The Impact of the Federal Open Market Committee's Quantitative Easing Announcements on Stock Market Volatility during the Global Financial Crisis

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The severity of the global financial crisis that emerged in 2007 necessitated an expansion of the standard monetary policy toolkit used by the Federal Reserve to stabilize the economy. A key element of that expansion was quantitative easing, an unconventional monetary policy tool that involves the large-scale purchases of financial assets by the Federal Reserve (Fed) (Mishkin, 2009). Such interventions have the potential to influence markets beyond those of the specific instruments purchased, including the stock market. The impact of these quantitative easing activities of the Fed, including the role played by the Fed's associated communication strategy, on the volatility of the US stock market is the focus of this study.

Unconventional monetary policy takes on many forms as it is more so defined by "what it is not" (Joyce et al., 2012). The policy encompasses tools used during periods of extreme economic crisis when traditional monetary policy tools i.e. tightening or loosening money supply or rate cuts are not effective or can no longer be used like when rates are at near zero levels. The most common form of this policy is an expansion of central banks' balance sheets in an attempt to influence interest rates rather than the usual short-term official rates (Joyce et al., 2012). In QE programs the focus is primarily on how the type and quantity of assets purchased will affect the financial market conditions (Williamson, 2017). Quantitative Easing has helped restore market confidence and acts as a resuscitator of the stock market by making stocks more attractive to investors. There are two main reasons behind this. First, an increase in the Fed's assets correlates significantly with the S&P 500. Second, reduction in long-term interest rates also raises prices in the equity market (Bhar et al., 2015). The reason the correlation between Fed's balance sheet and the S&P 500 index exists is because QE pushes down interest rates which lowers the return that investors can get from safe investments. Investors are pushed towards relatively riskier investments for higher returns which can be found in the stock market. This pushes up the prices in the stock market.

Other than the impact that Quantitative Easing has on prices in the stock market, there is also a second impact channel through which Quantitative Easing affects the market. This impact channel, hereon referred to as the Volatility Channel, is created by announcements regarding Quantitative Easing and will be the focus of this paper. The Volatility Channel affects the market through the investor sentiment that it generates. In 2008 and onwards, communication and Forward Guidance from the Federal Reserve was another key unconventional monetary policy tool used to reduce uncertainty about future course of policy actions and provide verbal assurance that rates will remain low. How these different communications were perceived by the market largely dictated market moves and volatility levels in the time period following the announcement. Ghysels et al. (2017) also mention this channel when discussing the impact of QE on the bond market and make note that the "mere announcement" that a Central Bank is entering the market makes investors reassess their economic and risks outlook (2017, p.219). The authors expand that any announcement about QE, initiation, expansion or end of the program, has a confidence-effect on the market i.e. it sends out signals about the future. This in turn

generates positive or negative sentiment among investors and determines how much volatility there will be and for how long. As explained in much of the literature on transparency and communication, Forward Guidance and general communication from a Central Bank about its economic outlook is instrumental in ensuring a smooth response to aggressive policy actions without causing sharp movements in asset prices as the market is "less likely to be caught unawares by policy actions" (Dincer and Eichengreen, 2014, p.191 and Blinder, 2008).

The paper will explore the question: *Did the nature of different FOMC announcements on Quantitative Easing, positive or negative, expected or surprise, have different impacts on stock market volatility*? The paper uses data from two different five-day windows for all 11 QE-related announcements in response to the Financial Crisis of '08 to see how the stock market was behaving during that time period. It considers minute-by-minute observations on volatility[1] on the day of the announcement, average daily volatility in the days surrounding the announcement, and the difference in daily volatility between announcement days and regular days. I believe that a QE announcement has no clear direction of impact in terms of whether it will cause a positive or negative shock in the stock market. Instead, I expect my analysis to reflect the nuance that persistence and magnitude of the volatility is determined by the nature of the announcement, surprise or expected; positive or negative. In the case of a surprise announcement I expect to see a higher magnitude of prolonged volatility than in the case of an expected announcement. This is because investors cannot preempt the Fed's policy decisions and projections and thus, cannot adjust their own investment positions until after the announcement (Hakkio and Keeton, 2009). In the case of a positive announcement I expect to see a short burst of volatility on the day of the announcement that quickly fades away. An announcement with negative projections should bring about more prolonged volatility that can be seen in the days following. This follows the same logic as that for surprise announcements. Investors will try to adjust their positions to safeguard their investments. Their adjustments will largely be based on "guesses about other investors' decisions" as they "have little historical experience on which to base their assumptions" in uncertain times of financial stress (Hakkio and Keeton, 2009, p.8). This leads to more prolonged volatility as investors follows a recursive behavior in the days following the announcement by basing decisions on each other. We cannot say much about the magnitude of volatility as this will largely depend on the level of negativity or fear that announcement provokes in the market about where the economy is headed. I do however expect that in general the daily observations of volatility will reduce in magnitude as we move along the road of recovery and closer the end of the three rounds of QE in 2014. This should signify that the market is calmer and that there is increased stability as the market recovers from the crisis, aided in part by Quantitative Easing.

Corbet et al.'s paper (2019) uses high frequency tick data to examine market reactions to QE announcements following the Financial Crisis in 2008. Through an EGARCH model, they find that volatility in the market is at its peak in the first hour following an announcement and then gradually decreases. Andersson's (2010) paper is an event study that examines market reactions in terms of volatility for both the US and the EU stock and bond markets. He uses 5-minute prices of four assets to find that the volatility spike in the US is greater than that in the EU. I use a similar event study methodology, but I make use of both 1-minute price data and daily price data for the S&P 500. Using the intraday data allows me to analyze the immediate response of

[1] Observations for volatility at one-minute intervals

the market to the policy announcement including any reactionary and short-term market moves that purely reflect market sentiment based on the wording of the Fed's press releases. The daily data then allows for a smoother relatively long-term analysis that shows the market reaction to the content of the press-release, i.e. the policy itself. Secondly, my paper is more focused on the stock market alone in the US in the specific time period of the Financial Crisis which allows me to produce a more in depth analysis of all 11 announcements in the time period as compared to existing literature that tends to focus more on just program initiation announcements.

II. Literature Review

What is the relationship between communication from the Federal Reserve and stock market volatility?

The efficacy of any monetary policy largely depends on communication on part of the Central Bank. Much of the literature on transparency identifies that any Central Bank action is only as good as the response it gets from the public so the Fed must be very diligent in the frequency of its communication and the words that it uses. It is a delicate balancing act to provide forward guidance without creating a lot of financial distress when the outlook seems negative, while simultaneously simplifying complex economics concepts to convey to the public. The choice between abundant forewarning and cautious silence leading up to a policy implementation is a critical one. Following the announcement, the task of explaining the reason for a policy's implementation and its projected effects also requires great care. All of these actions define the characteristics of an announcement, expected or surprise, positive or negative, and each will evoke different market responses.

Blinder et al. (2008) go as far as calling communication itself "an important and powerful part of the central bank's toolkit since it has the ability to move financial markets, to enhance the predictability of monetary policy decisions, and potentially to help achieve central banks' macroeconomic objectives" (2008, p.940). The authors note clear anticipatory pronouncements by a Central Bank, whatever they may be about, can help to reduce volatility by drowning out *noise* and instead giving a clear signal about future actions, especially in times of extreme crisis like in 2008. In fact, they identify signals from a Central Bank as one of the three distinct channels through which it operates. They observe various FOMC announcements and extrapolate from other literature that signaling creates genuine news because it has direct effects on short term interest rates specifically the expected future short rates.

However, signaling is not as simple in times of crisis as unconventional monetary policy is not a regularly used tool and requires use of heuristics. Blinder et al. (2008) caution that for a monetary policy to be effective it is important that the Central Bank's communication itself must have a high signal to noise ratio. In such a scenario it has been observed that clarity and quality of communication is associated with smaller policy surprises. Both the quality of writing style, and whether reports or speeches mention any numerical targets are highlighted as ways to reduce noise and increase signal. This is because the two characteristics lead to a marked reduction in private agents' uncertainty as evidenced by the "reduced volatility of interest rates" following the

Fed's Humphrey-Hawkins testimonies (Blinder et al., 2008, p.928). Both Blinder et al. (2008) and Dincer and Eichengreen (2009) conclude that while clear communication may sound simple in theory, in practice sending out a signal is quite complex especially during a financial crisis. If Central Banks are excessively transparent, revealing their own uncertainties about policy decisions or projections, or showing contentious discussion between committee members in the minutes of the meeting, then this "can heighten asset price volatility" (Dincer and Eichengreen, 2009, p.5). Thus, clearer communication can definitely reduce uncertainty and in turn volatility in the market, there is still a danger of excessive transparency or 'noisy' communication which can be counterproductive and actually increase volatility.

What volatility patterns can be seen in reaction to announcements by Federal Reserve?

Now that we have confirmed that communication from the Central Bank does in fact impact volatility levels in the market, we can delve further into the magnitude and persistence of volatility based on the nature of the announcement — surprise or expected; positive or negative. Bomfim (2003) conducts a study to look at how the nature and content of communications from the FOMC mainly regarding the target Fed Funds rate generates different levels of volatility. He calculates the evolution of stock return (r_t) in the days around FOMC meetings using daily data from 1989 to 1998 and the equation $r_t = x'_t \beta + u_t$ where $x'_t\beta$ is the mean of daily stock returns and u_t captures any unpredictable movements in daily returns. Bomfim's (2003) empirical work posts two main findings. Before the scheduled release of any major economic data or expected announcement, there is a "calm before the storm" (Jones et al., 1998, as cited in Bomfim, 2003). Market volatility is very low in magnitude because market participants' reluctance to trade ahead of some economic projection or policy decision. The second finding presents that surprise announcements generate a high amount of volatility and positive surprises tend to boost volatility more than negative ones in the short run. Bomfim (2003) reasons that positive news lifts the market from previously depressed levels the day before the meeting and incentivizes market participants to trade immediately following the announcement.

A more recent paper by Corbet et al.'s (2019) focuses directly on our event of interest, the Global Financial Crisis. They use an EGARCH methodology to look at intraday data for the S&P 500, VIX and US broad dollar index returns. The paper finds that volatility in the market is at its peak in the first hour following an announcement and then gradually decreases. The condition of factors like S&P 500 performance, investor confidence, market expectations are unique to each QE announcement and determine the speed of volatility decrease. It is also found that there is a larger increase in volatility when there is an expected announcement. In the case of an announcement without a forewarning there is short term volatility persistence which is amplified in the scenario when the announcement is positive. Explaining these patterns of volatility, Corbet et al. (2019) postulate that "the very nature of the implementation of quantitative easing generated a substantial increase in immediate volatility as financial markets attempted to incorporate this new information into their pricing structure" (2019, p.334). They also reason that large increases in volatility can reflect the market's mixed response to the FOMC's policy decisions.

Is there evidence that QE stabilizes the market and what makes QE successful?

The reaction of market participants to QE announcements is also largely based on their belief about the efficacy of Quantitative Easing programs. Urbschat and Watzka (2017) suggest that "asset purchase programs that were conducted in times of stressed markets and high uncertainty seem to have a stronger impact than programs that were announced when market conditions were relaxed." (2017, p.1). In times of a crisis there is a limitation of arbitrage across assets with different maturities. Williamson (2017) posits that this is because investors have different preferences for maturities of assets i.e. there is market segmentation. The purchase of long-maturity assets during QE lowers the supply of these assets. The scarcity increases its demand and in turn raises its price which reduces long-term interest rates as yield and price are inversely related. This will reduce the spread between long-term rates and short-term rates which are already close to the zero lower bound, overall flattening the yield curve (Williamson, 2017). Secondly, the total risk that can be held by market participants is reduced when there are less long-term securities available. This can lower the risk premium that investors need to purchase long term bonds. During the crisis the Central Bank takes on a "whatever-it-takes" approach as observed by Urbschat and Watzka (2017) in Mario Deaghi's speech during the Euro Area debt crisis (2017, p.9). The presence of the ECB as a major buyer reduced arbitrage restraints which in turn lowered the risk premium that investors demanded. This channel is only temporarily effective during a financial crisis which is why QE is said to be effective during times of financial distress. Urbschat and Watzka (2017) argue that the lowering of long-term interest rates plays a role distinct from already low short-term interest rates in determining aggregate demand and increasing output. Simultaneously, the purchase of assets injects liquidity into the market which boosts lending and in turn business activity.

A cross country analysis conducted by Gambacorta et al. (2014) on the long-term effects of QE for eight advanced economies finds that if the monetary policy is at the zero lower bound, then an exogenous increase in a Central Bank's balance sheet leads to a rise in economic activity and price level. The analysis was conducted using monthly data from 2008-2011 and clearly notes by comparing to other empirical findings (like increase in GDP) from before the financial crisis that such positive macroeconomic results from QE cannot be found outside of times of financial distress.

III. Methodology

Data Collection

This paper will adopt an "event-study" methodology to analyze market reaction to major policy announcements made by the Federal Open Market Committee between 2008 and 2014 encompassing the entire "QE life-cycle"[2] used to combat the shocks from the '08 financial crisis. The method closely follows the strategy for defining event windows around the announcement as

[2]"QE life-cycle" includes all announcements made during the time period 25th November 2008 to 29th October 2014 for the three rounds of Quantitative Easing and Operation Twist.

modeled by Hillsamer (2016). The events examined are divided in two categories, "Fed Days"[3] —a day on which the FOMC releases a statement— and "Normal Days"[4] — a day on which no FOMC activity takes place. This study uses data for daily prices for the S&P 500 and information on the dates and outcomes of the FOMC meetings and statements. Dates of the FOMC meetings are recorded from Federal Reserve.gov. There is a total of 11 announcements made during this time including introduction, expansion and ending announcements.[5] See Table 1 in the Appendix.[6]

Daily data for the S&P 500 has been retrieved from Bloomberg. It is then segregated into 11 time periods around the time of each announcement. The S&P 500 is selected to represent the US stock market because it consists of 500 stocks actively traded in the U.S.

Empirical Strategy

This event-study employs the volatility measure defined in Andersson (2010):

$$V_t = abs(100 * \log(\frac{R_t}{R_{t-1}}))$$

where R_t is the daily or minute-to-minute closing price of the S&P 500.

Volatility for the S&P 500 is calculated using the formula above on two levels, intraday volatility using high-frequency (one minute) price data, and daily volatility using daily price data. For intraday volatility, data is sourced from Bloomberg. The data available is between market hours that go from 9:30 a.m. to 4:15 p.m. There are three major announcement times in the Table 1 that are: 8:15 a.m., 12:30 p.m., 2 or 2:15 p.m. Figures 1a. through 4d. show volatility patterns for each announcement based on hours since the announcement on that day. The x axis shows hours since the announcement with hour 0 being the time of the announcement, hour 1 being one hour after the announcement, and hour -1 being one hour prior to the announcement.

Daily volatility is calculated for the eleven dates from Table 1 and then separated into two buckets — FOMC announcement days (Fed Days) and non-announcement days (Normal Days). In drawing comparisons between Normal Days and Fed Days, a corresponding weekday two weeks prior to each announcement day is selected to create similar sample sizes. Average volatility is calculated for two event windows: Window A, which addresses market volatility

[3] "Fed Days" are days on which the FOMC meets and releases a statement. For meetings lasting more than one day, the last day of the meeting is called the "Fed Day".
[4] "Normal Days" are identified as a corresponding weekday two weeks ahead of the "Fed Day". This controls for weekly trading patterns that may result from it being the same day of the week. A selection two weeks before should remove effects of (i) buildup of pre-meeting anticipation for an upcoming meeting and (ii) reaction to post-meeting fallout from a previous meeting, which might impact markets.
[5] As identified by Corbet et al. 2019
[6] Sourced from Federal Reserve.gov and Corbet et al. https://www.federalreserve.gov/newsevents/pressreleases.htm

after an announcement, and Window B, which includes volatility pre- and post- announcement[7]. Window A consists of the announcement day and four days following the announcement. Window B includes the announcement day, two days prior, and the two days following the announcement. The mean and standard deviation for each window in each period for the S&P 500 is presented in Table 2 in the appendix. Smaller summary tables are provided for each announcement within the text which includes average volatility for Fed Days and the Volatility Ratio.

The volatility ratio acts as a comparative measure for the difference between volatility on Fed Days and Normal Days. The ratio is calculated as follows:

$$\frac{1/n \sum_{f=1}^{f} V_f}{1/n \sum_{n=1}^{n} V_n}$$

Here, V_f is the volatility on Fed Days and V_n is the volatility on Normal Days. A volatility ratio greater than 1 signifies that volatility is higher on Fed Days than it is on a comparable Normal Day; below 1 implies the inverse. The magnitude of this ratio can highlight how much uncertainty surrounds days on which the FOMC meets and releases a statement.

IV. Results

Some commonalities that can immediately be seen in Table 2[8] which gives a slightly more long-term trend of volatility than the intraday data is that the volatility for all Windows goes down as we move closer to the end of Quantitative Easing rounds in 2014. This means that in the course of these 6 years, overall volatility in the market reduced and stability increased, attributable in part to the Fed and unconventional monetary policy. The volatility ratio for window A is mostly larger than that for window B which means that the difference between Fed Days and Normal Days volatility is almost always somewhat higher following an announcement. To go into more depth of the market response for each announcement we will now look at the daily volatility and intraday volatility for each announcement.

[7] Both windows consist of five-days which makes up one (business-day) week trading cycle and controls for any trading patterns resulting from the day of the week for example, high volumes on Wednesdays because it is the middle of the week and traders are working longer.

[8] see in appendix

QE 1

[9]While the market was expecting that the Fed would start to delve deeper into its toolkit as the economy plunged deeper into a crisis, the initiation of Quantitative Easing was unexpected. At this point the markets were in dire need of increased liquidity so overall this should have been a welcomed announcement. The evidence presents exactly this reaction as can be seen on two levels. The unexpected but positive announcement should generate a burst of volatility on the day of the announcement but in the days following should relatively stabilize markets.

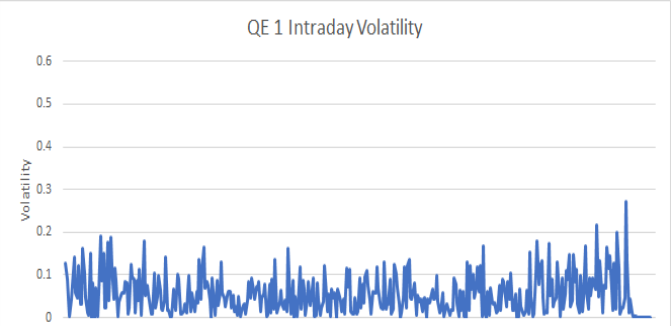


Figure 1 a

Looking at the very short term, the intraday data on the day of the announcement, this is the only announcement that was made at 8:15 a.m. ET so data availability starts at 9:30 a.m. ET a little over an hour after the announcement was made. This day is very volatile with spikes throughout the day as seen in Figure 1a. The volatility decreases through the day except for a large spike close to the end of the day which is not seen in any other program announcement. This highly volatile day is to be expected when the Fed makes its first ever announcement regarding implementation of unconventional monetary policy. If we compare the intraday graphs for all other program initiation announcements, we notice that QE1 brought about the smallest change in volatility.

The daily data in Table 3 analyzes market reaction to the announcement in the days following the announcement. On the day of the announcement for the first round of Quantitative Easing and the days following (i.e. Window A Fed Days), the average volatility is very high. However, this does not hold much meaning for how investors perceived the Fed's statement because the market had only recently found itself in a crisis so volatility was generally high even before the announcement as can be witnessed by the minimal difference between the average volatility of Fed Days Window A -days following the announcement- and Window B -including two days before the announcement. It can also be evidenced by the high average volatility for both Window A and Window B two weeks prior to the announcement in the normal days window.

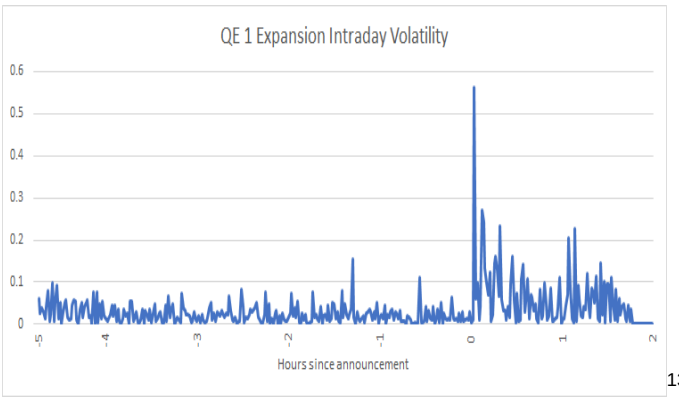
[9] Volatility on the day of the QE1 initiation announcement

Table 3: Summary Table for Daily Average Volatility and Volatility Ratio for QE Round 1[10]

	Fed Days Average		Volatility Ratio	
	Window A[11]	Window B[12]	Window A	Window B
QE 1 start	1.59	1.52	0.87	0.95
QE 1 Expansion	1.24	0.77	1.02	0.73
QE 1 end	0.21	0.13	1.17	0.81

Overall QE 1 seems to have a positive impact on market sentiment in the longer run as investors were reassured that the Federal Reserve was making full use of its toolkit to aggressively combat the economic downturn. The new implementation of unconventional monetary policy brought on hopes that the market would come out of this financial shock very soon. The volatility ratio for Window A is one of lowest in the whole data set and is below 1 which shows that the Fed's announcement actually had a calming effect on the market post the announcement. The volatility lowered on the days after the announcement than the level it was at two weeks prior on normal days. Secondly the volatility ratio for Window A is lower than for Window B which again shows that the overall volatility which again shows that there is more certainty and stability in the days following the announcement than in the days prior to the announcement.

[10] Complete calculations including normal days average can be found in the appendix
[11] Window A consists of the announcement day and four days following the announcement
[12] Window B includes the announcement day, two days prior, and the two days following the announcement



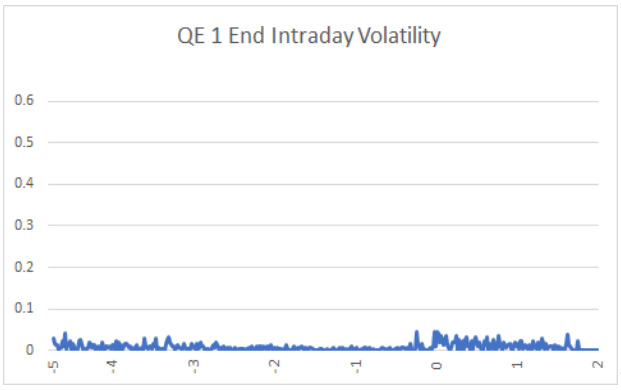
[13]

Figure 1 b

The expansion of the first round of QE brought out a very mixed response as parts of the market anticipated it while others had some inflationary concerns. In the intraday data we see that QE 1 expansion brought about the largest spike in volatility of all the announcements, but this quickly declines with little to no spikes in between (Figure 1b.). The Fed's wording of the announcement made it seem as though despite their aggressive efforts "the economy continues to contract"[14] which makes the investors fearful that even unconventional monetary will fall short.

The longer term shows much the same lukewarm market response as evidenced in Table 3. In the days directly following the QE 1 Expansion we noticed that volatility drops substantially especially in the next two days. This signifies a positive response in days after the announcement. There were some spikes in volatility in the days following which led to the average for Window A Fed Days being high. Fears grew that even unconventional monetary policy may not be enough to combat the shocks of the financial crisis. Prolonged quantitative easing, if overestimated, can also create excess liquidity in the market which can lead to inflation, so this announcement had a very mixed response from the market. This can be seen in the volatility ratio for Window A being very slightly above 1 meaning that the market was only slightly more volatile in the days following the announcement than on comparable normal days which is probably brought on by the side of the market that had concerns about inflation.

[13] Volatility on the day of the QE1 expansion announcement, hour zero is time of announcement
[14] https://www.federalreserve.gov/newsevents/pressreleases/monetary20090318a.htm



[15]

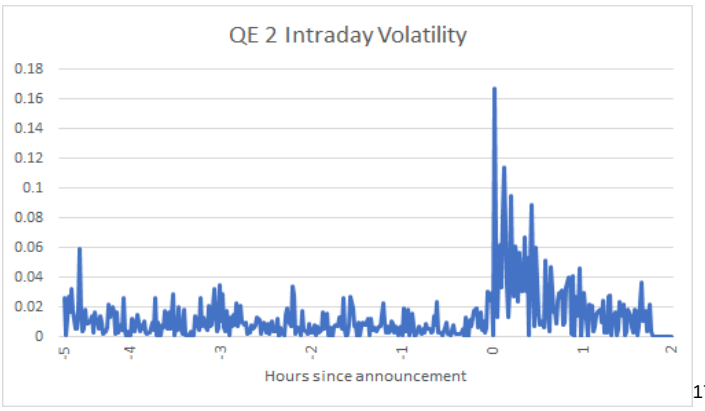
Figure 1 c

Given these investor fears, it is no surprise that the announcement about the end of QE 1 brought on very low volatility which we see in the average volatility for Window A Fed Days being very low. At this point the market wasn't just hoping but expecting the end of this round of Quantitative Easing. The intraday graph in figure 1c. presents much the same story with there being declining spikes in volatility post the announcement and overall very low level of volatility. The short burst in volatility at the time of the announcement that quickly dies out is in line with Bomfim's (2003) finding about market reaction to a positive announcement. We witness this in the volatility ratio for Window A that is above 1 because of the boost in volatility brought on by increased market participation.

QE 2

The announcement for the second round of Quantitative Easing came with abundant warning. This is why, on the day of the announcement, volatility (0.159)[16] is the lowest out of all volatility for program initiation days. The intraday volatility in figure 2a. also presents nothing of note with a small spike at the time of the announcement that quickly declines to the preannouncement low levels.

[15] Volatility on the day of the QE1 ending announcement, hour zero is time of announcement
[16] Daily volatility calculations for the period 2008 to 2014 can be provided upon request



[17]

Figure 2 a

We can also estimate the state of the market in the days leading up to the announcement by looking at Fed Days average volatility and volatility Ratio for Window B in Table 4. The average volatility is 0.320 which is very low and shows that in the days leading up to and including the day of the announcement the market was relatively stable and there was not a lot of price movement. The volatility ratio for Window B is also below 1 which shows that the volatility is not significantly higher on this announcement day than it is on a comparable normal day.

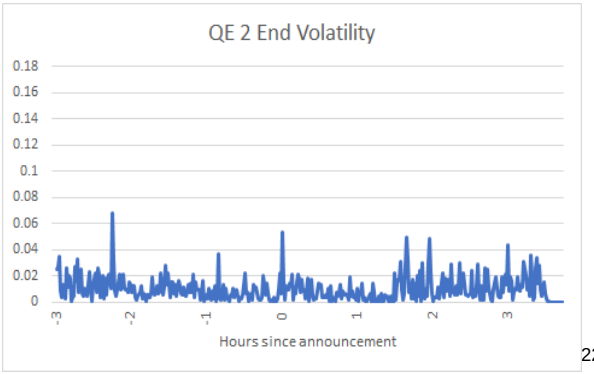
Table 4: Summary Table for Daily Average Volatility and Volatility Ratio for QE Round 2

	Fed Days Average		**Volatility Ratio**	
	Window A[18]	Window B[19]	Window A	Window B
QE 2 Start	0.32	0.31	2.20[20]	0.93
QE 2 End	0.37	0.35	1.11	1.07

However, as we look at the volatility ratio for Window A which focuses on volatility in the days after the announcement, the value is the highest of all the ratios. This is evidence of the fact that the Federal Reserve's wording has a great impact on market sentiment. The press release in

[17] Volatility on the day of the QE2 initiation announcement, hour zero is time of announcement
[18] Window A consists of the announcement day and four days following the announcement
[19] Window B includes the announcement day, two days prior, and the two days following the announcement
[20] Highest Volatility ratio in the program because the market felt like QE had been a failure and the market was depressed

November 2010 referred to the effectiveness (or lack thereof) of previous efforts to mitigate shocks and said that "progress toward its objectives has been disappointingly slow". They also described parts of the economy as "weak" and "depressed"[21]. This confirmed for investors that the first round of Quantitative Easing had been a failure and the economy was in dire need of support.



[22]

Figure 2 b

The day of the 'QE 2 End' announcement had a volatility of 0.282, higher than the volatility when the program started. The intraday volatility also presents a highly volatile day as the market realizes what the contents of the announcement could be (figure 2b.). The volatility persists through the day which may seem surprising because the press release had a much more positive note. It mentioned the economy's "moderate pace" of recovery and projected sustained growth in the future as well[23]. This volatility persists over the next couple of days as we see a volatility ratio of greater than 1 for Window A in Table 4. The pattern of volatility witnessed here is in line with the claims of Bomfim (2003) that positive FOMC decisions tend to significantly boost stock market volatility in the short run and that there is a larger and persistent boost in case of positive unexpected announcements. We see volatility persist over the next couple of days and not just on the day of because of the highly unexpected nature of the announcement. The QE round preceding this one had an expansion which is what the market expected. Note that after QE 2 all other QE programs had an expansion as well so the market was rightly taken by surprise. The FOMC also reassured investors that if needed they would return to Quantitative Easing which accounts for the positive market sentiment that led to persistently high volatility over the course of Window A.

Operation Twist

Operation Twist was first implemented in 1961 and proved to have little to no impact on mortgage rates and corporate borrowing costs. In fact, the program was largely disliked by the

[21] https://www.federalreserve.gov/newsevents/pressreleases/monetary20101103a.htm
[22] Volatility on the day of the QE2 end announcement, hour zero is time of announcement
[23] https://www.federalreserve.gov/newsevents/pressreleases/monetary20110622a.htm

public with a Bloomberg poll showing that 61% of polled economists thought that Operation Twist would be ineffective and 15% thought it would instead inhibit economic growth[24]. This explains why Operation Twist caused the most prolonged volatility. The volatility on the day of the announcement is the highest of any program announcement, and the average volatility for Window A Fed Days is also very high.

Table 5: Summary Table for Daily Average Volatility and Volatility Ratio for Operation Twist

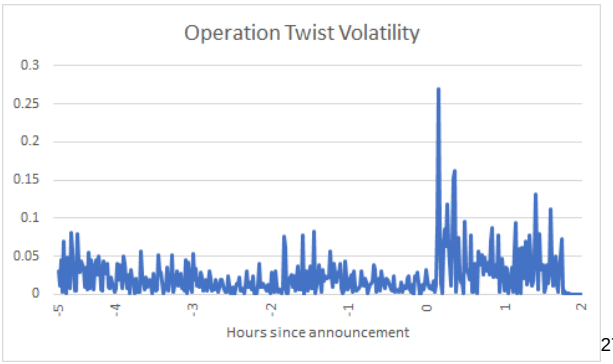
	Fed Days Average		**Volatility Ratio**	
	Window A[25]	Window B[26]	Window A	Window B
OT Start	0.89	0.69	1.24	0.81
OT Expansion	0.45	0.37	1.32	0.86

Looking at volatility ratio for Window B, as seen in Table 5, we can see that it is below one which means that the volatility in the days prior to this announcement was very close to normal days. However, for Window A the volatility is much greater than 1 which shows that the volatility of Fed days preceding the announcement are much higher. This is because an announcement was preempted but a lot of investors believed the Fed would just announce another round of QE.

[24] https://www.thebalance.com/what-is-operation-twist-416914

[25] Window A consists of the announcement day and four days following the announcement

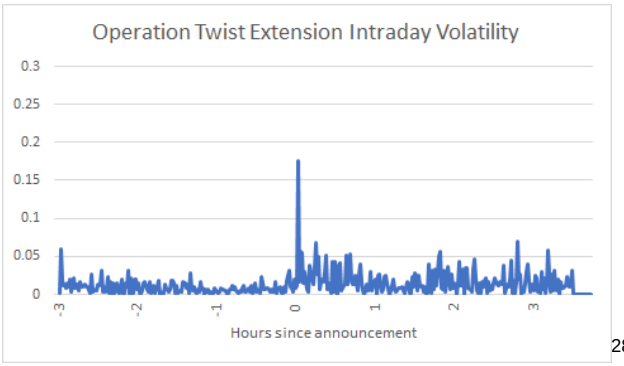
[26] Window B includes the announcement day, two days prior, and the two days following the announcement



[27]

Figure 3 a

The intraday volatility in figure 3a. shows much the same story with a very low volatility preceding the hours before the announcement. However, when the announcement is made that the new program is actually an Operation Twist there is a sharp rise in volatility. After falling slightly, the volatility continues to persist through the end of the day making it the most volatile announcement throughout this crisis. Towards the end of the day the spikes in volatility start reducing. This can be attributed to Chairman Bernake's press conference later the same day to reassure investors that the Fed would do whatever it takes to protect the economy should the situation worsen. It is not completely successful in pacifying the market as the Window A volatility ratio shows that volatility largely persists over the next few days.



[28]

Figure 3 b

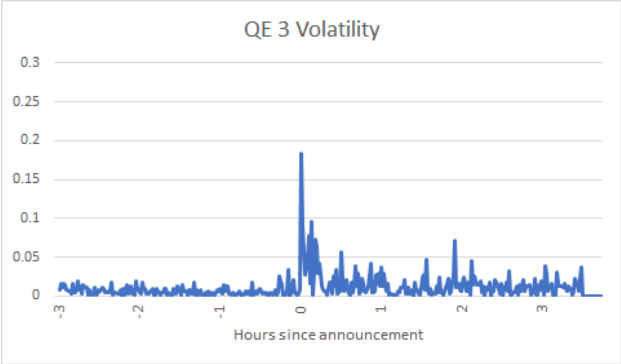
In the announcement of the Operation Twist Expansion the FOMC used much of the same wording as they did in the Operation Twist initiation announcement to convey their goal "that the program should put downward pressure on longer-term interest rates" (Corbet et al., 2019, p.332). The spike in volatility at the time of the announcement seen in figure 3b. could be caused by this action alone. Investors will perceive this as confirming their worst fear that the

[27] Volatility on the day of the Operation Twist initiation announcement, hour zero is time of announcement
[28] Volatility on the day of the Operation Twist Extension announcement, hour zero is time of announcement

Operation Twist is always unsuccessful. In fact, if we disregard the spike at hour 0 since this happens for almost each announcement, we notice that the spikes actually reach higher levels of volatility as the hours go by. The volatility persists over the next couple of days too. Even though the average volatility of Window A Fed Days seems low, if you look at the volatility ratio in Table 5 it is well above 1 which shows much higher volatility than comparable normal days. Even though expansion announcements are expected, the negative tone of this announcement generated high and persistent volatility.

QE 3

On September 13th, 2012 the Fed announced a third round of Quantitative easing. This announcement was very much expected by the market even at the time that Operation Twist was announced. In fact, investors had been disappointed that the Fed was not doing 'enough' to support the economy. Looking at the daily data in Table 6 below, the days leading up to the announcement saw an increased volatility compared to normal days which is reflected in the high Window B volatility ratio as the market speculated about the content of the announcement though an announcement in general was expected.



[29]

Figure 4 a

On the day of the announcement however, as the speculation zeroed in on a new round of Quantitative easing the volatility remained low and spiked very high only at the time of the announcement. During this press conference the Fed had positive projections and mentioned sectoral growth in areas of concern as well as increased commodity prices. As expected, the positive note generated a small burst of volatility in the first hour but then volatility quickly decreased after (figure 4a.). In the days following the volatility is much lower than comparable normal days as the volatility for Window A is much lower than 1. This makes intuitive sense as the market received its expected round of QE.

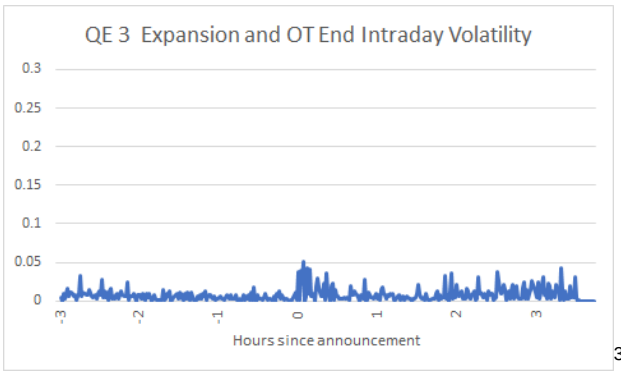
[29] Volatility on the day of the QE3 initiation announcement, hour zero is time of announcement

Table 6: Summary Table for Daily Average Volatility and Volatility Ratio for QE3 and OT End

	Fed Days Average		Volatility Ratio	
	Window A[30]	Window B[31]	Window A	Window B
QE3 Start	0.22	0.25	0.73	1.81
QE3 Expansion and OT End	0.30	0.15	1.82[32]	0.91

The day of the QE 3 expansion announcement was the very same day when the end of the operation twist was announced. The day of the announcement seems very volatile with many spikes and steep falls when looking at the intraday data however upon closer look we can see that the magnitude of the volatility is very little. Yet the volatility ratio for Window A shows a very high volatility for Fed Days than for comparable normal days in the days following the announcement. Even the volatility ratio for Window B is only slightly lower than 1 which means that the volatility on normal days and Fed Days was very similar in the days preceding the announcement. This is potentially because the Fed used much the same language at the end of the Operation Twist as it did during the initiation and expansion. It hoped that QE 3 "should maintain downward pressure on longer-term interest rates" which served as a stark reminder for investors that even though the Fed has used much of its toolkit, the economy was yet to return to its pre-crisis level[33].

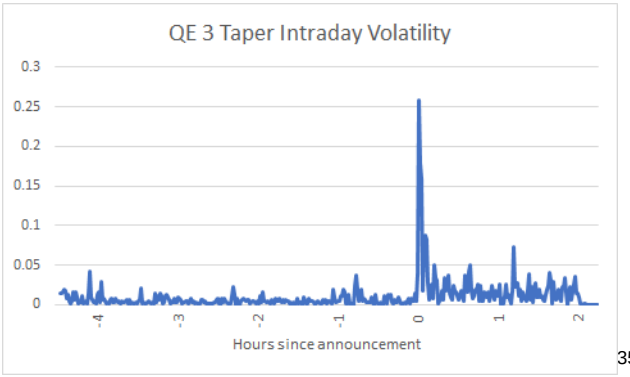
[30] Window A consists of the announcement day and four days following the announcement
[31] Window B includes the announcement day, two days prior, and the two days following the announcement
[32] High volatility ratio above 1 because of Fed's use of same language as before
[33] https://www.federalreserve.gov/newsevents/pressreleases/monetary20121212a.htm



[34]

Figure 4 b

The press release also made note of the external strains to the economy brought on by the spread of the financial crisis to the global market. Lastly, this press release put out specific targets for the unemployment rate, inflation and made note that the labor market must improve substantially to stop additional rounds of purchase of securities. Though overall this shows a positive note that the Fed is willing to go to any lengths to support the economy which accounts for the relatively smaller magnitude of volatility, the prolonged spikes throughout the day and the days following can be attributed to the general feeling of slow and inconsistent recovery (figure 4b.). Investors were also apprehensive that the targets set by the Fed were too ambitious and unsure of the impact these targets would have on the market.



[35]

Figure 4 c

Interestingly, QE3 taper showed nothing of note in the intraday data which is just one spike in the first hour, that quickly dies out (figure 4c.). The magnitude of this spike, however, is the highest in magnitude throughout the entire QE3 round. However, looking at Table 7 below, the volatility ratios for Window A and Window B are almost identical. This burst of volatility in the first hour and almost identical volatility levels prior and post announcement indicates there is no

[34] Volatility on the day of the QE3 Expansion and OT End announcement
[35] Volatility on the day of the QE3 Taper announcement, hour zero is time of announcement

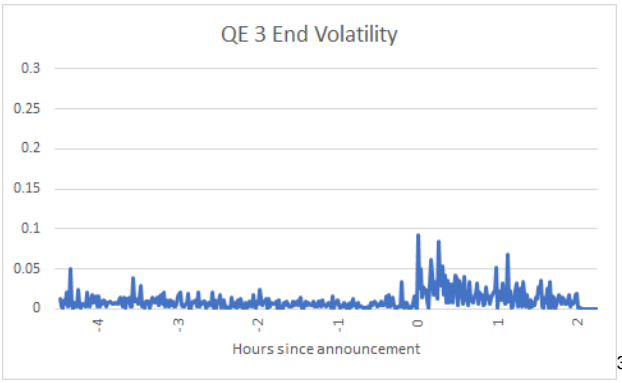
change in uncertainty levels because the QE 3 taper was largely positively received and expected because investors feared prolonged QE and injection of trillions of dollars would create an asset price bubble. This explains why the volatility for Window B i.e. in the day prior is also high because of this fear. The average volatility for window A is actually slightly lower because the announcement had a calming effect.

Table 7: Summary Table for Daily Average Volatility and Volatility Ratio for QE3 Taper and QE3 End

	Fed Days Average		Volatility Ratio	
	Window A[36]	Window B[37]	Window A	Window B
QE3 Taper	0.26	0.27	1.38	1.38
QE3 End	0.19	0.28	0.45	0.83

QE 3 end was of course anticipated after the taper and was a welcome announcement. Since the taper had already indicated to investors that recovery was near we don't see the extremely high magnitude volatility normally generated by an expected announcement (as in QE2) here, however, we do still see that QE3 end announcements generates the largest magnitude of volatility of all the QE end announcements as evidenced in figure 4d. The positive tone of this announcement incentivized market participants to trade as hypothesized by Bomfin (2003) which leads to a boost in short term volatility. The burst of volatility from the positive announcements die out as seen in the low average volatility for Window A in Table 7. The volatility decreases from Window B, so much like the taper this has a calming effect as expected. Following a similar logic, Window B volatility ratio, though below 1, is much higher than the volatility ratio for Window A. Thus, the announcement was clearly anticipated, perceived positively, and eased the market as it represented that the economy was on the path to recovery.

[36] Window A consists of the announcement day and four days following the announcement
[37] Window B includes the announcement day, two days prior, and the two days following the announcement



[38]

Figure 4 d

V. Conclusion

In the wake of the Global Financial Crisis, Quantitative Easing came out as an unconventional monetary policy tool that many Central Banks relied on when all else failed. The paper implemented an event study methodology to explore the question: *Did the nature of different FOMC announcements on Quantitative Easing, positive or negative, expected or surprise, have different impacts on stock market volatility*? Volatility is calculated on two levels, using 1-minute intraday data and daily data, to examine stock market reactions to QE announcements. The intraday data shows that volatility peaks in the hour after the announcement and gradually decreases after. The rate of decrease, any spikes in volatility in the hours after the announcement, and persistence in the days following are determined by the nature and content of the announcement.

It is confirmed that positive announcements lead to bursts of volatility that persist in the very short term on the day of the announcement and rarely the day after the announcement in the case when the announcements are expected. This is seen in a lot of the QE program ending announcements like QE1 end, QE3 taper and end as well as at the start of QE 3. If the positive announcement is unexpected however, as is the case with QE1 start and QE2 end, then volatility persists in the days following the announcement as investors want to take advantage of improved market conditions and are incentivized to trade more.

I am surprised to see that my data contradicts my hypothesis about unexpected announcements generating the highest volatility. The results show that expected announcements generate a higher magnitude of volatility that persists over the following days than unexpected announcements. This can be evidenced by the fact that the highest volatility ratio for Window A belongs to the announcement for the start of QE 2 which came with explicit warning from the Fed. QE 3 expansion was also expected and has a very high volatility ratio for Window A. To a large extent Operation Twist and Expansion also came with warning. The persistence of

[38] Volatility on the day of the QE3 End announcement, hour zero is time of announcement

volatility and increased uncertainty as compared to normal days caused by an expected announcement can be explained by rhetoric the Fed used when making the announcement. In the case of negative wording or projections we see high and persistent volatility for an expected announcement whereas in the case of positive wording for an expected announcement we see small spikes in volatility that do not persist as is the case for QE 3 program start announcement. This shows the crucial role the Fed's communication place in generating market reactions. My data also confirms my hypothesis that the average volatility decreases over the years which signifies that the economy is overall stabilizing and recovering.

Future work in the area of market reaction to QE announcements can look at two other announcements during this time period, Taper Tantrum and the May Scale Back Event. These weren't directly QE program announcements but still elicited major market responses. It could be interesting to see if responses to these announcements confirm the hypothesis about the nature and wording of an announcement presented in this study. This work can also be extended to look at market reaction to Quantitative Easing announcements more recently in the covid-19 recession period.

VI. Appendix

Table 1: FOMC announcement date and times

Event	Date Announced
QE1	Press Release. 25th November 2008, 8:15 a.m. EST
QE1 Expansion	Press Release. 18 March 2009, 2:15 p.m. EST
QE1 Ends	Press Release. 16 March 2010, 2:15 p.m. EST
QE2	Press Release. 3 November 2010, 2:15 p.m. EST
QE2 Ends	Press Release. 22 June 2011, 12:30 p.m. EST
Operation Twist	Press Release. 21 September 2011, 2:15 p.m. EST
Operation Twist Extension	20 June 2012, 12:30 p.m. EST
QE3	13 September 2012, 12:30 p.m. EST
QE3 Expansion and Operation Twist Ends	12 December 2012, 12:30 p.m. EST
QE3 Taper	18 December 2013, 2:00 p.m. EST
QE3 Ends	29 October 2014, 2:00 p.m. EST

Table 2: Daily Volatility calculations for the S&P 500

		S&P 500					
		Window A	Window B	Window A	Window B	Volatility Ratio	Volatility Ratio
		Fed Days	Fed Days	Normal Days	Normal Days	Window A	Window B
QE1	Mean	1.5943	1.5190	1.8348	1.5954	0.8689	0.9521
	Std Dev	1.5177	1.1728	0.8091	0.9805		
QE1 Expansion	Mean	1.2392	0.7716	1.2156	1.0625	1.0194	0.7262
	Std Dev	0.9769	0.4505	1.0716	0.9135		
QE1 Ends	Mean	0.2090	0.1264	0.1786	0.1563	1.1701	0.8084
	Std Dev	0.1187	0.1562	0.2461	0.1666		
QE2	Mean	0.3205	0.3071	0.1458	0.3288	2.1974	0.9342
	Std Dev	0.3003	0.3202	0.1773	0.2571		
QE2 Ends	Mean	0.3745	0.3460	0.3372	0.3249	1.1106	1.0650
	Std Dev	0.1769	0.1926	0.2436	0.2257		
Operation Twist	Mean	0.8859	0.6932	0.7123	0.8604	1.2438	0.8057
	Std Dev	0.5051	0.6151	0.4503	0.4307		
Operation Twist Extension	Mean	0.4534	0.3697	0.3433	0.4290	1.3207	0.8618
	Std Dev	0.3744	0.3736	0.2151	0.3702		

QE3	Mean	0.2234	0.2474	0.3073	0.1365	0.7272	1.8121
	Std Dev	0.2728	0.2561	0.3425	0.1379		
QE3 Expansion and OT Ends	Mean	0.2967	0.1546	0.1626	0.1696	1.8249	0.9119
	Std Dev	0.2105	0.1320	0.1283	0.1281		
QE3 Taper	Mean	0.2616	0.2719	0.1896	0.1976	1.3795	1.3760
	Std Dev	0.2671	0.2654	0.1732	0.1677		
QE3 Ends	Mean	0.1929	0.2834	0.4305	0.3410	0.4481	0.8311
	Std Dev	0.2012	0.2243	0.3050	0.3071		

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