The Effectiveness of the Federal Funds Rate as the U.S. Monetary Policy Tool Before, During and After the Great Recession

Michael S. Miller[1], Jin W. Choi

Abstract:

The effectiveness of the Federal Reserve's policy of quantitative easing via large-scale asset purchase programs has been studied extensively. This paper distinguishes itself by examining the effectiveness of the federal funds rate as the U.S. monetary policy tool before, during and after the Great Recession of 2007-09. The zero lower bound came into play one year into the Great Recession, having dropped 425 basis points from the cycle peak. We begin by evaluating using the Wald test for Granger causality and the Johansen test for cointegration presence whether or not the changes in the federal funds rate affected the term structure of Treasury securities. Given that equity markets are sensitive to changes in interest rates, we next examine the impact of the federal funds rate changes on the level and volatility of the U.S. stock market. Our analysis reveals that the Fed policy of lowering the federal funds rate during the Great Recession was effective, resulting in changes in the Treasury term structure during but not after the Great Recession. Additionally, the Fed's policy actions influenced the stock market and its volatility during the Great Recession only.

Key Words: *Great Recession, Federal Funds Rate, Term Structure, VAR Cointegration*

JEL Classification : *E43, E52*

1. Introduction

The Business Cycle Dating Committee of the National Bureau of Economic Research determined that a recession occurred in the U.S. between December 2007 and June 2009. Given the historic severity of the length, depth and breadth of the decline and subsequent recovery – the worst economic performance since the Great Depression of the 1930s – economists have dubbed this period the Great Recession (GR). Once the severity of this downturn became clear in 2008 U.S. policy makers were quick to use both fiscal and monetary policies to inject confidence and liquidity into the rapidly declining financial system and economy. The Fed's use later that year of not only substantial reductions in the Fed funds target rate but also quantitative easing via the purchase of $1.7 trillion in assets was strong evidence of an expansionary monetary policy of unprecedented magnitude. The $787 billion stimulus package passed in the early days of the Barak Obama administration is but one example of a very expansionary fiscal policy.

While fiscal policy tried to prop up the financial institutions and the economy directly by giving them immediate rescue funding, monetary policy was geared more toward providing lower interest rates and almost unlimited liquidity for financial institutions such as commercial banks, mortgage companies and investment banks. The primary tool used to provide liquidity was known as the large-scale asset purchase (LSAP) program, also called quantitative easing (QE). Rather than a single event, QE was instituted in four phases. The first action, known as QE1, began in December 2008[2]. Unlike normal Fed policy that limits asset purchases to Treasury bills, QE1 involved the targeted purchase of agency mortgage-backed securities (MBSs) and long-term Treasury securities as well. During QE1 the Fed accumulated over $1.7 trillion in mortgages and Treasuries. The next phase, QE2, occurred well after the official trough of the Great Recession of June 2009, lasting between November 2010 and June 2011. During this period, the Fed purchased an additional $600 billion in Treasury securities. The third phase involved a change in the average duration of the Fed's asset holdings known as Operation Twist, beginning in September 2011 and ending in December 2012. The Fed' actions extended the average bond maturity of its asset holdings from short term to long term yet did not in itself add any new monetary base to the economy. Since short-term rates as represented by the target range had hit the zero lower (ZLB) bound nearly three years earlier and could no longer lower rates in general, the Fed had to achieve lower intermediate and long rates by directly injecting liquidity into the markets for those securities. The fourth program, ongoing as of this

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[2] Prior to QE the Fed had changed the composition of its portfolio to provide short-term liquidity to financial firms and markets. This policy action occurred in the late summer of 2008. QE was then announced in November 25, 2008 but instituted in December 2008. Due to the unusually unresponsive economic recovery, the Fed instituted a series of QE programs for over 5 years.

writing, was QE3 which began in September 2012.[3] Initially, a monthly purchase of $40 billion in mortgage-backed securities was planned but the amount gradually increased to $85 billion.[4]

In the early days of the financial turmoil, beginning with mortgage market troubles in August 2007, the Fed responded with a reduction in the FF by 50 basis points in September, 25 basis points in October, and another 25 in December 2007 as seen in Table 1. The first reductions in the FF during the GR were in January 2008 when the Fed, in two moves, lowered the target by a total of 125 basis points. March and April of 2008 combined for another reduction in the FF by 100 basis points, to a 2.00% target. The reason for the actions was not, however, the GR since no one at the time knew the recession had begun. The Federal Open Market Committee's 2008 statements through April of that year speak of a weakened outlook for economic output, but the statements in April, June and August report expanding economic activity.[5] Clearly the drops in the FF that occurred through April 2008 were aimed solely at the financial weakness rather than output. It was not until a 100 basis point drop in the FF over two meetings in October 2008 that the FOMC explicitly recognized a marked slowing of economic activity. The ZLB was achieved in December 2008, when the FOMC statement announced the creation of a target range of 0.0-0.25% rather than a specific rate, based on weak output, labour markets, and credit conditions. The target remains at the ZLB as of this writing, in the third quarter of 2014, an unprecedented low rate for an unprecedented length of time.

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[3] Thornton (2013) and Fawley and Neely (2013) provide a detailed chronology of the Fed QE announcements and FOMC minutes releases.

[4] Tapering of QE3 was first mentioned by Ben Bernanke on June 19, 2013 but was not instituted until January 2014 when a monthly purchase reduction of $10 billion began. As of this writing, the FOMC appears ready to end QE3 in October 2014, assuming no unforeseen crises arising.

[5] To access all of the FOMC's statements, transcripts, and other materials for 2008, go to its website: http://federalreserve.gov/monetarypolicy/fomchistorical2008.htm.

Table 1. Effective Dates of Federal Funds Rate Changes		
Effective Date	When Occurred	Fed Funds Target Rate
June 29, 2006	Not in the Study Period	5.25%
September 18, 2007	Before the Great Recession	4.75 %
October 31, 2007		4.50%
December 11, 2007		4.25%
January 22, 2008	During the Great Recession	3.50%
January 30, 2008		3.00%
March 18, 2008		2.25%
April 30, 2008		2.00%
October 8, 2008		1.50%
October 29, 2008		1.00%
December 16, 2008 (QE1) to the present		Target changed to a Range of 0% – 0.25%

Source: Federal Reserve Bank of New York.
http://www.newyorkfed.org/markets/statistics/dlyrates/fedrate.html

These monetary actions are of great interest to both analysts and policy makers and have been studied in depth. We focus our attention instead on the Federal Reserve's use of federal funds target rate/range (FFR) to influence economic outcomes. In particular, this paper contributes to the literature by evaluating the overall effectiveness of the Fed's federal funds rate policy before, during and after the GR by examining its impact on the term structure of Treasury securities and the stock market.

2. Literature Review

A vast majority of the work on the effect of Fed policy actions during the GR focuses on LSAPs; thus we will set out the state of the literature on the effect of these purchases on the economy as a foundation on which to build our analysis of the effectiveness of the federal funds rate policy during the overlapping timeframe.

The impact of the LSAP program on major macroeconomic variables has been studied extensively using a macroeconomic modelling approach. For example Chen, Curida and Ferrero (2012) used a dynamic stochastic general equilibrium (DSGE) model to show that GDP grew by less than a third of a percentage point and inflation did not change after QE2. Baumeister and Benati (2010) used a Bayesian time-varying parameter structural VAR model, concluding that unconventional monetary policy actions such as the LSAP averted the risk of deflation and a collapse in output in both the U.S. and the U.K. Mora (2014) showed that the LSAP lowered consumer loan rates such as mortgage refinancing and auto loans but the strength of the pass-through to banks was weaker than the previous periods. Ng and Wright (2013), while surveying the business cycle's facts, showed through a time-varying VAR simulation that a ZLB can induce a case of non-linearity in business cycle analysis. They concluded, however, that the length of time was too short to render a meaningful interpretation.

There is as well a large volume of studies utilizing an event-study approach to examine the impact of the LSAP on the interest rates. For example, Chen, Curida and Ferrero (2012) provided a summary[6] of various event-study results that are done by Hamilton and Wu (2010), D'Amico and King (2010), Gagnon et al. (2011a), Neely (2012), Swanson (2011), etc. Their overall, and unanimous, conclusion was that the LSAP program did lower the 10-year Treasury yield by a statistically significant amount ranging between -13 to -107 basis points.

In addition to Treasury securities, Krishnamurthy and Vissing-Jorgensen (2011) evaluated the impact of the LSAP on the interest rates of mortgage-backed securities (MBSs) and corporate securities during QE1 and QE2. Their analysis showed that the Fed's purchase of MBSs and corporate securities during QE1 did lower their respective yields. However, during QE2 when Treasury securities were purchased by the Fed, Treasury yields fell more than the yields on MBSs and corporate securities. Swanson (2011) examined the cumulative effects of six Fed announcements during the Operation Twist period and concluded that they decreased long-term agency and corporate bond yields but by a smaller amount than Treasury yields. Additional studies done by Swanson (2013) and Swanson and Williams (2013) showed the same conclusion that the news of QE1 and QE2 affected the Treasury securities term structure by lowering yields on Treasury securities with maturity greater than a year. Nellis (2013) found that there was a stronger and more effective announcement impact in lowering long-term interest rates during QE1 than during QE2 and QE3. Foerster and Cao (2013), on the other hand, argued that expectations of upcoming LSAP announcements have more important impact on the interest rates than the actual announcements.

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[6] Kozicki, Santor, and Suchanek (2011) and Foerster and Cao (2013) also provide a good summary of research results on this topic.

There are additional studies that employed methodologies other than the macroeconomic modelling and event-study approaches to examine the impact of the LSAP program on interest rates. For example, Kozicki, Santor, and Suchanek (2011) and Stroebel and Taylor (2009) employed time series data to examine the impact of the LSAPs on interest rate spreads. While the former found the Fed's purchases of mortgage-backed securities decreased long-term interest rates, the latter found insignificant evidence of that when the option-adjusted spread was examined. On the other hand, using an affine term structure with the ZLB, Hamilton and Wu (2012) concluded that a maturity swap of short-term Treasuries for long-term Treasuries could result in the reduction of the 10-year Treasury rate by 13 basis points. In summary, these various types of studies on the LSAP program show that it had an appreciable effect on long-term interest rates and spreads.

3. Data and Methodologies

The Fed has used the FFR as its primary monetary policy tool for over 5 decades, settling on the zero lower bound as its ultimate weapon against the worst economic crisis in eighty years. We propose to study what role the policy played during the time periods surrounding the Great Recession. We investigate the following regarding this aspect of FFR actions: did movements in the target affect the term structure of Treasury securities? Did the movements in the target impact the stock market and its volatility as well? And lastly, what are the policy implications of the FF as a monetary policy tool, post-GR?

3.1 Time Periods of Study and Data

We use the St. Louis Federal Reserve Bank's weekly (Wednesday) data on the FFTR, all interest rates of Treasury securities, S&P 500 index and the Chicago Board Options Exchange's VIX index by defining the start of the Great Recession as the first Wednesday of January 2008 that ends on the last Wednesday of June 2009, a total of 18 months[7]. As shown in Table 2, we then define the pre-GR period as the 18 months preceding the GR from the first Wednesday of July 2006 to the last Wednesday of December 2007. Similarly, the post-GR period is defined as the 18

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[7] Given that the National Bureau of Economic Research announces a recession period by the month and quarter of turning points, the Federal Reserve Bank of St. Louis suggests and explains 3 ways to define the daily start and end of a recession. The first way is to use the midpoint method of picking the 15th day of the month; the second way is the trough method that uses the first day of the month; and the third way is to use the peak method of picking the first day of the following month. We use the peak method in this paper because it reflects a peak to a trough better. Also, see https://research.stlouisfed.org/fred2/data/USRECD.txt

months from the first Wednesday of July 2009 and the last Wednesday of December 2010.

Table 2. The Study Periods and Number of Weeks in Each Period

	Start Date	End Date	Number of Weeks
Pre Great Recession (Pre GR)	July 5, 2006	December 26, 2007	78
Great Recession (GR)	January 2, 2008	June 24, 2009	78
Post Great Recession (Post GR)	July 1, 2009	December 29, 2010	79

The FFR was changed 3 times during the pre-GR period, 7 times during the GR, and none during the post-GR period as shown in Table 1. While the change during the pre-GR period was a modest 100 basis points, the Federal Reserve was quite aggressive in lowering the rate by 425 basis points, reaching into the zero lower bound, during the GR period. For this analysis we collected the federal funds rate (FFR), U.S. Treasury securities with a maturity of 1 month (DGS1M), 3 months (DGS3M), 6 months (DGS6M), 1 year (DGS1), 2 years (DGS2), 3 years (DGS3), 5 years (DGS5), 7 years (DGS7), 10 years (DGS10), 20 years (DGS20), and 30 years (DGS30) along with the logarithmic value of S&P 500 stock index (SP500) and VIX index for the three sub-periods. Table 3 presents the descriptive statistics of the FFR and all sub-components of the Treasury term structure. The level of interest rates during each of the 3 periods clearly shows the downward trend, reflecting fully the intended goal of the Federal Reserve's policy tool during these periods. However, their volatility as measured by either the standard deviation or the range indicates extraordinary situation that was taking place during the GR. The FFR, being a policy variable, should show smaller volatility in normal times than other short-term interest rates that are determined by the market force. This observation was borne out during the pre- and post-GR periods as shown in the second and third columns of Table 3. For example, the range of 1.09% for FFR is smaller than that of 2.58% for DGS1M during the pre-GR period. Likewise, the range of 0.13% for FFR is smaller than that of 0.16% for DGS1M during the post-GR period.   However, during the GR, the FFR range of 4.14% is higher than the DGS1M range of 3.26% and those of all other interest rates of the Treasury term structure. This indicates in part that the Treasury market responded more calmly to the Federal Reserve's policy actions   during   the   GR   than   the   pre-   or   post-GR   periods.

Table 3. Descriptive Statistics of Federal Funds Rate and Each Member Rate in Treasury Term Structure (in %)

Pre-GR	FFR	DGS1M	DGS3M	DGS6M	DGS1	DGS2	DGS3	DGS5	DGS7	DGS10	DGS20	DGS30
Mean	5.10	4.61	4.67	4.80	4.71	4.53	4.49	4.54	4.59	4.68	4.93	4.85
Std. Dev.	0.28	0.66	0.63	0.56	0.55	0.54	0.51	0.41	0.35	0.27	0.21	0.20
Range	1.09	2.58	2.23	2.05	2.09	2.24	2.18	1.81	1.57	1.27	0.96	0.9
Minimum	4.21	2.66	2.95	3.25	3.17	2.96	2.99	3.33	3.58	3.92	4.4	4.36
Maximum	5.3	5.24	5.18	5.3	5.26	5.2	5.17	5.14	5.15	5.19	5.36	5.26
Count	78	78	78	78	78	78	78	78	78	78	78	78
GR	FFR	DGS1M	DGS3M	DGS6M	DGS1	DGS2	DGS3	DGS5	DGS7	DGS10	DGS20	DGS30
Mean	1.38	0.93	1.02	1.26	1.43	1.68	1.97	2.54	2.97	3.46	4.22	4.12
Std. Dev.	1.20	0.92	0.89	0.85	0.81	0.71	0.65	0.62	0.56	0.54	0.45	0.54
Range	4.14	3.26	3.23	3.21	2.95	2.33	2.3	2.25	2.18	2.08	1.92	2.18
Minimum	0.1	0.01	0.01	0.21	0.36	0.74	1	1.42	1.72	2.15	2.91	2.59
Maximum	4.24	3.27	3.24	3.42	3.31	3.07	3.3	3.67	3.9	4.23	4.83	4.77
Count	78	78	78	78	78	78	78	78	78	78	78	78
Post-GR	FFR	DGS1M	DGS3M	DGS6M	DGS1	DGS2	DGS3	DGS5	DGS7	DGS10	DGS20	DGS30
Mean	0.16	0.10	0.13	0.20	0.35	0.79	1.23	2.09	2.77	3.31	4.11	4.28
Std. Dev.	0.03	0.05	0.04	0.04	0.08	0.23	0.35	0.46	0.47	0.41	0.36	0.30
Range	0.13	0.16	0.15	0.19	0.29	0.88	1.28	1.61	1.63	1.52	1.33	1.2
Minimum	0.08	0.01	0.04	0.14	0.22	0.35	0.51	1.13	1.76	2.43	3.31	3.6
Maximum	0.21	0.17	0.19	0.33	0.51	1.23	1.79	2.74	3.39	3.95	4.64	4.8
Count	79	79	79	79	79	79	79	79	79	79	79	79

3.2   Methodologies

We first utilize the Granger causality model and the vector autoregressive model to examine the impact of the federal funds rate on the Treasury term structure. Then we estimate an ordinary least squares regression model to examine the impact of the Treasury term structure on the S&P 500 stock index and VIX stock market volatility index.

3.2.1   Causality and Cointegration of the Federal Funds Rate and Term Structure

In order to examine the impact of the federal funds rate changes on the Treasury term structure, we first employ the Granger causality test and then, the cointegration test. The Granger causality test can show if the change in FFR has Granger-caused the member interest rates of the Treasury term structure. The FFR, being the policy variable, the casual relationship can run only uni-directionally from FFR changes to the term structure. Modifying the model used by Carpenter et al. (2013), we propose to use Equation (1) to check the presence of Granger causality:

$$R_t = \alpha + \sum_{i=1}^{n} \beta_i FFR_{t-i} + \sum_{j=1}^{m} \delta_j R_{t-j} + \varepsilon_t \qquad (1)$$

where R_t is the member interest rates of the Treasury term structure; FFR_t is the federal funds rate; α, β_i and δ_j are regression coefficients; and ε_t is the error term. We use $n = m = 5$ due to the nature of the weekly data used[8]. The Wald test statistic is calculated via Stata to test if all β_i's are simultaneously equal to zero. If this null hypothesis is rejected, then FFR has Granger-caused the member interest rate of the Treasury term structure.

While the Wald test can shed insight into the unidirectional nature of FFR with term structure, a more robust examination of their long-run relationships can be accomplished by employing the Johansen test. Johansen (1988 and 1996, p.5) shows that when the variables have an I(1) process of nonstationarity with stationary differences, it is possible to reformulate them into levels and differences to examine the possibility of cointegration between or among variables. Following the vector autoregressive model suggested by Johansen (2004, p7), we modify it and use the

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[8] We choose $n = m = 5$ based on the Hannan-Quinn information criterion (HQIC), Schwarz Bayesian information criterion (SBIC), and Akaike information criterion (AIC) and the fact that some months have 5 weeks.

following equation to examine the degree of cointegration between the FFR and the member interest rate of the term structure[9]:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \varepsilon_t \tag{2}$$

where X_t is an (n x 1) vector of interest rates; ΔX_t is the first differenced value of X_t; D_t is a vector of the deterministic terms; Π, Γ_i, and Φ are the parameter matrices; and ε_t is the error term that is independently and identically distributed with mean zero and variance matrix, Ω.

While Seddighi (2012, p333) shows the decision criteria for detecting cointegration that are based on two similar likelihood ratio statistics of the trace and maximum Eigenvalues, we choose to use only the trace statistics shown below:

$$\lambda_{\text{trace}}(\text{r}) = -n \sum_{j=r+1}^{m} \ln(1 - \mu_j) \tag{3}$$

where r is the rank of the Π matrix; n is the sample size; m is the maximum number of characteristic roots; and μ_j is the value of the j-th characteristic root. The hypotheses are tested in the following sequence:

First: H_o: r = 0   vs. H_a: r $\geq$ 1

Second: H_o: r $\leq$ 1   vs. H_a: r $\geq$ 2

q-th: H_o: r $\leq$ q -1   vs. H_a: r = q   for $3 \leq q \leq m$

If $\lambda_{\text{trace}}(\text{r})$ is greater than the critical value provided in Johansen (1988), then we reject the null hypothesis and test the next hypothesis in the sequence until the first non-significant result is obtained. If we fail to reject the first null hypothesis of r = 0, for example, we can conclude that the variables are not cointegrated. Otherwise, we may conclude that they are cointegrated.

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[9] Thalassinos and Politis (2011 and 2012) also adopt a similar model to examine the cointegration in international stock markets and oil prices and US dollar.

3.2.2   Impact of the Federal Funds Rate and Term Structure on Stock Market

The change in the federal funds rate affects all interest rates, including the Treasury term structure. As the interest rates change, their impact should be felt on the stock market because stocks and bonds can be either substitutes or complements for an investment purpose. For example, Gagnon et al. (2011b) describe the role of term premium in investors' decision making by referring to Tobin's portfolio-balance effect. That is, holding default risk unchanged, investors will rebalance their portfolio mix based on term risk. As investors reshuffle their portfolio mix in debt securities, there will be a spillover effect into the stock market. Therefore, the effectiveness of the federal funds rate as a monetary policy tool can be examined via the stock market. We propose to compare the reaction of the S&P500 index and VIX volatility index[10] to the interest rate changes afforded by the federal funds rate changes during the three study periods.   The following regression models are estimated where the dependent variables are either the logarithmic value of S&P500 stock index (SP500) or stock volatility index (VIX) while the independent variables are the federal funds rate (FFR) or the member interest rate (R) of the Treasury term structure.

$$SP500_t = \alpha_1 + \beta_1 \cdot FFR_t + \delta_1 \cdot R_t + \varepsilon_t \tag{4}$$

$$VIX_t = \alpha_2 + \beta_2 \cdot FFR_t + \delta_2 \cdot R_t + v_t \tag{5}$$

where α_i, β_i and δ_i are the regression coefficients and ε_t and v_t are the standard residual terms that are independently and identically distributed with mean zero and fixed variance. In order to eliminate the possible first-order serial autocorrelation often present in this type of estimation, we use the method proposed by Newey and West (1987).

If the federal funds rate exerts equal influence on the stock market, the sign and magnitude of the regression coefficients should be almost the same in all three periods. However, if they are markedly different during the three periods, we may be able to detect the different influence and role the federal funds rate played in each period.

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[10] VIX is the ticker symbol for the Chicago Board Options Exchange volatility index which is also known as fear index or investor fear gauge. It is calculated from the implied volatility of S&P500 stock index options and is believed to provide forward-looking expectations into the stock market.

4.   Results

We provide here below the estimation results for all the equations presented above and the interpretation of their results.

4.1   The Wald Test for Granger Causality

Table 4 shows the Wald F-statistics and the p-value obtained from estimating Equation (1)[11]. Given the p-value of 0 for all the interest rates in the Treasury term structure during the pre-GR period, the federal funds rate has Granger-caused the term structure. We also find a very similar result during the GR. Except the 1-year and 3-year maturities, all other interest rates show a p-value of less than 0.05, indicating significance at the 5% significance level. Once again, during the GR, the federal funds rate has affected the term structure by having a Granger-causing relationship.   However, an opposite case is found during the post-GR period where no member of the term structure is significant at the 5% or even at 10% significance level. Because no Granger-causality is found during this period, it is judged that the federal funds rate had no influence on the term structure. This indicates that the zero lower bound via the quantitative easing was ineffective and moribund in stimulating other interest rates during the post-GR period.

Table 4. Wald F-Statistics for Granger Causality Tests of Federal Funds Rates on Treasury Term Structure

Maturity	Pre-GR	GR	Post-GR
1 year	18.4	4.54	3.58
p-value	0	0.47	0.61
2 years	31.03	12.74	7.02
p-value	0	0.03	0.22
3 years	38.17	9.69	5.89
p-value	0	0.08	0.32
5 years	41.41	16.67	6.65
p-value	0	0.01	0.25
7 years	38.51	16.22	6.15
p-value	0	0.01	0.29
10 years	34.95	18.75	6.52

[11] We eliminate from estimation the short-term interest rates with a maturity less than 1 year due to their high correlation with the federal funds rate.

p-value	0	0	0.26
20 years	30.37	16.27	7.12
p-value	0	0.01	0.21
30 years	26.28	11.5	6.31
p-value	0	0.04	0.28

4.2   The Johansen Test for Cointegration

Table 5 shows the rank of the cointegration vector and the trace statistics for the Treasury term structure, based on Equation (2). We find that there is cointegration of rank 1 or higher between the federal funds rate and each member of the Treasury term structure during the pre-GR period. However, for the post-GR period, none, except the 1-year maturity, shows cointegration. Therefore, the federal funds rate as a monetary policy tool during the pre-GR period has influenced the term structure but not so during the post-GR period. This finding supports the results obtained by the Wald test for Granger causality. During the GR, however, we find a different result. During the GR, no cointegration between the federal funds rate and the term structure is found via the Johansen test. In fact, there is a very strong statistical support at the 5% significance level that all save the 20-year maturity show a zero cointegration. This finding is in conflict with that of the Wald test. However, given that the zero lower bound came into effect in the twelfth month[12] of the GR, it seems that the Wald test for Granger causality weighed more on the first eleven months of the GR in analyzing the role of the federal funds rate as a monetary policy tool whereas the Johansen test for cointegration weighed more on last 7 months of the GR when the federal funds rate was near zero. Consequently, the Wald test shows the federal funds rate affecting the term structure during the GR but not so according to the Johansen test[13].

Table 5. Johansen Tests of Cointegration of Federal Funds Rates with Treasury Term Structure

Maturity		Pre-GR	GR	Post-GR
1 year	Coint Vector	1	0	1
	Trace Stat	3.60*	11.49*	3.96
2 years	Coint Vector	1	0	0
	Trace Stat	3.94	9.05*	12.98*

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[12] Given that the Great Recession per our study period began in January 2008 and ended in June 2009, the start of the ZLB in December 2008 coincides with the twelfth month in the 18 month-long Great Recession.

[13] This is an interesting but debatable point that needs further examination at another time.

3 years	Coint Vector	1	0	0
	Trace Stat	5.51	8.98*	13.00*
5 years	Coint Vector	1	0	0
	Trace Stat	6.25	9.94*	11.27*
7 years	Coint Vector	1	0	0
	Trace Stat	7.26	9.93*	11.17*
10 years	Coint Vector	1	0	0
	Trace Stat	8.54	14.15*	9.74*
20 years	Coint Vector	1	1	0
	Trace Stat	9.41	5.76	9.68*
30 years	Coint Vector	1	0	0
	Trace Stat	9.33	13.20*	9.19*

* indicates significance at the 5% significance level.

4.3.   Impact on the Stock Index

As Rigobon and Sack (2004) find that increases in the short-term interest rate have a negative impact on stock prices, interest rates do affect stock price. We estimate Equation (4) to examine the impact of the federal funds rate and each interest rate in the term structure on the logarithmic values of S&P 500 stock index. Because of this focus, we report in Table 6 only the regression coefficients of the federal funds rate, β_1, and term structure, δ_1, and omit the intercept term which captures the fixed effect.[14]

If the federal funds rate and the term structure play the equal and neutral role in the stock market, then all the coefficients should exhibit similar sign and magnitude during each of the three study periods.   However, the estimated results shown in Table 6 do not support this intuition. The pre-GR and post-GR periods show that neither the federal funds rate nor the term structure has affected the stock market significantly except when the federal funds rates are combined with the longer term interest rates of 10 years or more. The general tendency of statistically insignificant and negative coefficients associated with the federal funds rate and term structure observed during these two periods' weakly supports Rigobon and Sack (2004) who concluded a negative relationship exists between the interest rates and S&P 500 index. This weak negative tendency is completely reversed during the GR. All the

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[14] We do not report the values of this intercept term because we wish to focus on the impact of FFR and term structure on the stock market. However, all intercept terms show statistical significance at the 5% significance level or better. Upon request, however, the full regression information can be disclosed.

coefficients are statistically significant and positive, indicating that the decrease in the federal funds rate and the term structure observed during the GR did decrease the stock market. Of course, we recognize the endogeneity of interest rates and stock prices reacting to the multitude of variables, especially during the rapidly declining U.S. financial and economic conditions such as the GR that our study period covers. However, this reversal of a normal relationship found only during the GR indicates the uniqueness of the GR events associated with the ongoing financial crisis. In fact, the noteworthy positive and statistically significant coefficients observed during the GR may indicate a breakdown of a normal negative relationship between interest rates and stock prices[15]. If so, the federal funds rate as a monetary policy tool did influence the stock market in an unconventional way during the GR. It may have signalled and exacerbated the emerging urgency and thus, intensified the decline of the stock market.[16]

Table 6. The Impact of Federal Funds Rate and Treasury Term Structure on Logarithmic Values of S&P 500 Stock Index

Maturity	Pre-GR	GR	Post-GR
FFR	0.113	0.0993***	0.385
t-value	(1.71)	(3.96)	(1.35)
1 year	-0.101*	0.114***	-0.390*
t-value	(-2.60)	(3.98)	(-2.42)
FFR	0.0284	0.0980***	0.285
t-value	(0.48)	(5.06)	(0.86)
2 years	-0.057	0.145***	-0.109
t-value	(-1.53)	(5.91)	(-1.99)
FFR	-0.0097	0.113***	0.281
t-value	(-0.16)	(6.52)	(0.8)
3 years	-0.0376	0.137***	-0.066
t-value	(-0.94)	(5.85)	(-1.77)
FFR	-0.0446	0.119***	0.34
t-value	(-0.87)	(7.5)	(0.96)
5 years	-0.0215	0.133***	-0.039

[15] A negative relationship is deemed normal if a decreased yield in bond market forces investors to rebalance their portfolio mix by buying into the stock market, driving the stock price up.

[16] There is an alternative interpretation: the Fed was following events rather than causing them; the market was in free-fall in 2008-09 and the Fed responded to the financial panic with policy actions. Eventually, of course, the market did right itself and begin a long climb upward.

t-value	(-0.47)	(5.46)	(-1.40)
FFR	-0.0586	0.134***	0.394
t-value	(-1.31)	(8.22)	(1.12)
7 years	-0.0126	0.114***	-0.03
t-value	(-0.25)	(4.2)	(-1.10)
FFR	-0.0691*	0.136***	0.590
t-value	(-2.04)	(8.21)	(1.93)
10 years	-0.003	0.113***	-0.004
t-value	(-0.05)	(3.49)	(-0.15)
FFR	-0.0740**	0.142***	0.692*
t-value	(-3.04)	(8.99)	(2.26)
20 years	0.007	0.119**	0.014
t-value	(0.12)	(2.97)	(0.15)
FFR	-0.0773**	0.137***	0.835***
t-value	(-3.61)	(8.6)	(3.51)
30 years	0.018	0.110**	0.063*
t-value	(0.3)	(2.98)	(2.52)

*for p<0.05; ** for p<0.01; and *** for p<0.001.

4.4.   Impact on Stock Volatility

When the federal funds rate affects the term structure which in turn affects the stock price, there is little doubt that these related events will affect the stock market volatility. To examine the impact of the federal funds rate and the term structure on stock market volatility, we estimate Equation (5), using the Chicago Board Options Exchange's VIX index as a dependent variable and the federal funds rate and each member of the term structure as independent variables. As was the case with Table 6, Table 7 shows the estimation results for only the regression coefficients of the federal funds rate, β_2, and term structure, δ_2, and does not report the intercept term[17].

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[17] All intercept terms show statistical significance at the 5% significance level or better.

Table 7. The Impact of Federal Funds Rate and Treasury Term Structure on Stock Volatility, VIX

Maturity	Pre-GR	GR	Post-GR
FFR	2.45	-6.205	11.11
t-value	(0.39)	(-1.98)	(0.54)
1 year	-8.241**	-2.218	5.457
t-value	(-2.66)	(-0.51)	(0.7)
FFR	-3.026	-3.216	11.92
t-value	(-0.63)	(-1.96)	(0.49)
2 years	-5.479*	-8.987***	1.336
t-value	(-2.30)	(-3.99)	(0.42)
FFR	-6.820	-3.292*	13.16
t-value	(-1.54)	(-2.43)	(0.51)
3 years	-3.540	-10.54***	1.034
t-value	(-1.57)	(-5.34)	(0.46)
FFR	-10.11**	-4.535*	9.61
t-value	(-2.79)	(-2.51)	(0.36)
5 years	-2.02	-8.204**	0.243
t-value	(-0.91)	(-2.65)	(0.14)
FFR	-11.76***	-5.077**	6.411
t-value	(-3.70)	(-2.97)	(0.24)
7 years	-0.845	-8.180*	-0.199
t-value	(-0.38)	(-2.48)	(-0.12)
FFR	-13.36***	-6.239**	-1.552
t-value	(-4.96)	(-2.90)	(-0.06)
10 years	1.135	-4.589	-1.579
t-value	(0.53)	(-0.99)	(-0.85)
FFR	-14.09***	-5.954**	-11.77
t-value	(-5.68)	(-3.25)	(-0.51)
20 years	3.608	-7.413	-3.495
t-value	(1.46)	(-1.52)	(-1.85)
FFR	-14.18***	-4.683**	-14.29
t-value	(-5.95)	(-3.15)	(-0.76)
30 years	4.438	-10.25**	-6.316**
t-value	(1.87)	(-2.94)	(-3.39)

*for $p < 0.05$; ** for $p < 0.01$; and *** for $p < 0.001$

Table 7 reveals a general observation that there is a negative relationship between interest rates and VIX. This is particularly so for the pre-GR and GR periods when the federal funds rate and the term structure have a statistically significant and negative relationship with VIX. This indicates that as the federal funds rate and term structure decrease, the stock market volatility increases. When combined with the longer maturity of the term structure, the federal funds rate plays a more dominant role in impacting VIX than the term structure during the pre-GR period. In fact, the interest rates with a maturity of 5 years or more show a statistically significant impact on VIX. On the other hand, during the post-GR period, we observe no meaningful relationship between interest rates and VIX given that no coefficients are significant except the 30-year maturity. This indicates that the federal funds rate affected the stock market and its volatility during the pre-GR period but had no impact during the post-GR period. However, we find a much stronger role is played by all components of the term structure and the federal funds rate during the GR where many coefficients associated with the federal funds rate and term structure are statistically significant and negative. The absolute magnitude of the coefficients with the term structure is larger than that with the federal funds rate, except the 1-year and 10-year maturities. This observation also indicates that the impact of the term structure on VIX is larger than that of the federal funds rate during the GR. The stock market volatility reacted to the Treasury term structure more than to the federal funds rate. The post-GR period, however, shows a relative calm in that the stock market volatility is not affected by the interest rates except the 30-year maturity.

Because the three periods under our study represent one of the most challenging economic and financial times in the U.S. history, the federal funds rate may not have played its normal role as a monetary policy tool. While using the pre-GR period as the norm, we do not find any unusual pattern of behaviour for the post-GR period. However, the dominant role played by both the federal funds rate and the member rates of the term structure during the GR is noteworthy and may further indicate that all segments of the term structure can play a role in determining the stock market volatility, not just the main monetary policy tool, and the federal funds rate.

5. Conclusion

The federal funds rate showed some degree of Granger-causality with the Treasury term structure during the pre-GR and GR periods. Therefore, the federal funds rate as a monetary policy tool was effective in affecting other interest rates in the term structure during these two periods. While the same conclusion is possible for the pre-GR period under the cointegration examination, the Johansen test does not support the existence of cointegration during the GR period. The post-GR period

shows no Granger-causality and no cointegration between the federal funds rate and the components of the Treasury term structure. Therefore, the federal funds rate has affected the term structure during the pre-GR period, some during the GR period, and none at all during the post-GR period.

The impact of the federal funds rate on the stock index during the pre-GR and post-GR periods is negative but not supported with the statistical significance. This observation, however, shows that the decrease in the federal funds rate and thus, the downward shift in the term structure, generally caused the stock market to increase, due possibly to the investors' portfolio rebalancing effort. As the investors move out of the lower-yielding debt instruments and buy into the stock market, the portfolio rebalancing effect will create a negative relationship between the interest rate and the stock price. However, this negative relationship has changed into a positive relationship during the GR period. All the coefficients show statistically significant and positive magnitude, indicating that the decrease in the federal funds rate and the term structure decreased the stock market during the GR. Consequently, this noteworthy positive and statistically significant coefficients observed during the GR may indicate a breakdown of a normal negative relationship between interest rates and stock prices. If so, the federal funds rate as a monetary policy tool did not work via the portfolio rebalancing channel during the GR. It may have signalled and exacerbated the emerging urgency and thus, intensified the decline of the stock market.

When the impact of the federal funds rate on the stock market volatility is evaluated, we find a generally negative relationship between interest rates and VIX. This is particularly so for the pre-GR and GR periods, indicating that as the federal funds rate and term structure decreased, the stock market volatility increased. When combined with the longer maturity of the term structure, the federal funds rate played a more dominant role in impacting VIX than the term structure during the pre-GR period. However, the GR period shows a slightly different story in that the interest rates in the term structure have played a more dominant negative role than the federal funds rate. In fact, the absolute magnitude of the coefficients with the term structure is larger than that with the federal funds rate, except the 1-year and 10-year maturities. This observation also indicates that the impact of the term structure on VIX is larger than that of the federal funds rate during the GR. The post-GR period shows a relative calm in that the stock market volatility is not affected by the interest rates except the 20-year and 30-year maturities.

Because the three periods under our study represent one of the most challenging economic and financial times in the U.S. history, the federal funds rate may have not played its normal role as a monetary policy tool. While using the pre-GR period as the norm, we do not find any unusual pattern of behaviour for the post-GR period.

However, the dominant role played by the component rates of the term structure via the federal funds rate during the GR is noteworthy and may further indicate that all segments of the term structure can play a role in determining the stock price and stock market volatility, not just the federal funds rate. The main policy implication of this paper is that even in economically challenging periods such as deep recession and financial crisis, the federal funds rate impacts the Treasury term structure which in turn influences stock price and its volatility, as long as it does not reach into the zero lower bound.

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