measured by the number of shares that are traded during a specific time period. The number of shares traded on a particular day is known as the daily volume. Volume measures liquidity since the more shares are traded, the easier it might be to trade. However, one needs to take care when looking only at volume because some firms have more shares outstanding by orders of magnitude. Consider a firm that has a much lower price and more shares outstanding. More shares will be traded to purchase the same dollar amount, so the increased volume is a result of the differing shares outstanding and price, which may or may not indicate more liquidity. To account for these differences, we can also measure the share turnover of a stock over a specific time period. Turnover is the ratio of daily trading volume scaled by shares outstanding (reported as a percentage). Scaling the volume by shares outstanding allows us to compare the percentage of shares that are traded on a specific day. Both volume and turnover are measures of liquidity that impact the quality of a market. In our tests that follow, we also use Amihud's (2002) measure of illiquidity, which we denote as ILLIQ. It is the ratio of the absolute value of the daily stock return divided by volume (in millions). It measures the price impact of trading a security. If a stock is less liquid, then increased volume will move the price more, which will result in a higher return. If a stock is more liquid, then increased volume will move the price less, which will result in a smaller return. Thus, the absolute value of the return, or how much the price moves on a given day, is scaled by how much trading volume occurred that day. The larger Amihud's measure, the less liquid the stock must have been during trading. It is important to note that while volume and turnover measure liquidity (larger value equals more liquid), ILLIQ measures the illiquidity of a stock (larger value equals less liquid).

Another dimension of market quality is the volatility of stock prices. More volatile securities can be detrimental to overall market conditions and market participants. For example, increases in volatility could impact the expected return of assets, which thereby affects a firm's costs of capital. Increased volatility can also make it riskier to make a market in a particular stock. The increased risk to market makers can result in wider spreads and less liquidity for individual stocks. Increased market volatility can also impact the overall confidence of participants in the market. Less confidence in the market's ability to accurately price securities has broad implications. We use several different measures of volatility to further examine the effect of changing tick size on market quality. Our first measure is the natural log of the daily range of prices, which we refer to as LN(RANGE). LN(RANGE) is a range-based measure of volatility described in Alizadeh, Brandt, and Diebold (2002) and calculated as the natural log of the difference between the daily high price and the daily low price. LN(RANGE) is a useful measure of volatility because it can be calculated at the daily level without having to rely on intraday data. It has also been shown to be theoretically, numerically, and empirically superior to other measures of volatility by Alizadeh, Brandt, and Diebold (2002). In addition to LN(RANGE), we also estimate a conditional measure of volatility using a Garch(1,1) model, which we denote as GARCH. The Garch(1,1) measure of volatility takes a parametric approach and is described in Engle (1982). The Garch(1,1) methodology is useful because it accounts for the time-varying nature of volatility.

3. Results

In this section, we provide a brief overview of our results. Technical details are provided in the attached appendix. In general, we do not find evidence to support the idea that larger minimum tick sizes will improve the market quality of stock trading on US exchanges. Using both univariate and multivariate difference-in-difference tests, we find that trading volume decreases and price impact increases after the minimum tick sizes are increased during the SEC's pilot program. Both of these findings indicate a reduction in market quality and liquidity. Our results are robust to the different treatment groups, the different rollout periods, the exchange where the stock is listed, and the use of different control groups. The results are not only statistically significant but also economically meaningful. Relative to the stated control group, price impact increases from 18 percent to 24.5 percent and share turnover decreases from 4 percent to 7.8 percent for the first pilot group after implementation.

We also find that, relative to control stocks, volatility increases for the group of treatment stocks. Increased volatility is another indication of reduced market quality. These results are robust to a range-based measure of volatility (Alizadeh, Brandt, and Diebold 2002) and volatility calculated by fitting daily returns in a Garch(1,1) framework. In economic terms, difference-in-difference tests show that range-based volatility increases from 3 percent to 8 percent while Garch(1,1) volatility increases from 1.05 percent to 2.4 percent after implementation of the pilot program. Together, our findings indicate that increasing the minimum tick size adversely affects market liquidity and the overall quality of the market for the stocks in the treatment group.

Analysis of our market quality measures indicates that the SEC's pilot program was detrimental to the stability and liquidity of the affected stocks and that increasing the minimum tick size for small-capitalization stocks does not result in the hoped-for market improvements. These findings corroborate the results in recent studies (Griffith and Roseman 2017; Rindi and Werner 2017). Instead of increasing liquidity and aiding market stability, increasing the tick size appears to have the opposite effect. Table 2 summarizes our results, which are reported in more detail in the technical appendix.

Table 2. Results Summary: Effect of Pilot Program Groups on Market Quality

	Pilot 1		Pilot 2		Pilot 3	
	Effect on Q	**Statistically significant**	**Effect on Q**	**Statistically significant**	**Effect on Q**	**Statistically significant**
Illiquidity (ILLIQ)	Detrimental	Yes	Detrimental	Yes	Detrimental	Yes
Turnover	Detrimental	Yes	Detrimental	Mixed	Detrimental	Yes
Volatility LN(RANGE)	Detrimental	Yes	Detrimental	Mixed	Detrimental	Mixed
Volatility GARCH	Detrimental	Mixed	Detrimental	Mixed	Mixed	Mixed

Source: Authors' calculations.

4. Conclusion

In 2001, in accordance with direction from the SEC, US equity markets changed the minimum tick size from 1/16 of a dollar to increments of $0.01. A broad literature examining the impact of this type of change, referred to as decimalization, has shown that liquidity generally improves for traders that submit small orders. For instance, both bid-ask spreads and quoted depth decrease dramatically in response to the change in the minimum tick size. However, in small-cap stocks, it has been argued that the smaller spreads have disincentivized liquidity provision, resulting in a lack of supply. The idea is that smaller spreads, in small-capitalization stocks, do not create adequate profit opportunities for market makers. This lack of profitability deters market makers from trading in specific securities and could dramatically impact the market quality of trading in those stocks. Although this seems plausible, the cause of less liquidity in markets for small-capitalization stocks is debatable. To investigate the determinants of liquidity more fully, the SEC recently implemented a carefully designed pilot program to examine whether an increase in tick size could improve the market quality of small-cap securities. The SEC rolled out its pilot program for three different groups of securities on different dates and on different exchanges. A control sample of stocks was also selected to better isolate the results of the implementation of the pilot program.

Although the purpose of the pilot program was to find ways to improve the market quality of small-cap stocks, our tests seem to suggest that affected stocks become less liquid, using Amihud's (2002) measure of price impact. We also find that, relative to control stocks, share turnover and trading volume also decrease for pilot stocks. These results are generally robust to the three treatment groups of securities outlined in the SEC's pilot program and various rollout periods. In general, we are able to draw similar conclusions from both our univariate and multivariate tests. In a series of additional tests, we examine the volatility of stocks surrounding the tick size change. In particular, we use a range-based measure of volatility following Alizadeh, Brandt, and Diebold (2002), which captures range between intraday high prices and intraday low prices. We also estimate volatility using a Garch approach, which parametrically estimates the time-series variance of security returns. Using these measures, we find that, relative to control stocks, the volatility of pilot stocks generally increases. Again, these conclusions seem to hold in both our univariate and multivariate tests. Taken together, our results suggest that the market quality of affected stocks does not improve in response to the pilot, and, if anything, market quality deteriorates.

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Appendix: Technical Notes

A.1. Data Description

The data are obtained primarily from the Center for Research in Security Prices (CRSP). We gather the universe of securities from the CRSP database for the last two quarters (July 1 to December 31) of 2016, which is our sample time period. While the implementation days were staggered throughout September and October of 2016, we chose to analyze the last quarter to ensure that the pre- and postevent time periods are not confounded by the implementation of the pilot program on different exchanges. For instance, the NYSE implemented the pilot program for the three groups of treatment stocks on September 6, 2016. NASDAQ rolled out the pilot program differently. For instance, the pilot program began for a portion (100 stocks each) of the first and second treatment groups on October 10, 2016. The remaining stocks (400 stocks each) of the first and second treatment groups experienced the rollout on October 17, 2016. These staggered event days require us to examine a longer time period both before the first event and after the last event to ensure that our difference-in-differences tests have a proper control period. From the universe of stocks available on CRSP, we obtain the various securities that are part of the pilot program directly from both the NYSE and NASDAQ. We also identify the control variables that were initiated as part of the pilot program. The total number of stock-day observation is slightly more than 290,000.[4]

Summary statistics for the various samples are reported in table A1. Panel A of table A1 presents the summary statistics for the first treatment group of securities, which we designate as

[4] We note that, according to documentation provided by the exchanges, pilot securities were selected using a stratified sample of common, ordinary stocks, with a market capitalization on $3 billion, a closing price of $2.00 on the implementation day but greater than $1.50 on every day during the implementation period, a consolidated average daily volume of 1,000,000 shares or less, and a volume-weighted average price (VWAP) of at least $2.00 during the implementation period.

PILOT1. Panels B and C present results for the second treatment group, PILOT2, and third treatment group, PILOT3, respectively. Panel D shows the results for the control group of 1,400 stocks designated by the SEC. The table reports statistics that describe the sample. Panel A presents the summary statistics for the first pilot group of securities (PILOT1). Panel B shows the results for the second pilot group of stocks (PILOT2). Panel C presents the statistics for the third group of pilot stocks (PILOT3). Panel D shows the results for the control group of stocks. ILLIQ is the measure of Amihud's (2002) illiquidity, which is the ratio of the absolute value of returns scaled by daily volume (in millions). TURNOVER is the ratio of daily trading volume scaled by shares outstanding (in percentages). VOLUME is the number of shares that are traded on a particular day. LN(RANGE) is Alizadeh, Brandt, and Diebold's (2002) measure of range-based volatility, which is the natural log of the difference between the daily high price and the daily low price. GARCH is the conditional volatility obtained by fitting daily returns to a Garch(1,1) model.

Table A1. Summary Statistics

Panel A: Pilot Stocks—Group 1 (PILOT1)					
	ILLIQ	**TURNOVER**	**VOLUME**	**LN(RANGE)**	**GARCH**
	[1]	[2]	[3]	[4]	[5]
Mean	1.9144	0.6371	222,964,700	−0.8727	0.0256
Median	0.1065	0.3632	93,413,000	−0.8210	0.0209
Std. Dev.	8.1958	2.8209	508,233,050	1.0102	0.0221
Panel B: Pilot Stocks—Group 2 (PILOT2)					
Mean	2.3787	0.6142	205,698,040	−0.8365	0.0272
Median	0.1078	0.3466	90,183,000	−0.7985	0.0214
Std. Dev.	9.3537	2.2615	417,350,220	0.9783	0.1286
Panel C: Pilot Stocks—Group 3 (PILOT3)					
Mean	1.8667	0.6051	222,760,370	−0.9117	0.0257
Median	0.1012	0.3462	93,785,000	−0.8916	0.0214
Std. Dev.	7.9775	2.5087	520,486,700	1.0469	0.0445
Panel D: Control Stocks					
Mean	2.0509	0.6033	214,064,220	−0.8906	0.0260
Median	0.1061	0.3464	97,842,000	−0.8675	0.0212
Std. Dev.	8.5697	1.7632	493,819,760	1.0308	0.0603

Source: Figures based on author calculations using SAS software.

For the most part, the stocks in the treatment groups and the control sample have similar characteristics. Mean ILLIQ ranges from 1.91 for PILOT1 to 2.37 for PILOT2. Turnover and volume are also fairly similar in each of the groups. The average turnover of each group is between 0.6033 and 0.6371, and the average volume of each group is between 206 and 223 million shares. Our volatility measures are also similar across groups for both LN(RANGE) and GARCH. The objective of our tests below is to examine whether the variation shown in table A1 changes from the pre-event to the postevent period.

A.2. Univariate Analysis—Difference-in-Difference Tests

In this section of the technical appendix, we report our analysis from examining the pilot stocks before and after the program implementation dates. Given that there are not only three pilot groups but also several rollout dates that vary across different exchanges, we examine the differences in daily measures of market quality before and after the initiation of the program. The market quality measures we examine include ILLIQ, TURNOVER, VOLUME, LN(RANGE), and GARCH, where TURNOVER and VOLUME are measures of share turnover and trading volume at the daily level, respectively. Table A2 provides a description of the variables used in the analysis below.

Table A2. Variable Descriptions

Variable	Variable Description
ILLIQ	Amihud's (2002) measure of illiquidity, which is the ratio of the absolute value of daily returns scaled by volume
TURNOVER	Share turnover, which is the ratio of daily trading volume scaled by shares outstanding
VOLUME	Daily volume, which is the number of shares traded on a particular day
LN(RANGE)	Alizadeh et al.'s (2002) measure of stochastic volatility, which is the natural log of the difference between the intraday high price and the intraday low price
GARCH	Garch(1,1) volatility, which is the parametric estimate of conditional forecasted volatility discussed in Engle (1982)

Source: Authors.

Table A3 reports the mean of different variables during the pre-event period and the postevent period, where the event is the rollout of the SEC's pilot program. We also calculate the difference in means between the periods along with the corresponding t-statistic. The results are reported for the groups of pilots stocks from the NYSE sample (columns [1] through [3]) and the NASDAQ sample (columns [4] through [9]). Panel A reports the results for the first treatment group of pilot stocks (PILOT1) around the various rollout periods. Panel B shows the results for the second treatment group of stocks (PILOT2) around the various rollout periods. Panel C presents the analysis for the third treatment group of pilot stocks (PILOT3) around the various rollout periods.

Table A3. Event Study—Univariate Tests of Pilot Stocks

Panel A: First Group of Pilot Securities (PILOT1)									
	NYSE SAMPLE EVENT DATE (9/6/2016)			NASDAQ SAMPLE FIRST ROLLOUT (10/10/2016)			NASDAQ SAMPLE SECOND ROLLOUT (10/17/2016)		
	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
ILLIQ	0.7649	0.7143	−0.0506	1.5458	1.5092	−0.0366	1.7501	1.5478	−0.2023***
			(0.69)			(0.39)			(−2.70)
TURNOVER	0.6159	0.6589	0.0430***	0.5956	0.6527	0.0571***	0.6222	0.7152	0.0930***
			(2.93)			(4.62)			(3.02)
VOLUME	277,069.0	299,532.0	22,463.9***	253,462.0	274,059.0	20,596.3**	215,292.0	251,387.0	36,094.8***
			(2.87)			(3.33)			(6.30)
LN(RANGE)	−0.9347	−0.7476	0.1871***	−0.9280	−0.7140	0.2140***	−0.9598	−0.7387	0.2211***
			(11.65)			(16.79)			(21.36)
GARCH	0.0243	0.0256	0.0013***	0.0241	0.0259	0.0018***	0.0248	0.0273	0.0025***
			(4.44)			(8.19)			(10.49)

Panel B: Second Group of Pilot Securities (PILOT2)									
	NYSE SAMPLE EVENT DATE (9/6/2016)			NASDAQ SAMPLE FIRST ROLLOUT (10/10/2016)			NASDAQ SAMPLE SECOND ROLLOUT (10/17/2016)		
	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
ILLIQ	0.8543	0.7603	−0.0940	0.9970	1.0829	0.0859	2.6102	2.3978	−0.2124**
			(−1.29)			(1.19)			(−2.19)
TURNOVER	0.6135	0.6599	0.0465***	0.6566	0.7234	0.0668*	0.5645	0.6116	0.0472***
			(2.90)			(1.70)			(4.02)
VOLUME	241,385.0	266,281.0	24,896.8***	227,328.0	252,270.0	24,941.9***	196,068.0	223,109.0	27,040.9***
			(3.62)			(4.56)			(6.10)
LN(RANGE)	−0.8418	−0.6942	0.1476***	−0.8469	−0.6126	0.2343***	−0.9572	−0.7128	0.2444***
			(9.75)			(19.28)			(24.65)
GARCH	0.0233	0.0240	0.0007***	0.0235	0.0251	0.0016***	0.0256	0.0302	0.0045***
			(3.01)			(8.82)			(2.81)

(continued on next page)

Panel C: Third Group of Pilot Securities (PILOT3)									
	NYSE SAMPLE EVENT DATE (9/6/2016)			NASDAQ SAMPLE FIRST ROLLOUT (10/24/2016)			NASDAQ SAMPLE SECOND ROLLOUT (10/31/2016)		
	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference	Pre-event	Possevent	Difference
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
ILLIQ	0.7881	0.8703	0.0822	1.2093	1.2856	0.0762	1.8685	1.7373	−0.1311
			(1.02)			(0.86)			(1.63)
TURNOVER	0.5848	0.6559	0.0711***	0.5845	0.6212	0.0366**	0.6093	0.6381	0.0288
			(3.32)			(2.26)			(1.30)
VOLUME	255,683.0	306,843.0	51,160.0***	251,181.0	275,463.0	24,282.3***	214,934.0	250,678.0	35,744.3***
			(5.67)			(3.49)			(6.17)
LN(RANGE)	−0.9317	−0.7949	0.1369**	−0.9920	−0.7237	0.2683***	−0.9954	−0.7037	0.2917***
			(8.64)			(20.59)			(27.00)
GARCH	0.0234	0.0241	0.0007***	0.0245	0.0254	0.0009	0.0246	0.0271	0.0024***
			(3.12)			(1.48)			(11.60)

Notes: ILLIQ is the measure of Amihud's (2002) illiquidity. TURNOVER is the ratio of daily trading volume scaled by shares outstanding (in percentages). VOLUME is the number of shares that are traded on a particular day. LN(RANGE) is the natural log of the difference between the daily high price and the daily low price. GARCH is the conditional volatility obtained by fitting daily returns to a Garch(1,1) model. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

Panel A of table A3 reports the results for the first treatment group, which, as part of the pilot program, requires quotes to occur on \$0.05 increments but allows trades to occur on \$0.01 increments. Columns [1] through [3] of panel A report the results for PILOT1 on the NYSE, while columns [4] through [9] show the results for the two rollout periods for the NASDAQ sample. Column [1] reports the pre-event averages, while column [2] reports the postevent averages. Column [3] reports the difference (post minus pre) with corresponding t-statistics (reported in parentheses) that test whether the post-minus-pre difference is equal to zero. Although ILLIQ is lower for the NYSE stocks in PILOT1 after the initiation of the program (0.7649 before and 0.7143 after), the difference is not significant. Similar results can be seen for the initial rollout of PILOT1 stocks on NASDAQ, which occurred on October 10, 2016, and is reported in columns [4] through [6]. In contrast, a significant decrease in ILLIQ is detected in the second rollout of PILOT1 on NASDAQ, which occurred on October 17, 2016. Here, mean ILLIQ before the event was 1.7501 (column [7]) and decreased to 1.5478 (column [8]), a difference of −0.2023 that is significant at the 0.01 level (t-statistic = −2.70). In contrast to the generally insignificant change in illiquidity, we find significant changes when examining the rest of our market quality measures across the different columns. Differences in TURNOVER range from 0.043 for NYSE stocks to 0.093 for the second rollout on NASDAQ, with each difference significant at the 0.01 level. These results suggest that while ILLIQ does not meaningfully change, TURNOVER significantly increases in response to the pilot's implementation. Similarly, we find significant increases in VOLUME, LN(RANGE), and GARCH. While increases in turnover and volume are indicative of market quality improvements and consistent with the objective of the SEC, increases in our volatility measures (LN(RANGE) and GARCH) indicate that prices tend to become less stable during the postpilot period.

Panel B of table A3 reports the results for PILOT2, which require both quotes and trades to occur at $0.05 increments. Rollout dates for PILOT2 are the same as for PILOT1. The results in panel B are very similar to those in panel A, so we will focus most of our attention on the post-minus-pre differences. First, we find a similar pattern for post-minus-pre differences in ILLIQ with generally insignificant differences across columns, with the exception of the difference in column [9]. Similar to panel A, we also find increases in TURNOVER, VOLUME, LN(RANGE), and GARCH after the program initiation. It appears that the flexibility to trade at $0.01 increments makes very little difference when compared to the more rigorous requirement to both quote and trade at $0.05 increments.

Results from the third treatment group, which is similar to the second pilot group but also had a trade-at prohibition, are found in panel C of table A3. The NYSE program started on September 6, 2016, while the NASDAQ programs began on October 24, 2016, and October 31, 2016, respectively. Once again, we find very little difference in ILLIQ across the different program start dates. In fact, we do not observe a significant difference in column [9]. Although we find a similar pattern of increases for the other market quality variables, there are a couple of differences. TURNOVER is not significantly different from zero for the second NASDAQ rollout, and GARCH is not significantly different from zero for the first NASDAQ rollout. Otherwise, panel C produces qualitatively similar results to panels A and B.

Although we find differences in our market quality measures in our initial univariate tests, those differences could stem from differences associated with market conditions specific to the time period. To control for this possible time-period effect, we employ a difference-in-difference technique that first takes the difference between a particular treatment group and the control group and then takes the difference before and after the event. We examine the same variables as in the previous tables, but we designate a first difference variable with a D_ prefix. Thus, D_ILLIQ is the difference between the illiquidity for a stock in the treatment group and the average illiquidity of the control group. The other variables are calculated similarly. Table A4 reports results for the difference-in-difference tests. The layout of table A4 is analogous to that of table A3. Panels A, B, and C correspond to three different treatment groups, respectively, and each panel is organized by event date with NYSE in columns [1] through [3], the first rollout of NASDAQ in columns [4] through [6], and the second rollout of NASDAQ in columns [7] through [9]. Columns [3], [6], and [9] report the second differences from our difference-in-difference approach.

The conclusions that we draw in table A4 are very different from those in table A3. Panel A of table A4 reports results for the first treatment group. While the differences in D_ILLIQ are similar to our previous findings, changes in D_TURNOVER and D_VOLUME move in the opposite direction during the postevent period once we control for the difference-in-differences. In the NYSE stocks, D_TURNOVER goes from 0.074 to 0.0223, a difference of −0.0517, which is statistically significant at the 0.01 level. Although the change is not significant in the second rollout on NASDAQ, the first rollout on NASDAQ is similar in both magnitude and significance. Similarly, D_VOLUME decreases significantly in all three rollouts reported in panel A. With respect to table A3, the results here suggest that, relative to the control sample, the trading activity of stocks in the first treatment group decreases during the postimplementation period. While our volatility measures were strictly increasing in our basic univariate tests, we now find mixed results. We find that D_LN(RANGE) increases significantly, and in each of the rollouts, D_GARCH decreases significantly in the first two rollouts but remains relatively unchanged in the third rollout.

Table A4. Event Study—Difference-in-Difference Univariate Tests

Panel A: First Group of Pilot Securities (PILOT1)									
	NYSE SAMPLE EVENT DATE (9/6/2016)			**NASDAQ SAMPLE FIRST ROLLOUT (10/10/2016)**			**NASDAQ SAMPLE SECOND ROLLOUT (10/17/2016)**		
	Pre-event	**Postevent**	**Difference**	**Pre-event**	**Postevent**	**Difference**	**Pre-event**	**Postevent**	**Difference**
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
D_ILLIQ	−1.3214	−1.3177	0.0037	−0.5060	−0.5414	−0.0354	−0.3265	−0.4673	0.1408*
			(0.05)			(−0.37)			(1.88)
D_TURNOVER	0.0740	0.0223	−0.0517***	0.0403	−0.0073	−0.0475***	0.0685	0.0426	−0.0259
			(3.54)			(−3.88)			(−0.84)
D_VOLUME	88,814.6	71,476.3	−17,338.2**	58,604.9	37,290.1	−21,314.8***	21,829.6	8,605.7	−13,223.9**
			(−2.23)			(−3.47)			(−2.32)
D_LN(RANGE)	0.0344	0.1009	0.0665***	0.0318	0.0946	0.0628***	0.0023	0.0528	0.0505**
			(4.19)			(4.98)			(4.92)
D_GARCH	−0.0004	−0.0011	−0.0006**	−0.0008	−0.0014	−0.0006***	−0.0001	−0.0001	0.0000
			(−2.24)			(−2.76)			(0.16)
Panel B: Second Group of Pilot Securities (PILOT2)									
	NYSE SAMPLE EVENT DATE (9/6/2016)			**NASDAQ SAMPLE FIRST ROLLOUT (10/10/2016)**			**NASDAQ SAMPLE SECOND ROLLOUT (10/17/2016)**		
	Pre-event	**Postevent**	**Difference**	**Pre-event**	**Postevent**	**Difference**	**Pre-event**	**Postevent**	**Difference**
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
D_ILLIQ	−1.2321	−1.2734	−0.0413	−1.0551	−0.9693	0.0854	0.5336	0.3826	−0.1510
			(−0.57)			(1.19)			(−1.56)
D_TURNOVER	0.0716	0.0242	−0.0474***	0.1012	0.0639	−0.0373	0.0109	−0.0607	−0.0715***
			(−2.97)			(−0.95)			(−6.13)
D_VOLUME	53,127.8	38,551,.5	−14,576.3**	32,470.7	15,707.7	−16,763.0***	2,610.0	−19,580.0	−22,190.0***
			(−2.13)			(−3.09)			(−5.04)
D_LN(RANGE)	0.1275	0.1557	0.0282*	0.1130	0.1971	0.0841***	0.0047	0.0790	0.0742***
			(1.88)			(7.01)			(7.56)
D_GARCH	−0.0014	−0.0026	−0.0012***	−0.0014	−0.0022	−0.0008***	0.0007	0.0028	0.0021
			(−5.41)			(−4.53)			(1.28)

(continued on next page)

Panel C: Third Group of Pilot Securities (PILOT3)									
	NYSE SAMPLE EVENT DATE (9/6/2016)			NASDAQ SAMPLE FIRST ROLLOUT (10/24/2016)			NASDAQ SAMPLE SECOND ROLLOUT (10/31/2016)		
	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference	Pre-event	Postevent	Difference
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
D_ILLIQ	−1.2981	−1.1611	0.1370*	−0.8968	−0.6726	0.2242**	−0.2517	−0.1769	0.0748
			(1.70)			(2.52)			(0.93)
D_TURNOVER	0.0430	0.0195	−0.0235	0.0367	−0.0733	−0.1100***	0.0609	−0.0723	−0.1333***
			(−1.10)			(−6.81)			(-6.03)
D_VOLUME	67,426.3	78,845.4	11,419.2	59,426.4	24,724.5	−34,701.9***	23,120.9	−6,849.8	−29,970.6***
			(1.27)			(−5.01)			(−5.19)
D_LN(RANGE)	0.0374	0.0539	0.0166	−0.0235	0.0397	0.0631***	−0.0277	0.0373	0.0651***
			(1.05)			(4.89)			(6.07)
D_GARCH	−0.0014	−0.0025	−0.0011***	−0.0004	−0.0022	−0.0018***	−0.0004	−0.0006	−0.0002
			(−4.74)			(−2.77)			(−0.98)

Notes: The table reports the mean of different variables during the pre-event period and the postevent period, where the event is the rollout of the SEC's pilot program. We also calculate the difference in means between the periods along with the corresponding t-statistic. The results are reported for the groups of pilot stocks from the NYSE sample (columns [1] through [3]) and the NASDAQ sample (columns [4] through [9]). Panel A reports the results for the first treatment group of pilot stocks (PILOT1) around the various rollout periods. Panel B shows the results for the second treatment group of stocks (PILOT2) around the various rollout periods. Panel C presents the analysis for the third treatment group of pilot stocks (PILOT3) around the various rollout periods. D_ILLIQ is the difference between the measure of Amihud's (2002) illiquidity for a particular pilot stock and the illiquidity of the average control stock, where control stocks are those that are not part of any of the pilot samples. Similarly, D_TURNOVER, D_VOLUME, D_LN(RANGE), and D_GARCH are calculated. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

Panel B of table A4 reports the results for PILOT2, which requires both quotes and trades to occur at $0.05 increments. Panel B is similar to panel A in that we do not find significant differences in D_ILLIQ and generally find significant decreases in both D_TURNOVER and D_VOLUME. Also similar to panel A, we find that D_LN(RANGE) increases significantly but the effect on D_GARCH is mixed.

Panel C shows the results for PILOT3. For brevity, we focus our attention on the post-minus-pre differences. First, while panels A and B reveal little difference in D_ILLIQ, we see that, relative to the control sample, stocks part of the PILOT3 generally become more illiquid. D_ILLIQ increases significantly in two of the three rollouts and is in stark contrast to the negative and insignificant changes found in panels A and B. In addition to the differences in illiquidity, the biggest difference in panel C is the lack of significance in the NYSE rollout. D_TURNOVER, D_VOLUME, and D_LN(RANGE) are all insignificantly different from zero in the NYSE sample. The findings for the various NASDAQ rollout periods produce results similar to those in previous panels.

Table A4 clearly shows that the changes found in our univariate results in table A3 are not robust to using the control sample in a difference-in-difference approach. Once we control for the change in the market quality of the average firm in the control sample, we find a decrease in both turnover and volume. Given that one of the stated goals of the SEC was to improve the level of trading activity, the negative change in volume and turnover is problematic. Moreover, the dramatic increase in range-based volatility and price clustering could also be a sign of a less than efficient system of trading, which could lead to less informative prices.

Given that the conclusions we are able to draw from our univariate tests are not entirely clear across the treatment groups and across the various rollout periods, we recognize the need to continue to provide additional layers of robustness to our tests. We recognize the possibility that other factors could be influencing our results and therefore shift our analysis to a multivariate setting.

A.3. Multivariate Analysis of Liquidity—Difference-in-Difference Tests

Table A5 presents the results from estimating the following equation for the first treatment group of stocks (PILOT1).

$$TRADING_{i,t} = \beta_1 PILOT1_i + \beta_2 EVENT_t + \beta_3 PILOT1_i \times EVENT_t + \beta_4 LN(CAP)_{i,t} + \beta_5 LN(PRICE)_{i,t} + \beta_6 NYSE_i + \beta_7 LN(GARCH)_{i,t} + \alpha + \varepsilon_{i,t} \quad (1)$$

Columns [1] and [2] present the results for the NYSE sample of pilot stocks, while columns [3] through [6] show the results for the two sets of pilot stocks for the NASDAQ sample, respectively. We use two different proxies for trading activity as our dependent variables. First, LN(ILLIQ) is the natural log of Amihud's (2002) measure of illiquidity. Second, LN(TURNOVER) is the natural log of share turnover. We use the natural logs to normalize the distributions of both ILLIQ and TURNOVER. In addition, using the natural logs provides some ease in the interpretation of the coefficients. On another note, in unreported tests, we use the natural log of trading volume as an additional dependent variable. Here, we find nearly identical results to those when using turnover since the only difference is that turnover accounts for shares outstanding in the denominator and the independent variable LN(CAP) accounts for shares outstanding in the numerator. The independent variables of interest include PILOT1, which is equal to one if a particular stock is part of the SEC's first treatment sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/10/2016 in columns [3] and [4], and 10/17/2016 in columns [5] and [6]. PILOT1×EVENT is the interaction between the two indicator variables. The control variables include LN(CAP), the natural log of market capitalization; LN(PRICE), the natural log of the daily closing price; NYSE, an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(GARCH), the natural log of Garch(1,1) volatility. We estimate equation (1) and report both the coefficients and t-statistics obtained from robust standard errors.

Table A5. Multivariate Tests of Trading Activity—PILOT1 Stocks

	NYSE SAMPLE EVENT DATE (9/6/2016)		NASDAQ SAMPLE EVENT DATE (10/10/2016)		NASDAQ SAMPLE EVENT DATE (10/17/2016)	
	LN(ILLIQ)	LN(TURNOVER)	LN(ILLIQ)	LN(TURNOVER)	LN(ILLIQ)	LN(TURNOVER)
	[1]	[2]	[3]	[4]	[5]	[6]
PILOT1	−0.1987***	0.1563***	−0.1288***	0.1076***	−0.0912***	0.0938***
	(−9.72)	(10.50)	(−9.56)	(9.97)	(−8.71)	(10.71)
EVENT	0.0472***	0.0672***	0.0055	0.0836***	0.0262***	0.0992***
	(3.50)	(6.39)	(0.69)	(12.35)	(3.78)	(16.68)
PILOT1×EVENT	0.1871***	−0.0553***	0.2454***	−0.0778***	0.1891***	−0.0409***
	(7.39)	(−2.98)	(12.77)	(−4.97)	(12.02)	(−3.06)
LN(CAP)	−1.2454**	0.2513***	−1.5150***	0.5803***	−1.4949***	0.5556***
	(−164.11)	(40.68)	(−330.02)	(134.21)	(−376.06)	(148.52)
LN(PRICE)	0.6274***	0.2552***	0.8777***	−0.0335***	0.8297***	0.0123***
	(70.82)	(36.72)	(145.09)	(−6.15)	(158.77)	(2.58)
NYSE	−0.3104***	0.3073***	−0.0119	0.0258***	−0.0276***	0.0403***
	(−15.98)	(19.39)	(−1.49)	(4.14)	(−4.13)	(7.80)
LN(GARCH)	−0.1433***	0.8441***	−0.1785***	0.9210***	−0.2025***	0.9352***
	(−10.17)	(73.65)	(−18.98)	(96.72)	(−25.37)	(114.78)
CONSTANT	11.9276***	−2.1541***	14.3975***	−5.1352***	14.1954***	−4.9057***
	(136.00)	(−29.32)	(251.87)	(−90.14)	(285.80)	(−98.99)
ADJ. R^2	0.4543	0.1894	0.5077	0.2572	0.5028	0.2514
ROBUST SEs	Yes	Yes	Yes	Yes	Yes	Yes
N	63,234	65,183	163,893	169,152	225,032	233,733

Notes: The dependent variable is one of two variables: LN(ILLIQ) is the natural log of Amihud's (2002) measure of illiquidity, and LN(TURNOVER) is the natural log of share turnover. The independent variables of interest include PILOT1, which is equal to one if a particular stock is part of the SEC's first pilot sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/10/2016 in columns [3] and [4], and 10/17/2016 in columns [5] and [6]. PILOT1×EVENT is the interaction between the two indicator variables. The control variables include the following: LN(CAP) is the natural log of market capitalization; LN(PRICE) is the natural log of the daily closing price; NYSE is an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(GARCH) is the natural log of Garch(1,1) volatility. We report the coefficients with the corresponding t-statistics obtained from robust standard errors. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

With respect to the control variables, we find that LN(ILLIQ) is negatively related to LN(CAP), NYSE, and LN(GARCH), and positively related to LN(PRICE). When LN(TURNOVER) is used as the dependent variable, we find that each of the control variables produces positive estimates in columns [2] and [6]. Similar results are found in column [4], with the exception of the negative coefficient on LN(PRICE). Next, and in the tables that follow, we focus most of our attention on the variable of interest, which is the interaction between the PILOT and EVENT. In contrast to much of our univariate analysis, results in table A5 show a significant increase in the illiquidity of pilot stocks associated with the SEC program. PILOT1×EVENT has a coefficient of 0.1871 that is statistically significant at the 0.01 level in column [1]. In economic terms, these findings indicate that, relative to the control sample, ILLIQ increases almost 19 percent during the postevent period. Columns [3] and [5] show even stronger results for the NASDAQ sample with coefficients of 0.2454 and 0.1891, respectively. While ILLIQ increases, TURNOVER goes in the opposite direction as the interaction coefficients are negative and significant in columns [2], [4], and [6]. These results are not only statistically significant but also economically meaningful. For instance, in column [2], the interaction coefficient indicates that, relative to the control sample, share turnover of treatment stocks decreased 5.5 percent during the postevent period. Once again, these results seem to suggest that the pilot program reduces the level of liquidity and trading activity of affected stocks.

Next, we will focus our analysis on the change in volatility of pilot stocks vis-à-vis control stocks surrounding the increase in tick sizes in a multivariate framework. Table A6 presents the results from estimating the following equation for the first treatment group of stocks (PILOT1).

$$VOLATILITY_{i,t} = \beta_1 PILOT1_i + \beta_2 EVENT_t + \beta_3 PILOT1_i \times EVENT_t + \beta_4 LN(CAP)_{i,t} + \beta_5 LN(PRICE)_{i,t} + \beta_6 NYSE_i + \beta_7 LN(TURNOVER)_{i,t} + \alpha + \varepsilon_{i,t} \quad (2)$$

The dependent variable consists of either LN(RANGE) or LN(GARCH). Again, the natural logs of these variables helps in the normalization of the distributions and in the interpretation of coefficients. The independent variables are similar to those in equation (1) with the exception of including LN(TURNOVER), which controls for trading activity and liquidity. Table A6 reports the results from estimating equation (2). In general, we find that volatility is negatively related to market capitalization and the NYSE indicator variable, and positively related to share turnover. The coefficient on LN(PRICE) depends on the use of the different dependent variables. Focusing now on the interaction variable, we find that the coefficients on PILOT1×EVENT are positive and statistically significant at the 0.01 level in columns [1], [3], [4], [5], and [6]. In column [2], the interaction estimate is positive but not quite significant at the 0.10 level (coefficient = 0.0105, t-statistic = 1.57). These results seem to suggest that after controlling for a number of factors that influence the level of volatility and relative to control stocks, the volatility of stocks in the first treatment group appears to increase during the postevent period. In economic terms, we find that, relative to control stocks, the range-based volatility of treatment stocks increases by 3.2 to 6.3 percent, depending on the specification. When examining the economic magnitude of the interaction estimates, we find that, relative to control stocks, GARCH volatility increases by 1.1 to 1.6 percent. Combined with the previous table, the findings in table A6 indicate that not only do liquidity and trading activity worsen for stocks in the first treatment, but prices of these stocks also seem to become more unstable.

Table A6. Multivariate Tests of Volatility—PILOT1 Stocks

	NYSE SAMPLE EVENT DATE (9/6/2016)		NASDAQ SAMPLE EVENT DATE (10/10/2016)		NASDAQ SAMPLE EVENT DATE (10/17/2016)	
	LN(RANGE)	LN(GARCH)	LN(RANGE)	LN(GARCH)	LN(RANGE)	LN(GARCH)
	[1]	[2]	[3]	[4]	[5]	[6]
PILOT1	−0.0570***	0.0196***	−0.0297***	0.0158***	−0.0127***	−0.0041
	(−6.70)	(3.68)	(−5.01)	(4.41)	(−2.77)	(−1.37)
EVENT	0.0721***	0.0390***	0.1073***	0.0455***	0.1349***	0.0540***
	(13.57)	(10.32)	(30.78)	(19.31)	(44.40)	(26.31)
PILOT1×EVENT	0.0627***	0.0105	0.0463***	0.0157***	0.0322***	0.0163***
	(5.87)	(1.57)	(5.29)	(2.94)	(4.58)	(3.52)
LN(CAP)	−0.0759***	−0.0892***	−0.0662***	−0.0764***	−0.0648***	−0.0766***
	(−22.44)	(−45.36)	(−27.77)	(−54.91)	(−32.56)	(−64.28)
LN(PRICE)	0.7645***	−0.1827***	0.7602***	−0.1913***	0.7564***	−0.1950***
	(207.03)	(−82.05)	(277.01)	(−120.42)	(328.15)	(−141.69)
NYSE	−0.0735**	−0.0854***	−0.0711***	−0.0226***	−0.0712***	−0.0165***
	(−8.73)	(−16.07)	(−22.49)	(−9.67)	(−27.04)	(−8.54)
LN(TURNOVER)	0.2548***	0.1099***	0.2280***	0.1099***	0.2265***	0.1104***
	(86.96)	(69.42)	(105.68)	(95.20)	(124.87)	(112.38)
CONSTANT	−1.7072***	−1.9958***	−1.8546***	−2.1972***	−1.8701***	−2.1870***
	(−46.23)	(−91.60)	(−71.85)	(−139.94)	(−86.72)	(−163.79)
ADJ. R^2	0.6595	0.3281	0.5956	0.2740	0.6038	0.2800
ROBUST SEs	Yes	Yes	Yes	Yes	Yes	Yes
N	64,740	65,183	166,794	169,152	230,482	233,733

Notes: The dependent variable is one of two variables: LN(RANGE) is the natural log of the difference between the daily high price and the daily low price, and LN(GARCH) is the natural log of Garch(1,1) volatility. The independent variables of interest include PILOT1, which is equal to one if a particular stock is part of the SEC's first pilot sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/10/2016 in columns [3] and [4], and 10/17/2016 in columns [5] and [6]. PILOT1×EVENT is the interaction between the two indicator variables. The control variables include the following: LN(CAP) is the natural log of market capitalization; LN(PRICE) is the natural log of the daily closing price; NYSE is an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(TURNOVER) is the natural log of share turnover. We report the coefficients with the corresponding t-statistics obtained from robust standard errors. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

Perhaps finding that liquidity and trading activity and the price stability of pilot stocks worsen during the postevent period is an artifact of the first treatment, which requires trades to occur at $0.01 and quotes to occur on increments of $0.05. Next we replicate the analysis in tables A5 and A6 but examine the second treatment group relative to control stocks; table A7 shows these results. In other words, we estimate the following regression for the second treatment group and the control group, respectively:

$$TRADING_{i,t} = \beta_1 PILOT2_i + \beta_2 EVENT_t + \beta_3 PILOT2_i \times EVENT_t + \beta_4 LN(CAP)_{i,t} + \beta_5 LN(PRICE)_{i,t} + \beta_6 NYSE_i + \beta_7 LN(GARCH)_{i,t} + \alpha + \varepsilon_{i,t} \quad (3)$$

Here, the only difference between equation (3) and equation (1) is that we include PILOT2 instead of PILOT1 in our analysis. Similar to the results in table A5, we find a significant, positive coefficient on the interaction between PILOT2 and EVENT. For the NYSE sample, which is reported in column [1], the interaction term has a coefficient of 0.1330 with a corresponding t-statistic of 5.26. This coefficient indicates that, relative to control stocks, the illiquidity of stocks in the second treatment group increases by 13.3 percent. The relation is even stronger in the NASDAQ samples with coefficients of 0.2769 and 0.2661, respectively. Columns [2], [4], and [6] estimate the regression with LN(TURNOVER) as the dependent variable. Although the interaction term is negative for the NYSE stocks, it is not reliably different from zero (coefficient = −0.0218, t-statistic = −1.16). However, the coefficients on PILOT2×EVENT for the two NASDAQ samples are both negative and highly significant. In economic terms, the results suggest that the decrease in share turnover ranges from 2 percent to 9.3 percent for treatment vis-à-vis control stock during the postevent period.

Table A7. Multivariate Tests of Trading Activity—PILOT2 Stocks

	NYSE SAMPLE EVENT DATE (9/6/2016)		NASDAQ SAMPLE EVENT DATE (10/10/2016)		NASDAQ SAMPLE EVENT DATE (10/17/2016)	
	LN(ILLIQ)	LN(TURNOVER)	LN(ILLIQ)	LN(TURNOVER)	LN(ILLIQ)	LN(TURNOVER)
	[1]	[2]	[3]	[4]	[5]	[6]
PILOT2	−0.1179***	0.0943***	−0.1631***	0.1538***	−0.0348***	0.0016
	(−5.75)	(6.18)	(−11.77)	(13.90)	(−3.09)	(0.16)
EVENT	0.0443***	0.0693***	0.0042	0.0846***	−0.0346***	0.1241***
	(3.29)	(6.60)	(0.53)	(12.49)	(−4.33)	(18.12)
PILOT2×EVENT	0.1330***	−0.0218	0.2769***	−0.0927***	0.2661***	−0.0637***
	(5.26)	(−1.16)	(14.08)	(−5.80)	(15.70)	(−4.16)

LN(CAP)	−1.2076***	0.2161***	−1.4765***	0.5351***	−1.5022***	0.5693***
	(−164.41)	(36.52)	(−321.37)	(124.03)	(−345.89)	(137.61)
LN(PRICE)	0.5888***	0.2935***	0.8401***	0.0134**	0.8508***	−0.0160***
	(65.73)	(41.93)	(137.86)	(2.46)	(143.32)	(−2.83)
NYSE	−0.4254***	0.4052***	−0.0347***	0.0453***	−0.0521***	0.0674***
	(−22.09)	(25.75)	(−4.35)	(7.33)	(−6.85)	(11.37)
LN(GARCH)	−0.0929***	0.8081***	-0.1648***	0.9122***	−0.1397***	0.8633***
	(−6.64)	(72.39)	(−17.45)	(96.12)	(−15.03)	(81.43)
CONSTANT	11.8317***	−2.0203***	14.0680***	−4.7236***	14.4841***	−5.2876***
	(136.94)	(−28.20)	(245.54)	(−83.08)	(263.84)	(−91.53)
ADJ. R^2	0.4540	0.1939	0.4953	0.2423	0.5078	0.2432
ROBUST SEs	Yes	Yes	Yes	Yes	Yes	Yes
N	63,750	65,665	164,024	169,204	188,109	186,233

Notes: The dependent variable is one of two variables: LN(ILLIQ) is the natural log of Amihud's (2002) measure of illiquidity, and LN(TURNOVER) is the natural log of share turnover. The independent variables of interest include PILOT2, which is equal to one if a particular stock is part of the SEC's first pilot sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/10/2016 in columns [3] and [4], and 10/17/2016 in columns [5] and [6]. PILOT2×EVENT is the interaction between the two indicator variables. The control variables include the following: LN(CAP) is the natural log of market capitalization; LN(PRICE) is the natural log of the daily closing price; NYSE is an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(GARCH) is the natural log of Garch(1,1) volatility. We report the coefficients with the corresponding t-statistics obtained from robust standard errors. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

Table A8 replicates the tests from table A6 by estimating the following equation for the second treatment group of stocks (PILOT2).

$$\text{VOLATILITY}_{i,t} = \beta_1\text{PILOT2}_i + \beta_2\text{EVENT}_t + \beta_3\text{PILOT2}_i\times\text{EVENT}_t + \beta_4\text{LN(CAP)}_{i,t} + \beta_5 LN(PRICE)_{i,t} + \beta_6 NYSE_i + \beta_7 LN(TURNOVER)_{i,t} + \alpha + \varepsilon_{i,t} \quad (4)$$

Equation (4) is identical to equation (2) with the exception of including PILOT2 instead of PILOT1. Columns [1] and [2] report results for the NYSE sample, and columns [3] through [6] report results for the NASDAQ samples, respectively. Although the results are very similar to our previous findings, we do not find a significant change in either LN(RANGE) or LN(GARCH) for the NYSE sample. For instance, the coefficient on PILOT2×EVENT is 0.0067 in column [1] and 0.0024 in column [2], both of which are insignificant. However, we find robust evidence of changes in volatility in the NASDAQ samples. For example, the interaction estimates are 0.0528 and 0.0576 when LN(RANGE) is used as the dependent variable and 0.0238 and 0.0156 when LN(GARCH) is being used as the dependent variable. The magnitudes of the coefficients in table A8 are generally similar to corresponding coefficients in table A6. Here, we find some evidence that the volatility of stocks in the second treatment group increases relative to control stocks during the postevent period.

Table A8. Multivariate Tests of Volatility—PILOT2 Stocks

	NYSE SAMPLE EVENT DATE (9/6/2016)		NASDAQ SAMPLE EVENT DATE (10/10/2016)		NASDAQ SAMPLE EVENT DATE (10/17/2016)	
	LN(RANGE)	LN(GARCH)	LN(RANGE)	LN(GARCH)	LN(RANGE)	LN(GARCH)
	[1]	[2]	[3]	[4]	[5]	[6]
PILOT2	−0.0073	0.0052	−0.0052	0.0083**	−0.0097**	0.0047
	(−0.87)	(0.88)	(−0.92)	(2.26)	(−1.96)	(1.46)
EVENT	0.0718***	0.0390***	0.1076***	0.0456***	0.1192***	0.0504***
	(13.51)	(10.33)	(30.86)	(19.37)	(33.69)	(21.12)
PILOT2×EVENT	0.0067	0.0024	0.0528***	0.0238***	0.0576***	0.0156***
	(0.61)	(0.33)	(6.16)	(4.37)	(7.58)	(3.10)
LN(CAP)	−0.0650***	−0.0834***	−0.0647***	−0.0742***	−0.0611***	−0.0731***
	(−19.53)	(−44.16)	(−27.75)	(−55.09)	(−27.59)	(−56.43)
LN(PRICE)	0.7438***	−0.1893***	0.7562***	−0.1935***	0.7487***	−0.1986***
	(196.97)	(−85.87)	(276.48)	(−122.37)	(286.84)	(−129.30)
NYSE	−0.0812***	−0.0562***	−0.0786***	−0.0258***	−0.0730**	−0.0178***
	(−9.64)	(−10.81)	(−24.99)	(−11.19)	(−24.35)	(−8.04)
LN(TURNOVER)	0.2578***	0.1093***	0.2262***	0.1087***	0.2162***	0.1002***
	(86.52)	(68.19)	(106.34)	(95.02)	(103.99)	(85.05)
CONSTANT	−1.7822***	−2.0783***	−1.8631***	−2.2201***	−1.9036***	−2.2334***
	(48.95)	(−99.04)	(−74.11)	(−146.40)	(−78.81)	(−151.43)
ADJ. R^2	0.6430	0.2971	0.5946	0.2710	0.5836	0.2643
ROBUST SEs	Yes	Yes	Yes	Yes	Yes	Yes
N	65,200	65,665	166,906	169,204	183,451	186,233

Notes: The dependent variable is one of two variables: LN(RANGE) is the natural log of the difference between the daily high price and the daily low price, and LN(GARCH) is the natural log of Garch(1,1) volatility. The independent variables of interest include PILOT2, which is equal to one if a particular stock is part of the SEC's first pilot sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/10/2016 in columns [3] and [4], and 10/17/2016 in columns [5] and [6]. PILOT2×EVENT is the interaction between the two indicator variables. The control variables include the following: LN(CAP) is the natural log of market capitalization; LN(PRICE) is the natural log of the daily closing price; NYSE is an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(TURNOVER) is the natural log of share turnover. We report the coefficients with the corresponding t-statistics obtained from robust standard errors. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

Tables A9 and A10 again replicate the tests from tables A5 through A8 but examine the effect of the pilot program on the third treatment group of stocks. In general, we find that the results from tables A9 and A10 are very similar to those in the previous tables. More specifically, table A9 shows that, relative to control stocks, the illiquidity of treatment stocks increases during the postevent period. This result is robust to the different samples with the different rollout periods. When examining share turnover, we again find that turnover is lower for treatment versus control stocks during the postevent period in two of the three columns. However, these results seem to be driven by the two NASDAQ samples. Said differently, we do not find that turnover for pilot stocks in the NYSE sample meaningfully changes (relative to control stocks) during the postevent period, given that the coefficient on the interaction between PILOT3 and EVENT is not reliably different from zero. Table A10 shows the results when the dependent variables include our different measures of volatility. Again, the results in table A10 are similar to those in table A8. In the NYSE sample, we do not find that volatility changes for stocks in the third treatment group (relative to the control stocks). However, the results in columns [3] through [6] show positive and significant estimates on the interaction between PILOT3 and EVENT. These results suggest that for the NASDAQ samples, volatility increases during the postevent period. The magnitudes of these estimates are similar to corresponding coefficients from previous tables. Results from tables A9 and A10 indicate that the trade-at rule does not change the effect of increasing the minimum tick size in a meaningful way. Taken together, the findings in tables A5 through A10 seem to indicate that liquidity and trading activity worsen for treatment stocks vis-à-vis control stocks during the implementation of the pilot program. In general, these results are robust to different treatment samples and different rollout periods. Our results also show that volatility increases for treatment stocks (relative to control stocks) during the postimplementation period. Combined, our results seem to indicate that the quality of financial markets worsens in response to the pilot program.

Table A9. Multivariate Tests of Trading Activity—PILOT3 Stocks

	NYSE SAMPLE EVENT DATE (9/6/2016)		NASDAQ SAMPLE EVENT DATE (10/24/2016)		NASDAQ SAMPLE EVENT DATE (10/31/2016)	
	LN(ILLIQ)	LN(TURNOVER)	LN(ILLIQ)	LN(TURNOVER)	LN(ILLIQ)	LN(TURNOVER)
	[1]	[2]	[3]	[4]	[5]	[6]
PILOT3	0.0191	−0.0075	−0.0260*	0.0298***	−0.0146	0.0001
	(0.88)	(−0.45)	(−1.94)	(2.72)	(−1.38)	(0.01)
EVENT	0.0443***	0.0687***	−0.0378***	0.1693***	−0.0623***	0.2076***
	(3.30)	(6.54)	(−4.65)	(24.44)	(−7.48)	(29.39)
PILOT3×EVENT	0.0877***	−0.0282	0.3005***	−0.1646***	0.3002***	−0.1105***
	(3.21)	(−1.32)	(14.24)	(−9.29)	(17.15)	(−7.24)
LN(CAP)	−1.2149***	0.2180***	−1.4955***	0.5561***	−1.5030***	0.5631***
	(−155.04)	(33.64)	(−319.69)	(126.76)	(−339.24)	(134.91)
LN(PRICE)	0.5966***	0.2959***	0.8483***	0.0034	0.8424***	0.0039
	(64.41)	(39.74)	(138.05)	(0.61)	(144.57)	(0.74)
NYSE	−0.4261***	0.4009***	−0.0148*	0.0280***	−0.0070	0.0235***
	(−22.13)	(25.12)	(−1.85)	(4.49)	(−0.93)	(3.98)
LN(GARCH)	−0.0923***	0.8186***	−0.1566***	0.9021***	−0.1683***	0.9069***
	(−6.73)	(72.49)	(−16.73)	(95.35)	(−18.72)	(98.29)
CONSTANT	11.9080***	−2.0084***	14.3298***	−5.0242***	14.4022***	−5.1025***
	(131.74)	(-26.41)	(247.58)	(−87.77)	(260.53)	(−92.22)
ADJ. R^2	0.4317	0.1823	0.4930	0.2457	0.4979	0.2497
ROBUST SEs	Yes	Yes	Yes	Yes	Yes	Yes
N	63,452	65,387	163,771	168,991	179,964	186,078

Notes: The dependent variable is one of two variables: LN(ILLIQ) is the natural log of Amihud's (2002) measure of illiquidity, and LN(TURNOVER) is the natural log of share turnover. The independent variables of interest include PILOT3, which is equal to one if a particular stock is part of the SEC's first pilot sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/24/2016 in columns [3] and [4], and 10/31/2016 in columns [5] and [6]. PILOT3×EVENT is the interaction between the two indicator variables. The control variables include the following: LN(CAP) is the natural log of market capitalization; LN(PRICE) is the natural log of the daily closing price; NYSE is an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(GARCH) is the natural log of Garch(1,1) volatility. We report the coefficients with the corresponding t-statistics obtained from robust standard errors. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.

Table A10. Multivariate Tests of Volatility—PILOT3 Stocks

	NYSE SAMPLE EVENT DATE (9/6/2016)		NASDAQ SAMPLE EVENT DATE (10/24/2016)		NASDAQ SAMPLE EVENT DATE (10/31/2016)	
	LN(RANGE)	LN(GARCH)	LN(RANGE)	LN(GARCH)	LN(RANGE)	LN(GARCH)
	[1]	[2]	[3]	[4]	[5]	[6]
PILOT3	0.0060	0.0038	−0.0224***	−0.0056	−0.0198***	−0.0044
	(0.70)	(0.62)	(−3.97)	(−1.51)	(−4.39)	(−1.45)
EVENT	0.0736***	0.0396***	0.1384***	0.0520***	0.1469***	0.0487***
	(13.84)	(10.47)	(38.35)	(21.34)	(39.77)	(19.52)
PILOT3×EVENT	0.0148	−0.0040	0.0754***	0.0199***	0.0793***	0.0239***
	(1.38)	(−0.52)	(8.71)	(3.35)	(10.60)	(4.59)
LN(CAP)	−0.0764***	−0.0937***	−0.0686***	−0.0765***	−0.0683***	−0.0762***
	(−22.21)	(−47.36)	(−28.93)	(−54.98)	(−30.49)	(−56.85)
LN(PRICE)	0.7618***	−0.1722***	0.7598***	−0.1881***	0.7600***	−0.1910***
	(197.28)	(−75.63)	(277.35)	(−117.70)	(293.64)	(−124.69)
NYSE	−0.0861**	−0.0627***	−0.0697***	−0.0242***	−0.0695***	−0.0243***
	(−10.45)	(−11.65)	(−22.11)	(−10.35)	(−23.42)	(−10.97)
LN(TURNOVER)	0.2428**	0.1048***	0.2249***	0.1075***	0.2229***	0.1078***
	(86.48)	(69.40)	(106.54)	(94.53)	(110.88)	(97.42)
CONSTANT	−1.6951***	−1.9910***	−1.8308***	−2.2054***	−1.8346***	−2.1987***
	(-45.30)	(−91.48)	(−71.50)	(−140.44)	(75.56)	(−145.83)
ADJ. R^2	0.6556	0.2908	0.5989	0.2644	0.6039	0.2680
ROBUST SEs	Yes	Yes	Yes	Yes	Yes	Yes
N	64,906	65,387	166,603	168,991	183,417	186,078

Notes: The dependent variable is one of two variables: LN(RANGE) is the natural log of the difference between the daily high price and the daily low price, and LN(GARCH) is the natural log of Garch(1,1) volatility. The independent variables of interest include PILOT3, which is equal to one if a particular stock is part of the SEC's first pilot sample and zero otherwise. EVENT is equal to one if the current day is greater than or equal to the event date, which is 9/6/2016 in columns [1] and [2], 10/24/2016 in columns [3] and [4], and 10/31/2016 in columns [5] and [6]. PILOT3×EVENT is the interaction between the two indicator variables. The control variables include the following: LN(CAP) is the natural log of market capitalization; LN(PRICE) is the natural log of the daily closing price; NYSE is an indicator variable capturing whether a particular stock is listed on the NYSE; and LN(TURNOVER) is the natural log of share turnover. We report the coefficients with the corresponding t-statistics obtained from robust standard errors. ***, **, and * denote statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Source: Figures based on author calculations using SAS software.