Does the Fed Respond to the Stock Market?

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Abstract

We examine the feedback from the stock market to monetary policy. Using an identification approach based on intraday periodicity in volatility of index futures, we find a sharp increase in the response of monetary policy to stock returns during recessions. This finding is consistent with the existence of the so-called “Fed put.” However, given the similarity in the timing of bear markets it is difficult to disentangle whether the Fed responds to market downturns or the Fed interprets the market downturn as an increase in the probability of a recession in the near future. Somewhat surprisingly, we find that the response of monetary policy to stock returns was the same during the past two recessions of 2001 and 2008.

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“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

“William C. Dudley, the influential president of the Federal Reserve Bank of New York, said at a news conference in New York that the case for raising interest rates had become “less compelling” in recent weeks. It was the first public indication that Fed officials had been rattled by recent market turbulence, which had already led many investors to conclude the Fed would wait a little longer before raising rates.”

The New York Times, August 26, 2015

1. Introduction

Many investors believe that the Federal Reserve will ride to the rescue of financial markets in periods of market stress. The Fed’s pattern of reacting to financial crises and market declines by easing monetary policy has been labeled the “Fed put,” often named after the current Fed chairman, such as “Greenspan put” or, more recently, the “Bernanke put.” On the other hand, bear markets are often correlated 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. Understanding the link between monetary policy and the stock market is obviously important for investors, but also important for monetary policy makers because of the macroeconomic consequences of wealth effects that result from large changes in asset prices.

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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 See, for example, Poole (2008) for a good discussion of the issues involved.
The literature examining the effect of monetary policy on stock prices is vast.\textsuperscript{3} The feedback from stock returns to monetary policy, however, is not robustly understood. Many previous studies examining the link between monetary policy and equity markets use event study methodology which regresses daily stock returns on measures of monetary policy news. Estimates of the stock market response to monetary policy obtained from such regressions are likely to be biased. This bias is due, at least in part, to endogenous response monetary policy to stock returns (e.g., Rigobon and Sack, 2003). Kurov and Gu (2016) demonstrate that the bias in event study regression estimates becomes especially severe in periods of market stress. Stock and Watson (2017) recently produced an article summarizing the largest advances in time-series econometrics over the past 20 years. Of the numerous seminal articles mentioned, Rigobon and Sack’s (2003) identification through heteroskedasticity was highlighted. Rigobon and Sack (2003) use daily stock returns and interest rates to identify the reaction of monetary policy to the stock market and find a statistically significant response of policy to stock returns; however, their method is difficult to implement for testing whether this response is dependent upon market or macroeconomic conditions. To examine such time variation in the reaction of monetary policy to the stock market, we propose a modification of the identification through heteroscedasticity method. Our approach is based on the shift in volatility of index futures returns at the stock market opening. This approach allows us to identify the response of policy to stock returns under a weaker set of assumptions than required by the identification approach of Rigobon and Sack (2003). To preview our results, our estimations show that the Fed does react to stock market returns; we find a particularly sharp increase in this reaction during recessions and bear markets. Somewhat surprisingly, we find that the Federal Reserve’s policy response was quantitatively

\textsuperscript{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).
similar during the past two recessions. These findings are consistent with the existence of the “Fed put;” however, during the recovery beginning in 2009, we find that the Federal Reserve policy response is substantially greater than in the previous two expansions suggesting that the Fed has become more sensitive to adverse market movements. The rest of the paper proceeds as follows. Section 2 discusses our data and methodology, section 3 displays and discusses our results and section 4 concludes.

2. Sample Selection and Methodology

2.1. Sample Selection

Our sample period spans from October 1997 to September 2016. However, we divide our sample up depending upon the macroeconomic environment. That is, we posit that the Federal Reserve may respond differently to the stock market depending upon whether the overall economy is in a recession or if the stock market is in a bear market. Our rationale is that large decreases in asset prices which induce individuals or companies to increase savings or delay investment hinders the ability of the Federal Reserve to maintain full employment and stable prices.

We first split our sample into two sub-samples (recessions and expansions) and then subsequently divide the sample into five sub periods based upon the NBER business cycle dates (October 1997 – February 2001, March 2001 – November 2001, December 2001 – December 2007 – June 2009, July 2009 – September 2016). We separate our sample into five time periods because we believe that the two recessions and three expansions during our sample period were qualitatively different, which could have elicited different responses from the Fed. We use the NBER business cycle dates for an additional two reasons. First, our sample period does include the financial crisis; however, there is no agreed upon date in the literature at which the Financial Crisis began (i.e. J.P. Morgan’s purchase of Bear Stearns in March 2008, Federal Reserve’s TAF facility beginning in December 2007, Lehman Brothers’ bankruptcy in September 2008 etc.); as
such, we believe using the NBER recession dates provide a reasonable structure to split up the sample given that the financial crisis roughly corresponds to the NBER recession dates from Dec. 2007 – June 2009. Secondly, the NBER recession dates also provide a reasonable date on which the Federal Reserve began to use non-conventional methods to influence the economy. The Federal Reserve Board announced on December 12, 2007 the Term Auction Facility (TAF) to help ease pressure in the short-term funding markets. Prior to December 2007 in our sample, the Federal Reserve conducted conventional monetary policy. From December 2007 to July 2009, the Federal Reserve implemented numerous programs, including the TSLF, PDCF, AMLF, CPFF, MMIFF, established swap lines with foreign central banks, provided a $30 billion loan to J. P. Morgan, and began paying interest on excess reserves.\(^4\) Thus, we are able to examine the effects of monetary policy during a recession (March 2001 – November 2001) and an expansion (December 2001 – December 2007) under conventional monetary policy as well as a recession (December 2007 – June 2009) and an expansion (July 2009 – September 2016) during unconventional policy.

2.1. Methodology and Data

The link between monetary policy and stock returns can be described by the following equations:

\[
\Delta i_t = \beta R_t + \gamma z_t + \epsilon_t , \tag{1}
\]
\[
R_t = \alpha \Delta i_t + z_t + \eta_t , \tag{2}
\]

where \(\Delta i_t\) 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. \(\epsilon_t\) and \(\eta_t\) are

\(^4\) 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), and Money Market Investor Funding Facility (MMIFF)
innovations to the policy rate and the stock return, respectively. We assume that these innovations are uncorrelated with each other and with the common shocks \( z_t \). The coefficient \( \alpha \), which measures the response of stock returns to monetary policy, is the focus of a large previous literature mentioned above. The goal of our paper is estimating the coefficient \( \beta \), 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. 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. He finds no statistically significant reaction of monetary policy to stock returns over 2003-2007. 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. Our approach is based on 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 an identification tool.

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. It is, therefore, 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. To measure the short-term interest rate for this analysis, we use the rate on the nearby Eurodollar futures contract. These futures contracts are much more liquid than the fed funds futures. Gürkaynak et al. (2007) show that Eurodollar futures rates provide a good proxy for monetary policy expectations. Rigobon and Sack (2004) use daily changes in Eurodollar futures rates in their analysis of the impact of monetary policy on asset prices. 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. As noted above, we split our sample into the recessions and expansions as dated by the NBER.

Our estimation approach relies on using index futures returns and Eurodollar futures rate changes computed over 15-minute intervals. These returns and rate changes show evidence of

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5 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.
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.

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. It is, therefore, reasonable to assume that after 9:30 a.m. the variance of stock return shocks ($\sigma_\eta$) increases, and the variances of interest rate shocks ($\sigma_\varepsilon$) and economic news shocks ($\sigma_z$) remain stable.

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

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6 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 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.

7 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.
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 $\beta$ 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:

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

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

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 $\eta_t$ than the immediately preceding 15-minute interval (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 are:

$$\Omega_1 = \frac{1}{(1-\alpha\beta)^2} \begin{bmatrix}
\sigma_e + \beta^2 \sigma_{\eta_1} + (\beta + \gamma)^2 \sigma_z & \alpha \sigma_e + \beta \sigma_{\eta_1} + (\beta + \gamma)(1 + \alpha\gamma) \sigma_z \\
\alpha^2 \sigma_e + \sigma_{\eta_1} + (1 + \alpha\gamma)^2 \sigma_z & \alpha^2 \sigma_e + \sigma_{\eta_1} + (1 + \alpha\gamma)^2 \sigma_z
\end{bmatrix},$$

$$\Omega_2 = \frac{1}{(1-\alpha\beta)^2} \begin{bmatrix}
\sigma_e + \beta^2 \sigma_{\eta_2} + (\beta + \gamma)^2 \sigma_z & \alpha \sigma_e + \beta \sigma_{\eta_2} + (\beta + \gamma)(1 + \alpha\gamma) \sigma_z \\
\alpha^2 \sigma_e + \sigma_{\eta_2} + (1 + \alpha\gamma)^2 \sigma_z & \alpha^2 \sigma_e + \sigma_{\eta_2} + (1 + \alpha\gamma)^2 \sigma_z
\end{bmatrix}.$$  

The difference between these covariance matrices is

$$\Delta \Omega = \Omega_1 - \Omega_2 = \frac{(\sigma_{\eta_1} - \sigma_{\eta_2})}{(1-\alpha\beta)^2} \begin{bmatrix}
\beta^2 & \beta \\
\beta & 1
\end{bmatrix}. \quad (4)$$

The first term in equation (4) can be treated as a single parameter $\lambda \equiv \frac{(\sigma_{\eta_1} - \sigma_{\eta_2})}{(1-\alpha\beta)^2}$. This parameter 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). Rigobon and Sack (2003) use daily stock returns and interest rate changes. They divide the sample 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. This makes the identification assumptions difficult to justify. Instead of searching for covariance regimes across days, we use predictable variation in volatility within each day. 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, and most importantly for our research question, 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 policy to the stock market.

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8 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.
3. Results

3.1. Recessions vs. Expansions

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 macroeconomic environment. Table 1 Panel A shows the GMM estimates of the $\lambda$ and $\beta$ parameters during recessions and expansions. First, note that the estimate of $\beta$ during recessions is 0.011 versus 0.004 during expansions and statistically significant at the 1% level; the policy response of the Fed is roughly three times as high during recessions as expansions. While it could be that this policy response is higher because of the Financial crisis, as will be seen below, that actually is not the case. 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]

Table 1 Panel B displays the results from estimating (1) and (2) over the specific expansions and recessions as given by the NBER dates. We have two recessions in our sample time period. The first recession spanned from March 2001 - 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 compared to the great recession (Dec. 2007 – June 2009) where the unemployment rate increased from 5% at the beginning to 9.5% at the end. Surprisingly, the policy responses in both recessions are approximately the same. In the 2001 recession, $\beta$ was 0.012 and during the Great Recession $\beta$ was 0.0105 and both were significant at the 99% level. However, the degree of
heteroskedasticity of stock return innovations was 3 times greater (0.169 vs. 0.051) during the 2007-2009 recession than in 2001 recession as indicated by the estimate of $\lambda$.

It is important to note that these estimates suggest that a 10 percent fall in stock prices increased the likelihood of a 25-basis-point cut in the policy rate by about half. The estimates of $\beta$ during the three expansions are dramatically different. Note that the estimate during the expansion from 1997 – 2001 was 0.009 and from 2001 – 2007 was 0.007, both significant at the 1% level and similar to the estimate obtained by Furlanetto (2011); however, during the expansion after the Great Recession in 2009, the estimate of $\beta$ falls to 0.0016 and is only statistically significant at the 10% level. Given our measure of monetary policy changes, we believe this is likely a result of the unconventional policies that the Fed has undertaken and the result of interest rates being at the lower bound over the 2009-2015 time period. We re-estimate the effect below using a different monetary policy measure that we think better captures the Fed’s QE programs.

Given the dramatic differences between the three expansions, as a robustness check, we decided to re-estimate the effect of monetary policy during expansion of 1997 – 2001 and exclude the expansion of 2009-2016. Table 1 Panel C displays the updated estimates from expansions along with the original estimates during recessions. The policy response of the Federal Reserve during expansion increases to 0.008 which is very similar to the estimate in Furlanetto (2011); but it is important to note that the policy response during recessions is still approximately 40% larger than during expansions.
3.2. Bull vs. Bear Markets

According to the notion of the “Fed put,” the Federal Reserve becomes more responsive to stock returns in periods of large stock market declines, i.e., in bear markets. Given that the last two bear markets largely coincided with recessions, as a robustness check, we use the algorithm proposed by Pagan and Sossounov (2003) to identify turning points of bull and bear market phases. The estimation results reported in Table 2 show that the response of monetary policy to the stock market approximately doubles in bear markets compared to bull markets. Or results in Table 2 are largely similar to those in Table 1. During recessions the policy response is 0.011 and during bear markets the policy response is 0.12; likewise, during bull markets the policy parameter is 0.0061 and during expansions pre-2009, the policy parameter is 0.008. We believe that this finding is consistent with the existence of the “Fed put” and is not consistent with the Fed “leaning against the wind” by trying to deflate stock market bubbles. Put another way, the Federal Reserve responds more to stock market returns when there is either (1) adverse macroeconomic conditions (2) bear markets in which markets may be signaling a recession.

[Insert Table 2 here]

3.3. Time-Varying Responses

To further examine the time-varying response of monetary policy to stock returns, we estimate \( \lambda \) and \( \beta \) with GMM using a rolling window. The window includes 250 observations, roughly corresponding to a one-year period. Figure 2 plots the time-varying response of policy to stock returns with bear markets denoted by gray shading. The figure shows that this response

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9 The algorithm proposed by Lunde and Timmermann (2004) produces the same market cycle turning points in our sample period.
10 The difference between the estimates for bull and bear markets is statistically significant at the 1% level based on a \( t \)-test.
was quite 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 actually encompasses a longer time frame than the actual recession from March 2001 – November 2001. The estimate 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 FOMC, after 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.”

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. Overall, consistent with the results in Table 1, the estimates in Figure 2 show that the response of monetary policy to the stock market increased during recessions and bear markets.

3.4. Quantitative Easing Program

For seven years beginning in December 2008, the federal funds target rate remained at the zero lower bound. During this period, the Fed used a program known as quantitative easing (QE) and “open mouth operations” to lower long term interest rates. The QE program involved

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11 See the FOMC statement of May 4, 2004.
12 According to the mid-2008 estimate of the policy response coefficient, a 10 percent decline in stock prices causes a 25-basis-point cut in the short-term rate.
large-scale purchases of Treasury and mortgage-backed securities. 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 about the path of future rates. In this section, we examine the feedback from stock returns to policy expectations during the period from January 1, 2009 to September 31, 2016. In 2011, the FOMC began providing forward guidance for specific horizons. For example, the FOMC statement of August 9, 2011 mentioned that the Committee envisioned maintaining “exceptionally low levels for the federal funds rate at least through mid-2013.” Swanson and Williams (2014) provide evidence that this forward guidance moved market expectations of the lift-off from the zero lower bound from about one year to almost two years. In January 2012, the FOMC started releasing individual members’ projections of the appropriate levels of the fed funds rate for several time horizons. To measure changes in monetary policy expectations during the period of unconventional monetary policy, we use the implied yields of two-year Treasury futures contracts.13

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. We use the returns of the E-mini S&P 500 futures and the implied rates of 2-year Treasury futures contracts. The time-varying response of policy expectations to stock returns is shown in Figure 3. The response is statistically significant over the entire sample period but shows significant temporal variation. Note that there are essentially two peaks: one in the summer of 2011 and one in the fall of 2014. The decline beginning the summer of 2011 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.

13 For example, Hanson and Stein (2015) use the two-year Treasury yield to construct a proxy for monetary policy news.
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.

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 in 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. This approach allows estimating time-varying reaction of monetary policy to the stock market and can also be used in other contexts, for example to estimate the response of monetary policy to commodity prices. Our results show that conventional monetary policy is more responsive to stock returns in bear markets and recessions. This finding is consistent with the existence of a “Fed put.” However, our belief is that the “Fed put” is likely a result of the Fed using financial markets as a leading macroeconomic indicator and is attempting a “soft landing.” That is, the Fed eases policy in response to the market downturn because the market downturn forecasts an increase in the likelihood of adverse macroeconomic conditions in the near future.
References


Table 1: Panel A
Response of monetary policy to stock returns

<table>
<thead>
<tr>
<th>Policy response ($\beta$)</th>
<th>Expansion</th>
<th>Recessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0051***</td>
<td>0.0106***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.00174)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.0389***</td>
<td>0.1309***</td>
</tr>
<tr>
<td></td>
<td>(0.0019)</td>
<td>(0.0245)</td>
</tr>
<tr>
<td>Test of over identifying restrictions</td>
<td>0.9022</td>
<td>0.2437</td>
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<td>N</td>
<td>4249</td>
<td>590</td>
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The sample period is from Oct. 1997 through September 2016. The Expansions and Recessions are based upon the NBER recession dates. The two recessions date from March 2001 – November 2001 and from December 2007 – June 2009. Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.

Table 1: Panel B
Response of monetary policy to stock returns

<table>
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<th>Policy response ($\beta$)</th>
<th>Expansion</th>
<th>Recessions</th>
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<tbody>
<tr>
<td></td>
<td>0.12***</td>
<td>0.011***</td>
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<tr>
<td></td>
<td>(0.03)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.051***</td>
<td>0.169**</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.03)</td>
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<td>Test of over identifying restrictions</td>
<td>0.55</td>
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<td>N</td>
<td>855</td>
<td>186</td>
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The sample period is from March 1997 through September 2016. The regimes are assigned based on the NBER business cycle dates. Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.

Table 1: Panel C
Response of monetary policy to stock returns

<table>
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<th>Policy response ($\beta$)</th>
<th>Expansion (Pre-2009)</th>
<th>Recessions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.008***</td>
<td>0.011***</td>
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<td></td>
<td>(0.0005)</td>
<td>(0.00174)</td>
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<tr>
<td>$\lambda$</td>
<td>0.0366***</td>
<td>0.1309***</td>
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<tr>
<td></td>
<td>(0.0011)</td>
<td>(0.0245)</td>
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<tr>
<td>Test of over identifying restrictions</td>
<td>0.93</td>
<td>0.2437</td>
</tr>
<tr>
<td>N</td>
<td>2378</td>
<td>590</td>
</tr>
</tbody>
</table>

The sample period is from Oct. 1997 through September 2016. The Expansions and Recessions are based upon the NBER recession dates. The two expansions date from Oct. 1997 - March 2001 and December 2001 - December 2007 – June 2009. Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.
Table 2
Response of monetary policy to stock returns during bull and bear markets

<table>
<thead>
<tr>
<th></th>
<th>Bull market</th>
<th>Bear Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy response ($\beta$)</td>
<td>0.003***</td>
<td>0.0124***</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0016)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.0356***</td>
<td>0.0869***</td>
</tr>
<tr>
<td></td>
<td>(0.0018)</td>
<td>(0.0128)</td>
</tr>
<tr>
<td>Test of overidentifying restrictions</td>
<td>0.4686</td>
<td>0.423</td>
</tr>
<tr>
<td>N</td>
<td>3834</td>
<td>939</td>
</tr>
</tbody>
</table>

The sample period is from October 1997 through September 2016. The financial crisis period is from September 2007 to December 2008. 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 December 2008 (inclusive). Standard errors are shown in parentheses. *p*-values are shown for the test of overidentifying restrictions. *** 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 returns and rate changes

Panel B. Co-movement of 15-minute returns and rate changes
Figure 2
Time-varying response of monetary policy to stock returns during the conventional policy period

The sample period is from October 1, 1997 to September 30, 2016. The blue lines are 1.65-standard-error bands. 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 end of conventional policy.
Figure 3
Time-varying response of monetary policy expectations to stock returns during the zero lower bound period

Estimation using 2-year Treasury futures rate

The sample period is from November 1, 1998 to September 30, 2016. The blue lines are 1.65-standard-error bands. 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 end of conventional policy.
Appendix: Robustness Tests using 2-year Treasury futures for all analysis

Table A1. Response of monetary policy to stock returns

<table>
<thead>
<tr>
<th></th>
<th>Expansion</th>
<th>Recessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy response ($\beta$)</td>
<td>0.012*** (0.001)</td>
<td>0.021*** (0.003)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.03*** (0.002)</td>
<td>0.13*** (0.021)</td>
</tr>
<tr>
<td>Test of over identifying restrictions</td>
<td>0.054</td>
<td>0.906</td>
</tr>
<tr>
<td>N</td>
<td>4149</td>
<td>590</td>
</tr>
</tbody>
</table>

The sample period is from Oct. 1997 through September 2016. The Expansions and Recessions are based upon the NBER recession dates. The two recessions date from March 2001 – November 2001 and from December 2007 – June 2009. Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.

Panel B: Response of monetary policy to stock returns

<table>
<thead>
<tr>
<th></th>
<th>Expansion</th>
<th>Recessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 1997 – March. 2001</td>
<td>0.015*** (0.002)</td>
<td>0.0158*** (0.005)</td>
</tr>
<tr>
<td>March 2001 – Nov. 2001</td>
<td>0.019*** (0.003)</td>
<td>0.02*** (0.003)</td>
</tr>
<tr>
<td>Dec. 2001 – Nov. 2007</td>
<td>0.0078*** (0.0007)</td>
<td></td>
</tr>
<tr>
<td>Dec. 2007 – June 2009</td>
<td>0.041*** (0.003)</td>
<td></td>
</tr>
<tr>
<td>Expansion July 2009 – Sept 2016</td>
<td>0.3301</td>
<td>0.49</td>
</tr>
<tr>
<td>Expansion</td>
<td>186</td>
<td>404</td>
</tr>
<tr>
<td>Expansion</td>
<td>1459</td>
<td>1871</td>
</tr>
</tbody>
</table>

The sample period is from March 1997 through September 2016. The regimes are assigned based on the NBER business cycle dates. Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.

Panel C: Response of monetary policy to stock returns

<table>
<thead>
<tr>
<th></th>
<th>Expansion</th>
<th>Recessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Pre-2009)</td>
<td>0.016*** (0.002)</td>
<td>0.021*** (0.003)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.037*** (0.002)</td>
<td>0.1318*** (0.0212)</td>
</tr>
<tr>
<td>Test of overidentifying restrictions</td>
<td>0.048</td>
<td>0.90</td>
</tr>
<tr>
<td>N</td>
<td>2300</td>
<td>590</td>
</tr>
</tbody>
</table>

The sample period is from Oct. 1997 through September 2016. The Expansions and Recessions are based upon the NBER recession dates. The two expansions date from Oct. 1997 - March 2001 and December 2001- December 2007 – June 2009. Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.
Table A2
Response of monetary policy to stock returns during bull and bear markets

<table>
<thead>
<tr>
<th></th>
<th>2-Year Treasury</th>
<th>Bull market</th>
<th>Bear Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy response ($\beta$)</td>
<td>0.0091***</td>
<td>0.023***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0009)</td>
<td>(0.0157)</td>
<td></td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.035***</td>
<td>0.010***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0024)</td>
<td>(0.0157)</td>
<td></td>
</tr>
<tr>
<td>Test of overidentifying restrictions</td>
<td>0.016</td>
<td>0.054</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>3759</td>
<td>980</td>
<td></td>
</tr>
</tbody>
</table>

The sample period is from October 1997 through September 2016. The financial crisis period is from September 2007 to December 2008. 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 December 2008 (inclusive). Standard errors are shown in parentheses. $p$-values are shown for the test of overidentifying restrictions. *** indicates statistical significance at 1% level.