How Much Does the Fed Care About Stock Prices?

Alexander Kurov*, Eric Olson, and Gulnara Zaynutdinova

First Draft: February 2016
This Draft: August 2018

Abstract

We use a predictable change in the intraday volatility of index futures to identify the effect of stock returns on monetary policy. This identification approach relies on a weaker set of assumptions than required under identification through heteroskedasticity based on lower frequency data. Our identification approach also allows examining time variation in the reaction of monetary policy to the stock market. The results show a sharp increase in the response of monetary policy expectations to stock returns during recessions and bear markets. This finding is consistent with the existence of the so-called "Fed put."

JEL classification: E44; E52; E58; G14; G18

Keywords: Monetary policy, Stock returns, Intraday data, Futures, Identification, Heteroskedasticity

---

*Corresponding author. Department of Finance, College of Business and Economics, West Virginia University, P.O. Box 6025, Morgantown, WV 26506, E-mail: alkurov@mail.wvu.edu.

We thank Arabinda Basistha, Alex Hsu, Jun Ma, Harry Turtle, Mark Wohar, Marketa Wolfe and participants at the 2017 Financial Management Association conference for helpful comments and suggestions. Errors or omissions are our responsibility.

Alexander Kurov is a professor of finance in the Department of Finance, West Virginia University, Morgantown, West Virginia.

Eric Olson is an associate professor of economics in the Department of Economics, West Virginia University, Morgantown, West Virginia.

Gulnara Zaynutdinova is an assistant professor of finance in the Department of Finance, West Virginia University, Morgantown, West Virginia.

> "Let me be clear, there is no Fed equity market put. … We do not care about the level of equity prices, or bond yields or credit spreads per se. Instead, we focus on how financial market conditions influence the transmission of monetary policy to the real economy."
>
> William C. Dudley, President and CEO of the Federal Reserve Bank of New York, Remarks at Baruch College, December 1, 2014

> "Fed officials can confidently say what Dudley said when equities are at record highs. I would take them more seriously if they say things like this in the midst of a 10 percent sell-off in equities."
>
> Hedge fund manager Stephen Jen of SLJ Macro Partners, December 2014
> Quoted at http://blogs.reuters.com/james-saft

> "Global stock-market turmoil has weakened the case for raising interest rates in September, Federal Reserve Bank of New York President William C. Dudley said. … "From my perspective, at this moment, the decision to begin the normalization process at the September FOMC meeting seems less compelling to me than it was a few weeks ago," Dudley told a news conference Wednesday at the New York Fed."[1]
>
> Bloomberg, August 26, 2015

1. Introduction

Many investors believe that the Federal Reserve will rescue financial markets in periods of market stress. The Fed's pattern of reacting to market declines by easing monetary policy has been labeled the "Fed put," often named after the current Fed chairperson, such as "Greenspan put" or, more recently, the "Bernanke put." However, bear markets often coincide with recessions and the "Fed put" could be coincidental in that actual Federal Reserve policy is aimed at stabilizing employment and inflation rather than targeting financial markets (e.g., Poole, 2008). Cieslak and Vissing-Jorgensen (2017) argue that the Fed's reaction to the stock market may be justified if the equity market downturn predicts falling consumption or lower future investment.[2] Understanding the link between monetary policy and the stock market is obviously

[1] The news conference at which Mr. Dudley made the quoted remarks was held after the S&P 500 index fell by about 11 percent in five trading days. In the hours following his remarks, the S&P 500 increased by about 3 percent.

[2] For example, when the Federal Open Market Committee (FOMC) held an unscheduled conference call on January 21, 2008, Fed Chairman Ben Bernanke said in his initial remarks: "... the S&P 500 was off about 60 points today, close to 5 percent. That makes the cumulative decline in the S&P 500 since our last FOMC meeting 16½ percent. Obviously, it is not our job to target stock values or to protect stock investors, but I think that this is a symptom of both sharply mounting concerns about the economy and increasing problems in credit markets. On the economy, the data and the information that we can glean from financial markets reflect a growing belief that the United States is in for a deep and protracted recession." (Transcript of January 21, 2008 conference call, page 6.)

important for investors. It is also important for monetary policy makers because of the macroeconomic consequences of wealth effects that result from large changes in asset prices. While the literature analyzing the effect of monetary policy on stock prices is large,[3] the feedback from stock returns to monetary policy is not robustly understood.

Stock returns typically respond to changes in interest rates. Furthermore, stock returns and interest rates are simultaneously affected by macroeconomic news. This simultaneity makes it difficult to estimate the effect of the stock market on monetary policy. Rigobon and Sack (2003) use identification through heteroscedasticity to estimate the reaction of monetary policy to the stock market by using shifts in volatility regimes to identify the slope of the policy reaction function. They use daily stock returns and interest rates from 1985 to 1999 and find a statistically significant response of policy to stock returns. However, Lütkepohl (2013) highlights that identification through heteroskedasticity depends upon the volatility regimes being known, which is usually not the case in practice.

Our work builds upon Rigobon and Sack (2003) in that we use identification through heteroskedasticity to estimate the response of monetary policy to the stock market. In contrast to their approach, we use intraday data and exploit the recurring upward shift in volatility of index futures returns at the stock market opening. The main benefit of our approach is that the volatility shift occurs every trading day at the same time and is caused by the stock market opening rather than by endogenous economic fluctuations. This approach allows us to identify the reaction of monetary policy to stock returns under a weaker set of assumptions than required by the identification approach of Rigobon and Sack (2003). Our approach also allows analyzing time variation in the response of monetary policy to stock returns.

[3] Examples of studies in this area include Bernanke and Kuttner (2005), Ehrmann and Fratzscher (2004), Basistha and Kurov (2008), Wongswan (2009) and Kontonikas, MacDonald and Saggu (2013).

In most of our analysis we measure the short-term interest rate expectations using intraday prices of Eurodollar futures. Monetary policy expectations, reflected in interest rate futures prices, quickly react to new information. For example, these expectations fully adjust to scheduled macroeconomic announcements within one minute after the announcement (Ederington and Lee, 1995). Andersen, Bollerslev, Diebold and Vega (2007) use conditional heteroskedasticity of five-minute futures returns to identify contemporaneous responses of stock, government bond and foreign exchange markets to one another. Therefore, it is reasonable to examine contemporaneous links between intraday interest rate and equity futures prices and to use high-frequency changes in the variance of stock returns to identify the response of monetary policy expectations to equity prices.

It is important to note that because we use interest rate futures contracts rather than the effective federal funds rate or another interest rate, we are capturing the market's expectation of how monetary policy is likely to respond to the stock market. Beginning with Kuttner (2001), interest rate futures prices have been used extensively as forecasts of monetary policy.[4] All of the studies looking at the effect of monetary policy on stock prices cited above use this approach. Gürkaynak, Sack, and Swanson (2007) show that Eurodollar futures provide good forecasts of the future fed funds rate.[5]

Our estimations show that the expectations of monetary policy do react to stock market returns. Consistent with the existence of the Fed put, this reaction sharply increases during recessions and bear markets. We do not find any evidence that the Fed has tried to "lean against

---

[4] Interest rate futures prices also contain risk premia. However, as noted by Piazzesi and Swanson (2008), these risk premia tend to change slowly and are "differenced out" when one uses high frequency changes in futures prices.
[5] In a related paper, Gürkaynak, Sack and Swanson (2005) use principal components of intraday changes in fed funds futures and Eurodollar futures prices after policy announcements of the FOMC to estimate unexpected changes in the Fed's current policy rate and in the future path of policy.

the wind" and deflate high valuations in equity markets. We also find that the Federal Reserve has been much less responsive to the stock market after the 2008 financial crisis. This finding could be due to the zero lower bound being a binding constraint on short-term interest rates.

2. Sample Selection and Methodology

2.1. Sample Selection

Our sample period spans from October 1997 to March 2018. As part of assessing the effect of the stock market on monetary policy, we test whether the structural response of the Federal Reserve to the stock market depends on the state of the economy. We first split our sample into two sub-samples (expansions and recessions). We subsequently divide the sample into four parts (expansions and recessions under conventional and unconventional monetary policy). We split our sample based on the NBER business cycle dates for two reasons. First, our sample period includes the global financial crisis; however, there is no agreed upon date at which the financial crisis began (i.e., the bank run at Northern Rock in September 2007, J.P. Morgan's purchase of Bear Stearns in March 2008, Lehman Brothers' bankruptcy in September 2008, etc.). We believe that the NBER recession dates provide a reasonable way to divide the sample given that the financial crisis roughly corresponds to the NBER recession dates from December 2007 to June 2009. Second, the NBER recession dates also provide a reasonable date on which the Federal Reserve began to use unconventional methods to influence the economy.[6] Therefore, we are able to examine the effect of the stock market on monetary policy during a recession (March 2001 –

[6] Prior to December 2007 in our sample, the Federal Reserve conducted conventional monetary policy. The Federal Reserve Board announced on December 12, 2007 the Term Auction Facility (TAF) to help ease pressure in the short-term funding markets. From December 2007 to July 2009, the Federal Reserve implemented numerous programs, including the Term Securities Lending Facility (TSLF), Primary Dealer Credit Facility (PDCF), Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), Commercial Paper Funding Facility (CPFF), Money Market Investor Funding Facility (MMIFF), established swap lines with foreign central banks, provided a $30 billion loan to J. P. Morgan, and began paying interest on excess reserves.

November 2001) and two expansions (October 1997 – February 2001 and December 2001 – November 2007) under conventional monetary policy, as well as a recession (December 2007 – June 2009) and an expansion (July 2009 – March 2018) during unconventional policy.

As noted in the introduction, the "Fed Put" is primarily a belief by some market participants that the Federal Reserve responds to adverse developments in equity markets with cuts in the short-term rates. We use the algorithm proposed by Pagan and Sossounov (2003) to identify turning points of bull and bear market phases to examine if the Fed responds to the stock market symmetrically in bull and bear markets.[7] While there is significant overlap between recessions and bear markets, the dates do differ. The 2001 recession began in March 2001 whereas the bear market began almost a year earlier in April of 2000; the recession ended in November of 2001 but the bear market did not end until October of 2002 according to the Pagan and Sossounov methodology. During the Great Recession, the turning points for the economy and the stock market are much closer. The recession began in December 2007 and the bear market began in November 2007, whereas the bear market ended in March 2009 and the recession ended in June 2009.

To summarize, by splitting our sample as outlined above we can test the following hypotheses regarding the Federal Reserve's response to the stock market. First, we can examine whether the structural relation is different depending on whether the U.S. economy is in an expansion or in a recession. Second, we can assess whether the Fed responds differently to the stock market in bull versus bear markets. Third we can test whether the structural relation

[7] The algorithm proposed by Lunde and Timmermann (2004) produces the same market cycle turning points in our sample period. We use the turning points based on these algorithms reported in Maheu, McCurdy and Song (2012).

changed in 2008 due to the degree to which the Fed came to rely on unconventional monetary policy tools and forward guidance.[8]

2.2. Methodology

Following Rigobon and Sack (2004), the link between monetary policy and stock returns is described by the following equations:

$$\Delta i_t = \beta R_t + \gamma z_t + \varepsilon_t \,, \tag{1}$$

$$R_t = \alpha \Delta i_t + z_t + \eta_t, \tag{2}$$

where Δi_t is the change in the policy interest rate, R_t is the stock return, and z_t represents common macroeconomic shocks influencing stock prices and interest rates. ε_t and η_t are innovations to the policy rate and stock returns, respectively. Following Rigobon and Sack (2004), we assume that these innovations are uncorrelated with each other and with the common shocks z_t. The coefficient α, which measures the response of stock returns to monetary policy, is the focus of a large previous literature mentioned in the introduction. The goal of our paper is estimating the coefficient β, which captures the reaction of monetary policy to the stock market. Neither of these two parameters can be consistently estimated with OLS because of the simultaneity of the relation between monetary policy and stock returns and due to the presence of unobserved economic shocks z_t.

Rigobon and Sack (2003) propose using heteroskedasticity of the daily aggregate stock returns to estimate the response of monetary policy to the stock market. Using a sample period from 1985 to 1999, they show that the Federal Reserve is expected to increase (cut) the policy rate by about 25 basis points in response to a 10 percent increase (decline) in the S&P 500 index.

[8] For an analysis of macroeconomic effects of forward guidance before and after the financial crisis, see Campbell, Evans, Fisher, and Justiniano (2012).

However, Furlanetto (2011) shows that this estimate is driven to a large extent by the Fed's reaction to the stock market crash in 1987 and finds no statistically significant reaction of monetary policy to stock returns over the 2003-2007 period. This identification approach relies on regime shifts in the covariance of the structural shocks. The covariance regimes are identified by computing the covariance matrix of reduced-form shocks to stock returns and interest rates in a 30-day rolling window. However, as noted by Lütkepohl (2013), the dates of regime shifts have to be estimated, which negatively affects the reliability of the parameter estimates.

Rigobon and Sack (2004) show that the response of stock returns to monetary policy can be identified using the increase in variance of policy shocks on days of important policy announcements. We propose a conceptually similar identification through heteroskedasticity approach to measure the effect of stock returns on monetary policy. Instead of estimating the volatility regimes following Rigobon and Sack (2003), we use the intraday periodicity in volatility observed in index futures markets. We use the E-mini S&P 500 futures, which were introduced in September 1997 and trade on an electronic trading platform, Globex. Based on the availability of the E-mini futures data, our sample period in this analysis begins in October 1997. Globex operates virtually around the clock, and trading is quite active after 8 a.m. ET. However, the level of trading activity and volatility in the E-mini S&P 500 futures sharply increases after the opening of the stock market and the beginning of open outcry trading in the regular S&P 500 futures at 9:30 a.m. We use this predictable increase in volatility caused by market structure as our identification tool.

Rigobon and Sack (2004) use daily changes in the rate on the nearby Eurodollar futures contracts in their analysis of the impact of monetary policy on asset prices. Similarly, in most of our analysis we use the rate on the nearby Eurodollar futures to measure the short-term interest rate.[9] The Eurodollar futures contracts are much more liquid than the fed funds futures. They are also less influenced by shifts in the timing of policy decisions that have no effect on the expected near-term path of monetary policy (Rigobon and Sack, 2004). For much of our sample period (until February 2003) we have Eurodollar futures data only for the floor trading hours from 8:20 a.m. to 3:00 p.m. ET. Therefore, we use only data from 8:20 a.m. to 3:00 p.m. in the analysis.

Our estimation approach relies on using index futures returns and Eurodollar futures rate changes computed over 15-minute intervals.[10] These returns and rate changes show evidence of a small amount of negative autocorrelation, perhaps due to price discreteness and bid-ask bounce. To remove this autocorrelation and possible lead-lag relation between the two variables, in the analysis that follows we use residuals from a vector autoregressive (VAR) model of 15-minute E-mini S&P 500 futures returns and Eurodollar futures rate changes. The model includes one lag of the two variables.[11]

Panel A in Figure 1 shows variances of the VAR residuals with the E-mini S&P futures' variance denoted by the gray line and the Eurodollar rate variance denoted by the blue. The figure shows that the variance of index futures returns in the interval from 9:30 a.m. to 9:45 a.m. increases by approximately a factor of five compared to the previous 15-minute interval, whereas the variance of the Eurodollar futures rate is essentially unchanged over the same 15-minute interval. The shift in variance of index futures returns is driven by the increase in trading activity and the resulting revelation of information in the stock market after the market opening.[12] It is,

---

[9] The expiration months of Eurodollar futures contracts are March, June, September and December. The nearby contract becomes relatively illiquid in its last few days of trading. Therefore, we switch to the next-to-mature contract when its daily contract volume exceeds the nearby contract volume.

[10] As a robustness check, we also used 30 minute intervals. The results were essentially unchanged.

[11] We used the Akaike information criterion to select the lag length but we also ran the model with more than one lag and the results were essentially unchanged.

[12] French and Roll (1986) provide evidence that the increase in variance of stock returns during exchange trading hours is driven primarily by private information, which is incorporated in prices through trading. Holden and

therefore, reasonable to assume that after 9:30 a.m. the variance of stock return shocks (σ_η) increases, and the variances of interest rate shocks (σ_ε) and economic news shocks (σ_z) remain constant.[13]

[Insert Figure 1 here]

Panel B in Figure 1 shows that the correlation of index futures returns and Eurodollar futures rate changes in the interval from 9:30 a.m. to 9:45 a.m. increases by a factor of 10 from the previous 15-minute interval. This increase in correlation is driven by the shift in the relative importance of stock return and interest rate innovations. It is consistent with endogenous response of monetary policy expectations to stock returns. The shift in covariance of stock returns with interest rate changes can be used to estimate the parameter β in equation (1). The only intraday interval in which this covariance becomes negative is the interval from 2:15 p.m. to 2:30 p.m. containing scheduled FOMC announcements, which is consistent with the increase in variance of monetary policy shocks after FOMC announcements.

To obtain an estimator of the response of monetary policy to stock returns, equations (1) and (2) are written in reduced form as follows:

$$\Delta i_t = \frac{1}{1-\alpha\beta}[(\beta+\gamma)z_t + \beta\eta_t + \varepsilon_t],$$

$$R_t = \frac{1}{1-\alpha\beta}[(1+\alpha\gamma)z_t + \eta_t + \alpha\varepsilon_t].$$

As argued above, the intraday interval from 9:30 a.m. to 9:45 a.m. (interval 1) has higher variance of the stock return shocks η_t than the immediately preceding 15-minute interval

Subrahmanyam (1992) develop a model that predicts that trading on private information generated during nontrading hours will be concentrated at the opening of the market.

[13] Most major scheduled U.S. macroeconomic announcements are made at 8:30 a.m. and 10:00 a.m. As the figure shows, volatility of returns and rate changes is relatively high in the intervals that contain these announcements. The only scheduled macroeconomic announcement made between 9:15 a.m. and 9:45 a.m. is the industrial production and capacity utilization announcement made by the Federal Reserve Board at 9:15 a.m. in the middle of each month. Dropping days of these announcements from the sample has little effect on the results.

(interval 2). All other model parameters are assumed to be equal in both intervals. Under these assumptions, the covariance matrices of stock returns and interest rate changes for the two intervals are:

$$\Omega_1 = \frac{1}{(1-\alpha\beta)^2}\begin{bmatrix} \sigma_\varepsilon + \beta^2\sigma_{\eta1} + (\beta+\gamma)^2\sigma_z & \alpha\sigma_\varepsilon + \beta\sigma_{\eta1} + (\beta+\gamma)(1+\alpha\gamma)\sigma_z \\ . & \alpha^2\sigma_\varepsilon + \sigma_{\eta1} + (1+\alpha\gamma)^2\sigma_z \end{bmatrix},$$

$$\Omega_2 = \frac{1}{(1-\alpha\beta)^2}\begin{bmatrix} \sigma_\varepsilon + \beta^2\sigma_{\eta2} + (\beta+\gamma)^2\sigma_z & \alpha\sigma_\varepsilon + \beta\sigma_{\eta2} + (\beta+\gamma)(1+\alpha\gamma)\sigma_z \\ . & \alpha^2\sigma_\varepsilon + \sigma_{\eta2} + (1+\alpha\gamma)^2\sigma_z \end{bmatrix}.$$

The difference between these covariance matrices is

$$\Delta\Omega = \Omega_1 - \Omega_2 = \frac{(\sigma_{\eta1}-\sigma_{\eta2})}{(1-\alpha\beta)^2}\begin{bmatrix} \beta^2 & \beta \\ \beta & 1 \end{bmatrix}. \quad (3)$$

The first term in equation (3) can be treated as a single parameter $\lambda \equiv \frac{(\sigma_{\eta1}-\sigma_{\eta2})}{(1-\alpha\beta)^2}$. $\sigma_{\eta1}$ and $\sigma_{\eta1}$ are variances of stock return residuals for the two intervals obtained from the VAR. Therefore, λ captures the degree of heteroskedasticity of stock return innovations between the two intervals. The two parameters (λ and β) can be estimated using the generalized method of moments (GMM). Since three moment conditions can be used to estimate these two unknown parameters, the GMM estimator is overidentified.

It is useful to compare this estimator of the response of monetary policy to stock returns with the identification through heteroskedasticity estimator of β proposed by Rigobon and Sack (2003). They divide the sample of daily stock returns and interest rate changes into four regimes based on variances and covariances of reduced-form shocks and use these regimes for identification. Elevated stock return volatility is the key criterion used to define the covariance regimes. The parameters α, β, γ and σ_ε are assumed to be constant across the regimes. However, each of these parameters is likely to change in bear markets, when stocks become more volatile.[14] This could make the identification assumptions problematic. The advantage of our approach is that instead of searching for covariance regimes across days, we use predictable variation in volatility within each day. We believe this makes the identification assumptions mentioned above more plausible.

We can also assume that the variance of common shocks σ_z is constant between the first and second half of the 30-minute interval used in estimation. With fewer parameters to estimate due to this assumption, our identification approach requires only one shift in the covariance matrix, as opposed to at least three regimes required to implement the Rigobon and Sack (2003) procedure. Our identification assumptions can be tested using a standard test of overidentifying restrictions. Finally, our identification approach allows estimating the time-varying response of monetary policy to stock returns. In comparison, the Rigobon and Sack (2003) approach requires at least a few years of data to estimate β, making it difficult to analyze time variation in the response of monetary policy to the stock market.

3. Results

Sections 3.1 and 3.2 present the estimated response of monetary policy expectations to the stock market in different states of the economy and in bull versus bear markets. In Section 3.3, we estimate the time-varying effect of the stock market on policy expectations using a rolling window. Section 3.4 presents results for a similar rolling window estimation with a different monetary policy measure that better captures the Fed's unconventional policy employed after the financial crisis of 2008.

---

[14] For example, Chen (2007) shows that the effect of monetary policy on stock returns (α) is much larger in absolute value in bear markets then in bull markets. Basistha and Kurov (2008) find that the response of the stock market to monetary policy news is much stronger in recessions and in tight credit conditions.

3.1. Expansions vs. Recessions

As noted above, we first split our sample into recessions and expansions. Our primary conjecture is that the Federal Reserve responds differently to the stock market depending upon the expectations of the future macroeconomic environment. Panel A of Table 1 shows the GMM estimates of the λ and β parameters during recessions and expansions. First, note that the estimate of β during recessions is 0.0106 versus 0.0050 during expansions and both are statistically significant at the 1% level; the policy response of the Fed is roughly twice as high during recessions relative to expansions. The *t*-test shown in the last column of Table 1 rejects the hypothesis that the response of monetary policy to stock returns is the same in expansions and recessions at the 1% significance level. Also, observe that for both expansions and recessions the test of overidentifying restrictions suggests that our identifying assumptions are not rejected.

[Insert Table 1 here]

Panel B of Table 1 displays the parameter estimates for the expansions and recessions as given by the NBER dates under *conventional* monetary policy whereas Panel C displays the results under *unconventional* monetary policy. The first column in each panel displays the results from recessions and the second column displays the results from expansions. Note that we have two recessions in our sample period. The first recession spanned from March 2001 to November 2001 and was relatively mild; the unemployment rate only increased from 4.3% at the beginning of the recession to 5.5% at the end. In contrast, during the second recession (December 2007 – June 2009) the unemployment rate increased from 5% at the beginning of the recession to 9.5% at the end. Interestingly, the responses of policy to the stock market in both recessions are approximately the same. Note in Panel B, that in the 2001 recession, β is 0.0122 and in Panel C during the more recent recession, β is 0.0105. Both of these estimates are significant at the 1% level; however, the degree of heteroskedasticity of stock return innovations is three times greater during the 2007-2009 recession than in 2001 recession as indicated by the estimates of λ.

Based on the β estimate for the 2001 recession, a 10 percent move in the S&P 500 index moves the expected short-term interest rate by about 12.2 basis points in the same direction. This means that, for example, a 10 percent fall in stock prices increases the likelihood of a 25-basis-point cut in the policy rate by about half ($12.2/25 = 0.49$).

The estimates of β during the two expansionary parts of the sample are dramatically different from each other. The estimate during the expansions from 1997 to 2001 and from 2001 to 2007 is 0.0083. This estimate is significant at the 1% level and similar to the estimate obtained by Furlanetto (2011) for the 1988-2003 period. However, during the expansion that started in 2009, the estimate of β falls to 0.0018 and is also statistically significant at the 1% level. Given our measure of monetary policy changes, this could be a result of short-term interest rates being at the zero lower bound over the 2009-2015 period. The third column in each panel shows the difference between the coefficients during recessions and expansions. Note that the difference between the coefficients is statistically significant at the 1% level for the unconventional monetary policy period in Panel C but not for the conventional policy period in Panel B. The difference between the recession and expansion estimates is roughly twice as large during the unconventional monetary policy period. In terms of the market expectations of policy actions, the results are dramatically different between the expansions. Our results suggest that a 10 percent increase in the stock market during an expansion prior to 2008 would increase the likelihood of a 25-basis-point increase in the expected policy rate by about one-third. After 2008, the likelihood falls to about seven percent.

3.2. Bull vs. Bear Markets

As mentioned in Section 2.1, in addition to dividing the sample into expansions and recessions, we also examine the response of monetary policy expectations to the stock market in bull and bear markets. As in Table 1, Panel A of Table 2 displays the results from all bull markets and all bear markets in our sample period, Panel B displays the results during conventional monetary policy and Panel C shows the results during unconventional monetary policy. The first column displays the results from bear markets, the second column displays the results from bull markets, and the last column shows the difference between the coefficient estimates.

The estimation results in Table 2 show that the response of monetary policy to the stock market approximately quadruples in bear markets compared to bull markets. The estimated coefficients in Table 2 are largely similar to those in Table 1. During recessions, the estimated responses of policy are 0.0106, 0.0122, and 0.0105 in the combined, conventional policy and unconventional policy samples, respectively. During bear markets, the corresponding estimates in Table 2 are 0.0122, 0.0123, and 0.0110. As shown in the last column of Table 2, the hypothesis that the policy response coefficients in bull and bear markets are equal is rejected at the 1% level for all three time periods. In terms of the likelihood of Federal Reserve action, note that the probabilities in bear markets are very similar to those in recessions; a 10 percent decline in the stock market increases the likelihood of a 25-basis-point cut in the Federal Funds rate by about 50 percent. In bull markets, a 10 percent increase in the stock market during conventional monetary policy increases the likelihood of a 25-basis-point rate hike by about 20 percent whereas the likelihood during unconventional policy is around seven percent.

Overall, our results are not consistent with the Fed "leaning against the wind" by trying to deflate stock market bubbles.[15] The differences in the magnitude of the policy response coefficients between adverse and positive economic environments documented in this and the previous sub-section suggest the existence of the Fed put. Our results strongly support Roubini's (2006) characterization that the Federal Reserve has followed a "mop up after" approach to monetary policy and asset prices. That is, our results are consistent with an asymmetric response of policy to large increases and decreases in asset prices: no tightening of policy on the way up but aggressive monetary easing on the way down to contain the collateral damage to other parts of the macroeconomy.

[Insert Table 2 here]

3.3. Time-Varying Responses

To further examine the time-varying response of monetary policy to stock returns, we estimate λ and β with GMM using a rolling window. The window includes 250 observations, roughly corresponding to a one-year period (in terms of trading days). Figure 2 Panel A plots the time-varying response of policy to stock returns with bear markets denoted by gray shading and Panel B displays the same results with recessions denoted by gray shading. Panel A shows that the response was relatively small in 1999 and early 2000 but increased sharply in March 2000 as the technology stock bubble imploded and a bear market in equities started. Additionally, note that the bear market encompasses a longer time frame than the actual recession from March 2001 – November 2001 as shown in Panel B. The estimate of the policy response to the stock market generally remained above 0.01 until the beginning of 2003 and fell to zero by the end of that year as the expansion ensued. It started increasing again in early May 2004. This occurred after the

[15] Bernanke (2002) argues that it is very difficult for a central bank to effectively act against asset bubbles.

FOMC, following an extended period of maintaining very low fed funds target rates, stated that that "policy accommodation can be removed at a pace that is likely to be measured."[16]

[Insert Figure 2 here]

For much of the 2005-2007 period, the monetary policy response coefficient fluctuated around 0.005 and was often statistically insignificant. The time-varying coefficient started increasing again in August 2007 as the subprime crisis started. The largest increase, however, began in January 2008. By mid-2008, the policy response coefficient reached 0.025, before beginning to decline again in mid-October 2008, as the short-term rates approached the zero lower bound.[17] In 2010-2014 the policy response coefficient remained close to zero before beginning to climb in 2015 as the lift-off from the zero lower bound approached. Overall, consistent with the results in Tables 1 and 2, the estimates in Figure 2 show that the response of monetary policy to the stock market increases during recessions and bear markets.

3.4. Treasury Yields and Post-2008

As a robustness check, we use the implied yields of the two-year Treasury note futures contracts as a measure of changes in monetary policy expectations.[18] For seven years beginning in December 2008, the federal funds target rate remained at the zero lower bound and the Fed used quantitative easing programs (QE) and "open mouth operations" to lower long-term interest rates. The QE program involved large-scale purchases of Treasury and mortgage-backed securities, while the "open mouth operations" involved increased use of forward guidance and providing economic and interest rate projections in an effort to guide the market expectations

[16] See the FOMC statement of May 4, 2004.
[17] According to the mid-2008 estimate of the policy response coefficient, a 10 percent decline in stock prices leads to an expectation of a 25-basis-point cut in the short-term rate.
[18] For example, Hanson and Stein (2015) use the two-year Treasury yield to construct a proxy for monetary policy news.

about the path of future rates. The implied yields of Treasury security futures represent a reasonable proxy for changes in monetary policy expectations during the period of unconventional monetary policy.

Again, we examine the feedback from stock returns to monetary policy expectations during the zero lower bound period by using the same methodology as in Section 3.3. The time-varying response of policy expectations to stock returns is shown in Figure 3. Note that while the coefficient estimates in Figure 3 are somewhat larger than those in Figure 2, qualitatively the results are almost identical. Both measures of policy expectations (the Eurodollar futures rate and the two-year Treasury futures rate) suggest that the Fed became much less responsive to the stock market once the financial crisis subsided. This is consistent with the existence of the Fed put. In Figure 3, the response of the two-year Treasury futures rate to the stock market declines in the summer of 2011, which coincides with FOMC's "mid-2013" forward guidance. This finding is consistent with Swanson and Williams (2014), who show that the zero lower bound became a binding constraint on the medium-term interest rates in late 2011.

[Insert Figure 3 here]

The sensitivity of policy expectations to stock returns increased again in May 2013 after Fed Chairman Ben Bernanke stated that the Fed would start reducing asset purchases under the QE program if warranted by economic data. Investors interpreted this as a signal that liftoff from the zero lower bound could occur sooner than previously believed, possibly contributing to increased sensitivity of policy expectations to stock returns. Moreover, it is also interesting to note that in both figures, expectations of Fed policy become more responsive to the stock market during 2016 when there was considerable uncertainty regarding the outcomes of the Brexit vote as well as the U.S. presidential election.

4. Summary and Conclusions

We estimate the reaction of monetary policy to stock returns using a novel identification approach based on the intraday volatility pattern in index futures markets. Our approach does not rely on the assumption used by Rigobon and Sack (2003) that the model parameters, including the reaction of policy to the stock market, are constant on days of high and low stock return volatility. Our approach allows estimating time-varying reaction of monetary policy to the stock market and can also be used in other contexts. For example, future studies can use this approach to estimate the response of monetary policy to commodity prices. Our results show that monetary policy is more responsive to stock returns in recessions and bear markets. This finding is consistent with the existence of a “mop up after” approach to monetary policy and asset prices. That is, the market expects an asymmetric response of monetary policy to changes in asset prices in good and bad economic times.

References

Andersen, T. G., Bollerslev, T., Diebold, F. X., Vega, C. (2007). Real-time price discovery in stock, bond and foreign exchange markets. *Journal of International Economics*, 73, 251-277.

Basistha, A., Kurov, A. (2008). Macroeconomic cycles and the stock market's reaction to monetary policy. *Journal of Banking and Finance*, 32, 2606-2616.

Bernanke, B. (2002). Asset-price "bubbles" and monetary policy. Remarks before the New York Chapter of the National Association for Business Economics, New York. http://www.federalreserve.gov/boarddocs/speeches/2002/20021015/default.htm.

Bernanke, B. S., Kuttner, K. N. (2005). What explains the stock market's reaction to Federal Reserve policy? *Journal of Finance*, 60, 1221-1257.

Campbell, J. R., Evans, C. L., Fisher, J. D., Justiniano, A. (2012). Macroeconomic effects of Federal Reserve forward guidance. *Brookings Papers on Economic Activity*, 2012, 1-80.

Chen, S. (2007). Does monetary policy have asymmetric effects on stock returns? *Journal of Money, Credit and Banking*, 39, 667-688.

Cieslak, A., Vissing-Jorgensen, A. (2017). The economics of the Fed put. Working paper, Duke University and University of California at Berkeley.

Ederington, L. H., Lee, J. H. (1995). The short-run dynamics of the price adjustment to new information. *Journal of Financial and Quantitative Analysis*, 30, 117-134.

Ehrmann, M., Fratzscher, M. (2004). Taking stock: Monetary policy transmission to equity markets. *Journal of Money, Credit, and Banking*, 36, 719-737.

French, F., Roll, R. (1986). Stock return variances: The arrival of information and the reaction of traders. *Journal of Financial Economics*, 17, 5-26.

Furlanetto, F. (2011). Does monetary policy react to asset prices? Some international evidence. *International Journal of Central Banking*, 7, 91-111.

Gürkaynak, R. S., Sack, B., Swanson, E. (2005). Do actions speak louder than words? The response of asset prices to monetary policy actions and statements. *International Journal of Central Banking*, 1, 55-93.

Gürkaynak, R. S., Sack, B., Swanson, E. (2007). Market-based measures of monetary policy expectations. *Journal of Business and Economic Statistics*, 25, 201-212.

Hanson, S. G., Stein, J. C., (2015). Monetary policy and long-term real rates. *Journal of Financial Economics*, 115, 429-448.

Holden, C. W., Subrahmanyam, A. (1992). Long-lived private information and imperfect competition. *Journal of Finance*, 47, 247-270.

Kontonikas, A., MacDonald, R., Saggu, A. (2013). Stock market reaction to fed funds rate surprises: State dependence and the financial crisis. *Journal of Banking and Finance*, 37, 4025-4037.

Kuttner, K. N. (2001) Monetary policy surprises and interest rates: Evidence from the Fed funds futures market. *Journal of Monetary Economics*, 47, 523-544.

Lunde, A., Timmermann, A. G. (2004). Duration dependence in stock prices: An analysis of bull and bear markets. *Journal of Business & Economic Statistics*, 22, 253-273.

Lütkepohl, H. (2013). Identifying structural vector autoregressions via changes in volatility. In VAR models in macroeconomics – New developments and applications: Essays in honor of Christopher A. Sims (pp. 169-203). Emerald Group Publishing Limited.

Maheu, J. M., McCurdy, T. H., Song, Y. (2012). Components of bull and bear markets: Bull corrections and bear rallies. *Journal of Business & Economic Statistics*, 30, 391-403.

Pagan, A. R., Sossounov, K. A. (2003). A simple framework for analysing bull and bear markets. *Journal of Applied Econometrics*, 18, 23-46.

Piazzesi, M., Swanson, E. T. (2008). Futures prices as risk-adjusted forecasts of monetary policy. *Journal of Monetary Economics*, 55, 677-691.

Poole, W. (2008). Market bailouts and the "Fed put." *Federal Reserve Bank of St. Louis Review*, 90, 65-74.

Rigobon, R., Sack, B. (2003). Measuring the reaction of monetary policy to the stock market. *Quarterly Journal of Economics*, 118, 639-669.

Rigobon, R., Sack, B. (2004). The impact of monetary policy on asset prices. *Journal of Monetary Economics*, 51, 1553-1575.

Roubini, N. (2006). Why central banks should burst bubbles. *International Finance*, 9, 87-107.

Swanson, E., Williams, J. (2014). Measuring the effect of the zero lower bound on medium- and longer-term interest rates. *American Economic Review*, 104, 3154-3185.

Wongswan, J. (2009). The response of global equity indexes to U.S. monetary policy announcements. *Journal of International Money and Finance*, 28, 344-365.

Table 1
Response of monetary policy expectations to stock returns

Panel A. All expansions and recessions in the sample period

	Recessions	Expansions	Difference in coefficients (Recession – Expansion)
Policy response (β)	0.0106***	0.0050***	0.0056***
	(0.0017)	(0.0006)	(0.0018)
Heteroskedasticity parameter (λ)	0.1309***	0.0374***	
	(0.0245)	(0.0020)	
Test of overidentifying restrictions	0.2520	0.8946	
N	590	4632	

Panel B. Expansions and recession under conventional monetary policy (October 1997 – November 2007)

	Recession March 2001 – Nov. 2001	Expansion Oct. 1997 – Feb 2001 and Dec. 2001 – Nov. 2007	Difference in coefficients (Recession – Expansion)
Policy response (β)	0.0122***	0.0083***	0.0039
	(0.0034)	(0.0011)	(0.0035)
Heteroskedasticity parameter (λ)	0.0516***	0.0366***	
	(0.0106)	(0.0027)	
Test of overidentifying restrictions	0.1413	0.9409	
N	186	2378	

Panel C. Expansion and recession under unconventional monetary policy (December 2007 – March 2018)

	Recession Dec. 2007 - May 2009	Expansion June 2009 – March 2018	Difference in coefficients (Recession – Expansion)
Policy response (β)	0.0105***	0.0018***	0.0087***
	(0.0019)	(0.0004)	(0.0019)
Heteroskedasticity parameter (λ)	0.1692***	0.0383***	
	(0.0344)	(0.0028)	
Test of overidentifying restrictions	0.3937	0.4635	
N	404	2277	

The sample period is from October 1997 through March 2018. The expansions and recessions are based on the NBER business cycle dates. The two recessions date from March 2001 to November 2001 and from December 2007 to June 2009. Standard errors are shown in parentheses. *p*-values are shown for the test of overidentifying restrictions. A *t*-test is used to test whether the difference in coefficients in panel A is statistically significant. *** indicates statistical significance at 1% level.

Table 2
Response of monetary policy expectations to stock returns during bull and bear markets

Panel A. All bull and bear markets in the sample period

	Bear markets	Bull markets	Difference in coefficients (Bear – Bull)
Policy response (β)	0.0122***	0.0032***	0.0090***
	(0.0014)	(0.0005)	(0.0014)
Heteroskedasticity parameter (λ)	0.1008***	0.0358***	
	(0.0156)	(0.0020)	
Test of overidentifying restrictions	0.3507	0.4332	
N	1005	4218	

Panel B. Bull and bear markets under *conventional* monetary policy (October 1997 – November 2007)

	Bear markets	Bull markets	Difference in coefficients (Bear – Bull)
Policy response (β)	0.0123***	0.0057***	0.0066***
	(0.0016)	(0.0012)	(0.0020)
Heteroskedasticity parameter (λ)	0.0672***	0.0279***	
	(0.0082)	(0.0019)	
Test of overidentifying restrictions	0.5615	0.4332	
N	643	1899	

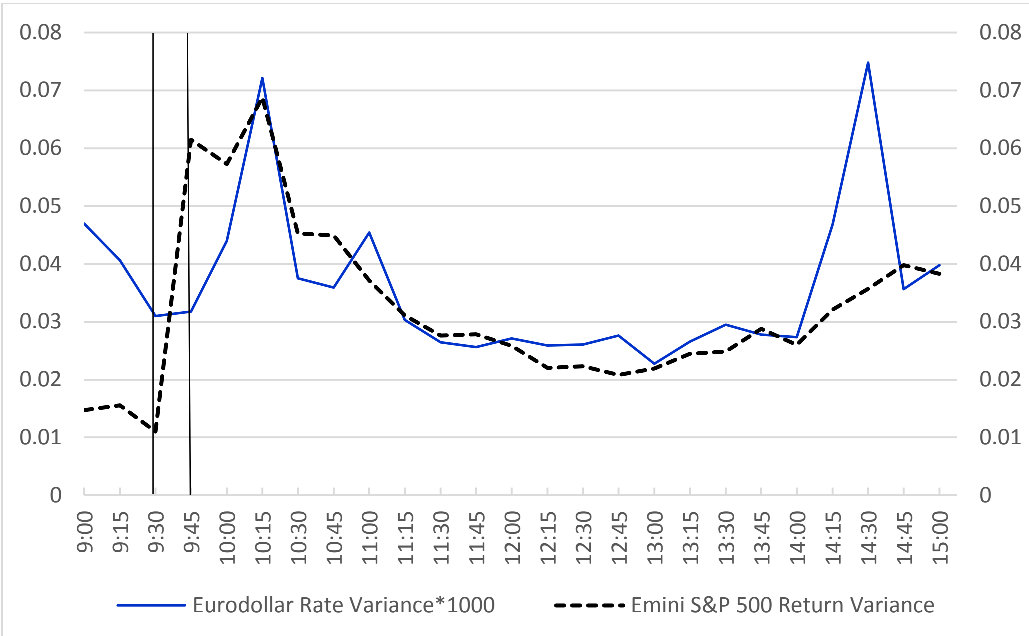
Panel C. Bull and bear markets under *unconventional* monetary policy (December 2007 – March 2018)

	Bear markets	Bull markets	Difference in coefficients (Bear – Bull)
Policy response (β)	0.0110***	0.0018***	0.0092***
	(0.0019)	(0.0004)	(0.0019)
Heteroskedasticity parameter (λ)	0.1777***	0.0392***	
	(0.0156)	(0.0028)	
Test of overidentifying restrictions	0.4550	0.2725	
N	362	2319	

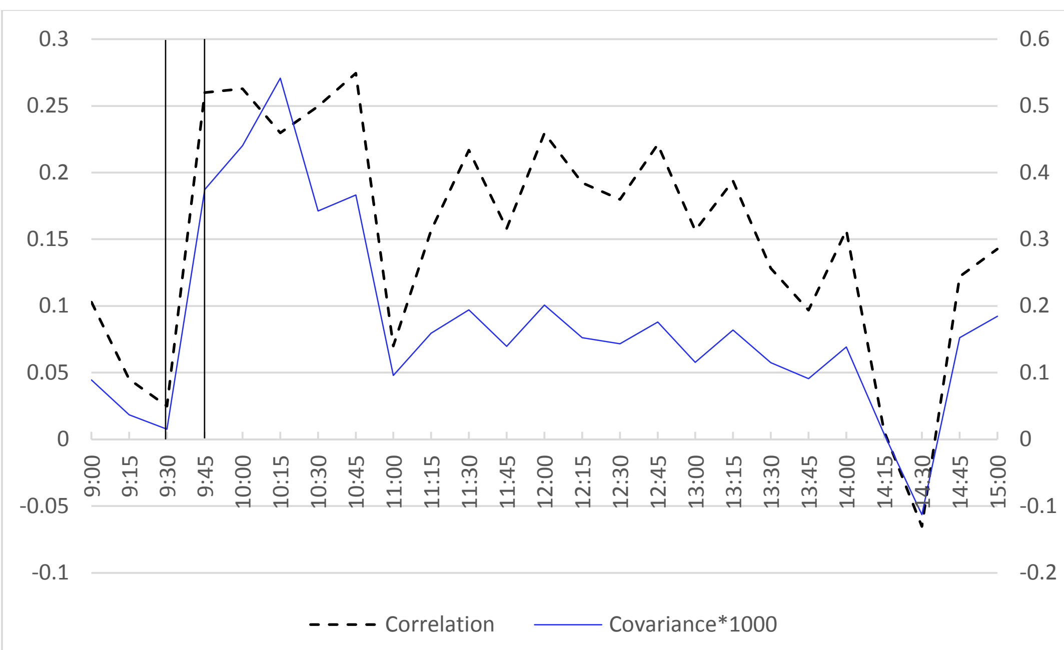
The sample period is from October 1997 through March 2018. Bull and bear markets are classified with Pagan and Sossounov (2003) algorithm. The bear market periods are from April 2000 to October 2002 and from November 2007 to March 2009. Standard errors are shown in parentheses. *p*-values are shown for the test of overidentifying restrictions. A *t*-test is used to test whether the difference in coefficients is statistically significant. *** indicates statistical significance at 1% level.

Figure 1
Intraday periodicity in volatility and comovement of index futures returns and Eurodollar futures rate changes

Panel A: Variance of 15-minute E-mini S&P 500 returns (left-hand axis) and variance of Eurodollar rate changes (right-hand axis)



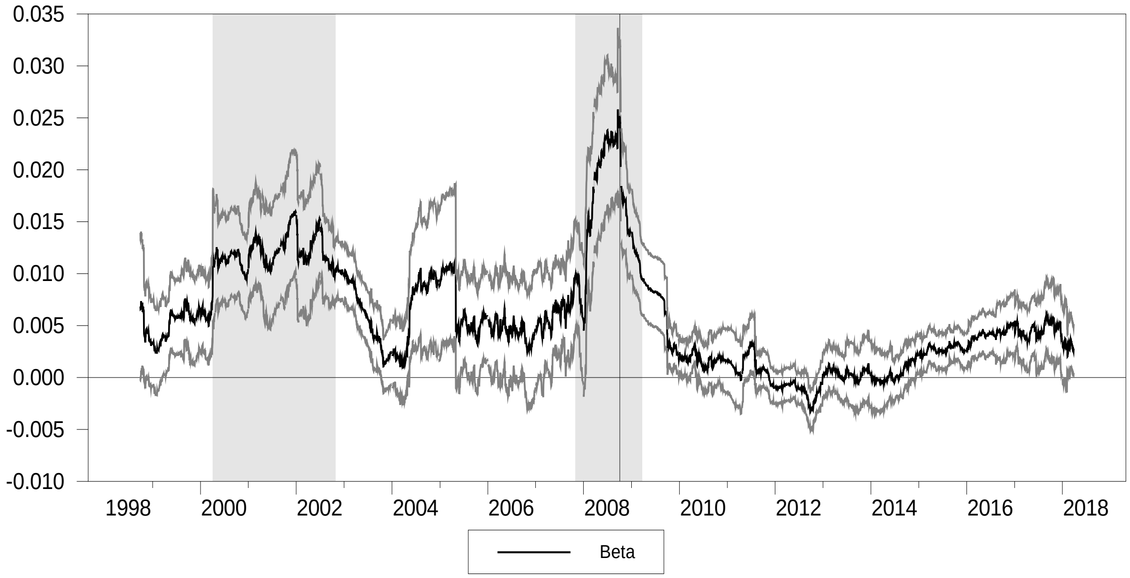
Panel B. Correlation (left-hand axis) and covariance (right-hand axis) of 15-minute E-mini S&P 500 returns and Eurodollar rate changes



The sample period is from October 1, 1997 to March 30, 2018.

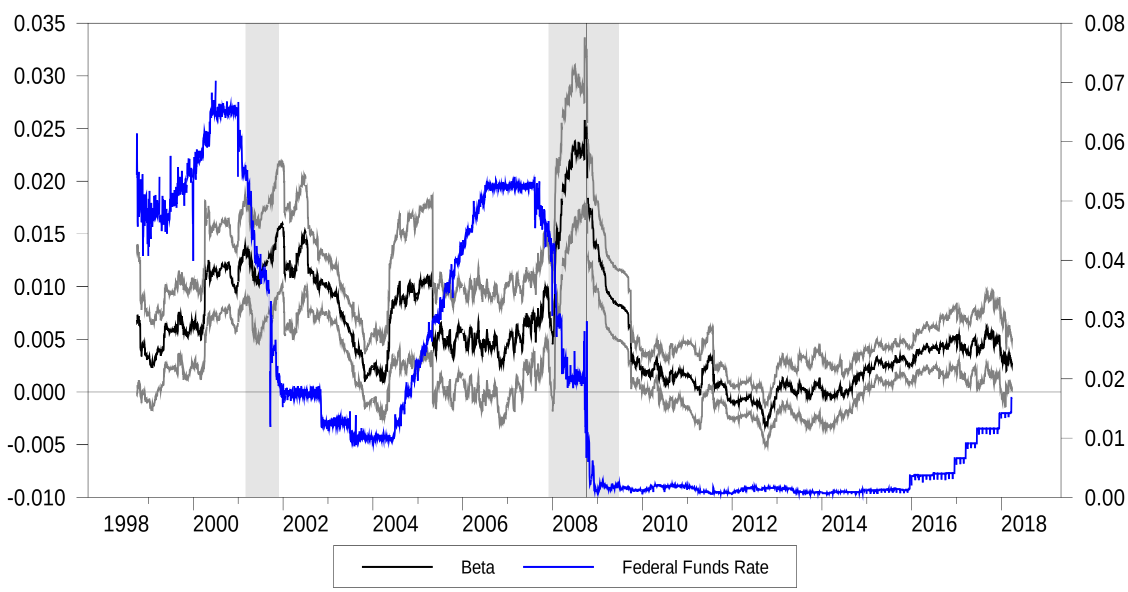
Figure 2
Time-varying response of monetary policy expectations to stock returns (estimation using nearby Eurodollar futures rate changes)

Panel A: Bear Markets



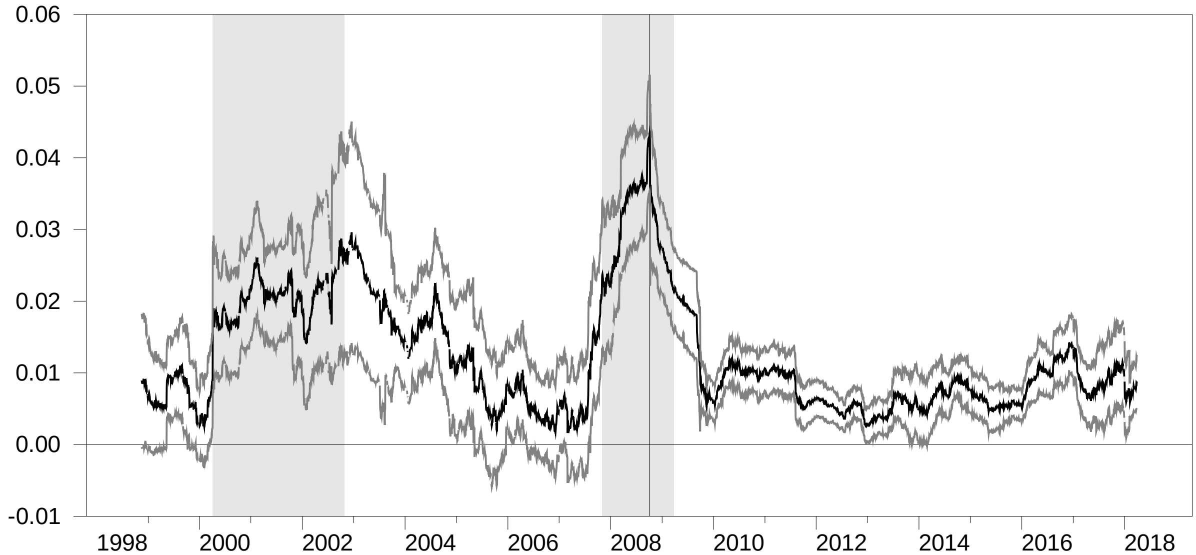
The sample period is from October 1, 1997 to March 30, 2018. The black line is the estimated response of monetary policy expectations to stock returns and measured on the left-hand axis. The gray lines are 1.65-standard-error bands. Shaded areas represent bear markets are classified with Pagan and Sossounov (2003) algorithm. The vertical line in the graph is the date on which the Federal Reserve began paying interest on excess reserves which marked the shift to unconventional policy.

Panel B: Recessions



The sample period is from October 1, 1997 to March 30, 2018. The black line is the estimated response of monetary policy expectations to stock returns and measured on the left-hand axis. The gray lines are 1.65-standard-error bands. The blue line is the Federal Funds Rate and measured on the right-hand axis. Shaded areas represent recessions as given by the NBER. The vertical line in the graph is the date on which the Federal Reserve began paying interest on excess reserves which marked the shift to unconventional policy.

Figure 3
Time-varying response of monetary policy expectations to stock returns
(estimation using two-year Treasury futures rate changes)



The sample period is from October 1, 1997 to March 30, 2018. The gray lines are 1.65-standard-error bands. Shaded areas represent bear markets are classified with Pagan and Sossounov (2003) algorithm. The vertical line in the graph is the date on which the Federal Reserve began paying interest on excess reserves which marked the shift to unconventional policy.