

The Effects of Federal Funds Rate Surprises on S&P 500 Volatility and Volatility Risk Premium[‡]

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ABSTRACT

In this paper, we examine the effects of expected and surprise components in Federal funds target rate changes on realized and implied volatility. We find that surprise changes in the target rate significantly increase volatility. Consistent with the efficient market hypothesis, our analysis suggests that the expected component of a target rate change as well as the target rate change itself, do not significantly affect volatility. We also show that larger than expected decreases in the Federal funds target rate tend to lower the volatility risk premium.

KEYWORDS: Implied volatility, Realized volatility, Federal funds futures, Monetary policy surprises, Volatility risk premium.

JEL Codes: G11, G13, G14, E44, E52, E58.

[‡] We would like to thank the Editor (Christian Wolff) and two anonymous referees for helpful comments and insightful suggestions that greatly improved the contents and presentation of the paper. The first author gratefully acknowledges financial support from FQRSC, IFM2 and SSHRC. The second author gratefully acknowledges financial support from the American University of Beirut's University Research Board.

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1. INTRODUCTION

The effect of monetary policy on securities markets has been of key interest and importance to investors, policymakers, researchers and the financial press. Central bankers have long referred to the effects of monetary policy on financial variables. Analysts and pundits point to the pronounced reaction of the stock market to news regarding monetary policy. Stock markets respond, according to analysts and the financial press, to a multitude of monetary policy-related announcements such as regular meetings of the Federal Open Market Committee (FOMC), wording of FOMC statements, changes in Federal Reserve (Fed) leadership or changes in the stance and direction of monetary policy.

The academic literature (e.g., Mishkin, 2007) describes the channels through which monetary policy affects the stock market as well as the important role that asset markets play in the monetary transmission mechanism.¹ In particular, the flexibility of asset prices and the forward-looking nature of stock markets allows for an almost instantaneous impact of Fed actions on stock returns and volatilities.

The effects of monetary policy changes on financial variables are extensively discussed and documented in the literature. Cook and Hahn (1989), Thornton (1998), Kuttner (2001) and Cochrane and Piazzesi (2002) investigate the effect of monetary policy on interest rates. Thorbecke (1997), Patelis (1997), Goto and Valkanov (2002), D'Amico and Farka (2011), Zebedee, Bentzen, Hansen and Lunde (2008), Rigobon and Sack (2004), and Bernanke and

¹ A change in the federal funds rate is closely associated with changes in various short-term interest rates. This, in turn, influences the discount rate used to value the cash flows of different equities and may thus increase or decrease stock returns and volatility. A second channel through which monetary policy affects the stock market is through financial leverage: each rate change by the Fed changes the cost for firms to finance their activities through issuing debt. Both of these channels can impact stock market returns and volatilities.

Kuttner (2005) find that monetary policy surprises lead to lower stock returns. Another line of research (Basistha and Kurov, 2008; Bomfim, 2003; Chulia, Martens and van Dijk, 2010; Jansen and Tsai, 2010; Kurov, 2010) uncovers a significant effect of monetary policy on stock market volatility and investor sentiment and detects asymmetries in the response of financial variables to Federal funds rate surprises. In the context of foreign exchange markets, Fatum and Scholnick (2008) present evidence that monetary policy surprises significantly affect exchange rates.

A parallel literature examines the role of macroeconomic news and, more generally, the price discovery process in financial markets. Ederington and Lee (1993) relate macroeconomic announcements to time-of-day and day-of-the-week patterns in the volatility of interest rate and foreign exchange futures markets. Andersen, Bollerslev, Diebold and Vega (2003) investigate the response of the U.S. spot exchange rate to macroeconomic announcements and examine asymmetries with respect to the sign of the news. Andersen, Bollerslev, Diebold and Vega (2007) explore the effect of U.S. macroeconomic news on the returns, correlations and volatilities of U.S. and foreign stock, bond and foreign exchange futures markets. Bollerslev, Cai and Song (2000) provide evidence of a significant response of the volatility of U.S. Treasury bond futures to macroeconomic announcements. Boyd, Hu and Jagannathan (2005) closely inspect the effect of unemployment news on stock market returns across the states of the business cycle and report evidence of the importance of interest rates during economic expansions.

In this paper, we examine the effects of the expected and surprise elements of Federal funds rate changes on stock returns and two measures of stock market volatility: option implied volatility, as measured by the VIX index, as well as realized volatility computed from daily stock returns. Our paper makes several contributions to the literature. First, a novel aspect of our paper

is that it studies the reaction of both implied and realized volatilities to monetary policy surprises. While previous research focuses on examining the response of realized volatility to monetary policy surprises, our findings tend to suggest that monetary policy shocks increase implied volatility. We attribute this finding to the possible presence of risk premiums and argue that the increase in both measures of volatility is due to the leverage effect. Second, we show that larger than expected decreases in the Federal funds target rate tend to lower the volatility risk premium. Our results indicate that a 25 basis points Federal funds rate surprise decreases the volatility risk premium by 1.1 to 3.7 percentage points depending on the surprise measure employed. Third, to the best of our knowledge, this is the first paper to report a significant increase in implied volatility due to Federal funds rate surprises. While some existing studies (Nikkinen and Sahlstrom, 2004; Carr and Wu, 2006; Chen and Clements, 2007) examine the behaviour of implied volatility around FOMC announcement days, they do not distinguish between the expected and surprise components of a target rate change or examine the effect of monetary policy surprises on realized volatility. Furthermore, we report that at monthly frequency, the Federal funds rate surprises and macroeconomic factors significantly affect implied volatility but not realized volatility.

In this study, we capitalize on the availability of implied volatility indices to treat volatility as an observable rather than a latent process. It is generally believed that examining and modeling implied volatility could be more insightful than examining realized volatility for several reasons. First, implied volatility can be interpreted as market uncertainty (Whaley, 2000) and thus possesses a richer informational content than other measures of volatility (Poon and Granger, 2003). Second, derivatives contracts written on the VIX index are actively traded on the Chicago Board Options Exchange (CBOE) and the steady trading volume growth of these

derivatives contracts makes examining the factors affecting implied volatility even more timely.² This distinguishing feature of implied volatility proves to be of great practical importance for investors seeking to treat volatility as an underlying asset rather than an unobservable measure.

Two papers that are closely related to ours are by Chulia, Martens and van Dijk (2010) and Lunde and Zebedee (2009). Both studies examine the effect of surprise and expected components of target rate changes on realized volatility computed from high frequency returns. While our paper also employs realized volatility computed from squared daily returns, we complement the findings of these studies by showing a significant effect of Federal funds rate surprises on a different and arguably more relevant measure of volatility: namely, implied volatility. An advantage of studying the response of both measures of volatility is the ability to examine whether implied and realized volatilities respond differently to monetary policy surprises. Also, availability of data on both implied and realized volatilities allows us to construct the volatility risk premium and analyze its response to monetary policy surprises. Moreover, Chulia, Martens and van Dijk (2010) and Lunde and Zebedee (2009) use high frequency data to discern the effect of surprises on volatility. Although interesting and useful in many respects, the use of high frequency data only considers the effects of shocks on volatility in a very narrow time window. Our results show that the response of volatility is longer lived and suggest that such a response could be more informative from a trading and policy perspective.

The rest of the paper is organized as follows. Section 2 describes the data and the construction of monetary policy surprises. Section 3 reports and discusses the results from the empirical analysis. Section 4 offers some concluding remarks.

² Hull (2006) provides a textbook treatment of different trading strategies involving put and call options (such as straddles and strips) for a given forecast of implied volatility. Since options written on the S&P 500 index are widely available, such trading strategies can obviously be used by profit seeking investors.

2 DATA AND VARIABLE DESCRIPTION

2.1 Daily and monthly data

The daily analysis undertaken in this paper is an event study, while the monthly analysis is a regular time series analysis. The daily data used in the paper³ consist of observations on (i) VIX or realized volatility levels, (ii) returns on the S&P 500 index (iii) actual target rate change, and (iv) expected and surprise components of a target rate change for all dates on which there is a meeting of the Federal Open Market Committee (FOMC)⁴ for the period February 4, 1994 to December 11, 2007. Thus, we define “an event” as a meeting of the FOMC. The period under consideration spans a total of 116 meetings of the FOMC of which 31 involved target rate increases, 21 involved target rate decreases and 64 resulted in no target rate change. The data comprise changes of 25 basis points, 50 basis points or 75 basis points in the Federal funds target rate. We omit the observation for the September 17, 2001 FOMC inter-meeting from our sample, as in Bernanke and Kuttner (2005) and others, since this is the first day of trading following the September 11th attacks. Our sample includes both regularly scheduled and unscheduled meetings of the FOMC. The construction of the surprise and expected components of a target rate change makes use of Federal funds futures data as detailed in Section 2.3.

A monthly analysis is undertaken using a dataset covering the period January 1994 to December 2007. Monthly data on interest rates and macroeconomic variables are obtained from the Federal Reserve Bank of St. Louis Economic Database (FRED). The dataset consists of the

³ Data on federal funds futures prices, which are employed to compute the daily and monthly expected and surprise components of a target rate change, are purchased from the Commodity Research Bureau (CRB). Data on the levels of the VIX index is obtained from the website of the Chicago Board Options Exchange (CBOE), while federal funds target rate data are obtained from the Federal Reserve Bank of St. Louis Economic Database (FRED).

⁴ We note that prior to 1994, the Fed did not announce a Federal funds target rate. We avoid this pre-1994 lack of transparency in FOMC actions by starting our sample in 1994. The dates of FOMC meetings, FOMC minutes as well as target rate decisions can be found on the Board of Governors’ website: <http://www.federalreserve.gov/monetarypolicy/fomc.htm>.

monthly level of realized and implied volatility (sampled at the end of the month), the monthly measure of the expected and surprise components of a target rate change, as well as macroeconomic variables such as industrial production growth, employment growth and inflation. We also employ Federal funds futures data to construct the expected and surprise components of a target rate change at the monthly level. The details of the computation are provided in Section 2.4.

2.2 S&P 500 implied and realized volatility

The measure of implied volatility used throughout this paper is the Chicago Board Options Exchange's (CBOE) VIX implied volatility index. The VIX's construction is based on a weighted average of out-of-the-money, European-style puts and calls written on the S&P 500 index with a wide range of strikes. The VIX index has a constant thirty calendar day expiry and its construction is model independent. A review of the construction, properties and interpretation of the VIX index can be found in Carr and Wu (2006), Whaley (2000), and Fleming, Ostdiek and Whaley (1995).

In addition to option implied volatility, realized volatility computed from daily returns on the S&P 500 index is employed. Following Gospodinov, Gavala and Jiang (2006), a rolling sample of overlapping daily squared return data is used in constructing realized volatility as

$$RV_{d,\tau} = \sqrt{\frac{1}{\tau} \sum_{i=d+1}^{\tau} r_i^2}, \quad (1)$$

where $r_d = \ln(P_d) - \ln(P_{d-1})$ denotes the continuously compounded returns on the S&P 500 index, P_d denotes the closing price on the S&P 500 index on day d of month t and $\tau = 22$. As

noted in Gospodinov, Gavala and Jiang (2006), computing realized volatility as in equation (1) allows for direct comparisons between realized and implied volatility.⁵

2.3 Measuring daily monetary policy surprises from Federal funds futures

Federal funds futures, officially known as thirty-day interest rate futures, are in essence futures contracts that settle on the average of the month's overnight Federal funds rate. The contract is cash-settled daily (i.e., it is marked to market) and the initial contract size is five million dollars. Default risk in Federal funds futures is negligible due to cash settlement and collateral requirements. Federal funds futures contracts trade on the Chicago Board of Trade (CBOT) where contracts for several different deliveries exist. Krueger and Kuttner (1996), Gurkaynak, Sack and Swanson (2007) and Hamilton (2009) test for unbiasedness and rationality in the Federal funds futures market and find that Federal funds futures rates are excellent predictors of the Federal funds rate.

In this paper, we use Kuttner's (2001) method for measuring monetary policy shocks from Federal funds futures rates. Let $f_{t,d}^0$ denote the nearest maturity futures rate on day d of month t . Kuttner's (2001) proposed surprise component on day d of month t (for each target rate change by the FOMC) is given by:

$$\Delta i^{u,0} = \frac{D}{D-d} (f_{t,d}^0 - f_{t,d-1}^0), \quad (2)$$

where D denotes the number of days in month t with $d=1,\dots,D$ and $t=1,2,\dots,12$.⁶ This surprise measure is referred to as the *current month surprise*.

⁵ The realized volatility is annualized with the multiplication factor $\sqrt{252}$.

Poole and Rasche (2000) recommend the use of an unscaled, one-day change in the one-month-ahead futures rates to measure monetary policy surprises. Let $f_{t,d}^1$ denote the one-month-ahead futures rate for month t and day d . Then, Poole and Rasche's (2000) surprise is computed as:

$$\Delta i^{u,1} = f_{t,d}^1 - f_{t,d-1}^1. \quad (3)$$

The Poole and Rasche (2000) measure avoids scaling, and arguably contains more information since its computation involves longer dated futures contract which are more informative about monetary policy expectations at a longer horizon. This surprise measure is referred to as the *one-month-ahead surprise*.

Gurkaynak, Sack and Swanson (2007) (see also, Gurkaynak, Sack and Swanson, 2005; and Gurkaynak, 2005) also suggest incorporating futures price information past the current month. They propose an appropriately weighted difference between the current month surprise and the one-day change in the futures rate from the month containing the next FOMC meeting. Gurkaynak, Sack and Swanson's (2007) monetary policy surprise is computed as:

$$\Delta i^{u,2} = \frac{D_2}{D_2 - d_2} [(f_{t,d}^2 - f_{t,d-1}^2) - \frac{d_2}{D_2} \Delta i^{u,0}], \quad (4)$$

where $f_{t,d}^2$ is the futures rate from the month containing the next FOMC meeting, and d_2 and D_2 are the day of the next of FOMC meeting and the number of days in the month containing the next FOMC meeting, respectively. The surprise measure in equation (4) has the advantage of

⁶ As in Kuttner (2001), we construct the surprise component of a target rate change using equation (1), but use the unscaled change in the one-month-ahead futures rate when the target change occurs during the last seven calendar days of the month. When the change in the target rate occurs on the first day of the month, the one-month futures rate from the last day of the previous month is employed instead of $f_{t,d-1}^0$.

not being subject to the timing surprise (the surprise with regard to the timing of the Fed's next move). Below we refer to this surprise measure as the *two-month-ahead surprise*.⁷

The summary statistics for our daily data are presented in Table 1. Panel A of Table 1 provides information regarding the number of FOMC meetings in our sample, the average target rate change at those meetings as well as the average surprise as computed in equations (2), (3) and (4).

[Insert Table 1 here]

In line with previous studies, the level of realized volatility tends to be lower than the level of implied volatility. Interestingly, Table 1 shows that for negative changes in the target rate, the level of realized or implied volatility is substantially higher than its corresponding level for positive rate changes. Also, the change in volatility is, on average, larger for negative target rate changes. Returns on the S&P 500 index also tend to be larger following negative rate changes.

The current month and one-month-ahead surprise measures computed using equations (2) and (3) are highly correlated (the correlation coefficient is 0.96) while the surprise measures in equations (2) and (4) display a weaker correlation of 0.39. The surprise measures in equations (3) and (4) display a correlation coefficient of 0.52. We note that the positive correlation between the monetary policy surprises is expected by construction. More specifically, the computations for the current month and one-month-ahead surprises are identical when the FOMC meeting occurs towards the end the end of month. When the next FOMC meeting takes place during the next month, this also creates an overlap between the one-month-ahead and two-months-ahead surprises. The overlap in the construction of the various surprises leads to a positive correlation between them.

⁷ We note that this surprise has also been referred to in the literature (e.g., Gurkaynak, 2005; Gurkaynak, Sack and Swanson, 2007; and Kurov, 2010) as the level surprise.

For each of the surprise components of target rate changes in equations (2), (3) and (4), the expected component of a policy rate change can be calculated as the difference between the actual target rate change by the Fed and the unexpected part of the rate change:

$$\Delta i^{e,j} = \Delta i - \Delta i^{u,j}, j = 0,1,2, \quad (5)$$

where Δi denotes the target rate change by the Fed and $\Delta i^{u,j}$ denotes one of the surprise measures described above.

2.4 Measuring monthly monetary policy surprises from Federal funds futures

Monthly monetary policy surprises are also computed from Federal funds futures data. We follow Bernanke and Kuttner (2005) and define the monthly surprise as the difference between the average target rate for month t and the one-month futures rate on the last day of month $t-1$:

$$\bar{\Delta i}_t^u = \frac{1}{D} \sum_{d=1}^D i_{t,d} - f_{t-1,D}^1, \quad (6)$$

where $i_{t,d}$ denotes the Federal funds target rate on day d of month t , $f_{t-1,D}^1$ is the futures rate from the last day of month $t-1$ and D denotes the last day of month t and, hence, the number of days in month t . In turn, a measure of the monthly expected component of a target rate change can be computed as the difference between the futures rate on the last day of month $t-1$ and the Federal funds rate target on the last day of month $t-1$:

$$\bar{\Delta i}_t^e = f_{t-1,D}^1 - i_{t-1,D}. \quad (7)$$

In contrast to daily surprises, the monthly surprises are regularly spaced and thus form typical time series data to which time series methods can be applied.

3 ECONOMETRIC METHODOLOGY AND RESULTS

3.1 The response of volatility to Federal funds rate surprises: daily analysis

In order to investigate the effect of Federal funds target rate changes on implied volatility, event study regressions similar to those used in Bernanke and Kuttner (2005) and Chulia, Martens and van Dijk (2010) are employed. Let V_t denote the realized or implied volatility level on the day of the target change⁸ and $\Delta V_t = V_t - V_{t-1}$ be the change in the level of volatility between the day of the target rate change and the previous day. The response of volatility to target rate changes is estimated using the following regression model:⁹

$$\Delta V_t = \alpha + \beta \Delta i_t + \varepsilon_t. \quad (8)$$

The target rate change is then decomposed into an expected and a surprise component and the effect of each component on implied volatility is studied using the following regression model:

$$\Delta V_t = \alpha + \beta^e \Delta i_t^e + \beta^u \Delta i_t^u + \varepsilon_t. \quad (9)$$

First differences of volatility are used for compatibility with the previous literature (e.g., Chen and Clements, 2007; Chulia, Martens and van Dijk, 2010; Fleming, OstDiek and Whaley, 1995; Nikkinen and Sahlstrom, 2004). Since the presence of a unit root in implied volatility is strongly rejected by the data (the results are available from the authors upon request), this transformation induces over differencing and gives rise to a moving average component in the residuals of equations (8) and (9). Therefore, Newey and West's (1987) heteroskedasticity and autocorrelation

⁸ For the sake of notational simplicity, we abstract from indexing by days throughout the methodology section and use instead the subscript t to denote time. For the daily event study analysis, it is implied that this refers to a specific day d in month t (when the target change occurs) while such a distinction is not needed for the monthly analysis. We also abstract from assigning a superscript to refer to a specific daily surprise measure, since the models are always estimated for the three daily surprise and expected measures described in Section 2.3.

⁹ We opt to use changes in implied or realized volatility as dependent variables in equations (8) and (9) to circumvent problems associated with the high persistence of both volatility measures (see Table 1) and to be consistent with prior studies. Defining the change in the log levels of volatility as a dependent variable in equations (8) and (9) also produces similar results.

consistent (HAC) standard errors are used to ensure valid inference. Additionally, we employ daily compounded returns on the S&P 500 index as a dependent variable in equations (8) and (9) in order to measure the response of stock market returns to monetary policy surprises over the same period.

The results from estimating equations (8) and (9) for S&P 500 returns, change in implied volatility and change in realized volatility are reported in Panels A, B and C of Table 2.

[Insert Table 2 here]

The estimates from the daily regression (8) suggest that the change in the Federal funds target rate has a positive, but statistically insignificant (at 5% level) effect on implied (realized) volatility as a unit percentage change in the Federal funds target rate tends to increase the change in VIX (realized) volatility by 1.08 (0.92) percentage points. In line with previous studies (Bernanke and Kuttner, 2005), we find that a target rate change affects returns negatively but insignificantly.

Table 2 also reports the results when the target rate change is decomposed into an expected and a surprise component and some interesting observations emerge from this decomposition. The results indicate that the expected component of a rate change has a statistically insignificant effect while the surprise component has a large, positive and significant effect on volatility. In particular, a percentage point Federal funds rate surprise increases the change in VIX (realized volatility) by 2.80 to 8.04 (1.48 to 7.08) percentage points depending on the surprise measure used.

The insignificant coefficient associated with the expected rate change is consistent with the market efficiency hypothesis which entails a response of financial variables only to new information arrivals. Furthermore, the positive, large and statistically significant coefficient of

the surprise rate change suggests that investors adjust their portfolio allocation in light of the “news” contained in the monetary policy change which increases trading and, in turn, volatility.

Our results regarding the effect of Federal funds rate surprises on stock returns confirm those of previous studies (Bernanke and Kuttner, 2005; Chulia, Martens and van Dijk, 2010; Zebedee, Bentzen, Hansen and Lunde, 2008) in that the surprise element of a target rate change decreases stock returns. Our finding that stock returns and volatility only respond to Federal funds rate surprises but not to the expected component of a rate change are also in line with the efficient markets hypothesis (e.g., Bernanke and Kuttner, 2005; Chulia, Martens and van Dijk, 2010) according to which a forward-looking, efficient stock market should only respond to the arrival of new information. However, the results reported in Table 2 complement the existing literature by assessing the response of both implied and realized volatility to Federal funds rate surprises. An interesting feature of the results in Table 2 is that implied and realized volatilities appear to react differently to monetary policy surprises. In order to test statistically if implied and realized volatility respond differently to monetary policy shocks, we employ a bivariate system of seemingly unrelated regressions (SUR) with changes in implied and realized volatility as dependent variables and Federal funds rate surprises as independent variables.¹⁰ The results from the Wald test of equality of the parameters associated with each of the surprise measures reveal that the null cannot be rejected at conventional levels of significance which suggests that the two volatility measures do not exhibit a differential reaction to monetary policy shocks.

In order to control for the effect of macroeconomic news that are released on the same day as FOMC meetings on volatility, we re-estimate equation (9) while including as regressors the surprise components of a number of important macroeconomic announcements. As

¹⁰ We thank an anonymous referee for suggesting this test. The results are available from the authors upon request.

commonly used in the literature (e.g., Fatum and Scholnick, 2008; Andersen, Bollerslev, Diebold and Vega, 2003, 2007), we measure expectations for non-farm payroll employment, the consumer price inflation and the change in industrial production using the Money Market Services (MMS) survey. The surprise component of each macroeconomic release is computed as the difference between the actual announcement (or as reported) value and the median forecast of about forty money market managers surveyed by MMS. More specifically, let $A_{k,d}$ and $E_{k,d}$ denote, respectively, the announced value and median forecast value for the k^{th} macroeconomic announcement on day d . The surprise component of the k^{th} macroeconomic announcement is computed as $S_{k,d} = A_{k,d} - E_{k,d}$. Equation (9) is then augmented to control for the surprise component in each macroeconomic announcement as:

$$\Delta V_t = \alpha + \beta^e \Delta i_t^e + \beta^u \Delta i_t^u + X_t' \beta + \varepsilon_t, \quad (10)$$

where the vector X_t includes the surprise component of the macroeconomic release on the days in which it coincides with FOMC meetings, and takes on the value of zero when the FOMC meeting and the macroeconomic announcement occur on different days.¹¹

The results from estimating equation (10) using changes in implied and realized volatility as dependent variables are reported in Panels A and B of Table 3, respectively.

[Insert Table 3 here]

The results in Table 3 indicate that the significance of the coefficients associated with the Federal funds rate surprises is maintained for both realized and implied volatility when the macroeconomic surprises are controlled for. We note, however, that implied volatility no longer

¹¹ A similar approach is used by Fatum and Scholnick (2008) to control for the macroeconomic surprises.

exhibits a larger response to monetary policy surprises, relative to realized volatility, when the macroeconomic news are included in the regression.

We also advance a simple interpretation of our results that is in agreement with Bernanke and Kuttner (2005) who find that a Federal funds rate surprise decreases stock market returns. Bernanke and Kuttner (2005) argue that a funds rate surprise decreases stock returns due to either an increase in the discount rate used to value cash flows (dividends) from stocks, an increase in the equity premium or a decrease in expected future dividends. Regardless of the exact channel through which surprises affect stock returns, we posit that due to the well-known negative correlation between returns and volatility (“leverage effect”), a decrease in stock returns will translate into higher volatility. We turn next to assessing the effect of monetary policy surprises on the difference between implied and realized volatility and to investigating whether monetary policy surprises affect stock market volatility through the returns channel.

3.2 The volatility risk premium and monetary policy surprises

The efficiency, unbiasedness and predictive content of implied volatility for future realized volatility has been investigated in a number of studies (e.g. Bandi and Perron, 2006; Chernov, 2007; Christensen and Prabhala, 1998; Gospodinov, Gavala and Jiang, 2006; among others) with somewhat mixed results. The general consensus emerging from these studies favours the view that implied volatility is a useful, albeit biased, predictor of future realized volatility.

A growing line of research relates the rejection of the unbiasedness of implied volatility to the presence of volatility risk premiums. Bollerslev, Gibson and Zhou (2011), Bollerslev, Tauchen and Zhou (2009), Carr and Wu (2009) and Chernov (2007) provide theoretical and empirical accounts of the presence, determinants and magnitude of volatility risk premiums.

Given that implied volatility can be perceived as investors' forecast of future realized volatility, we define the volatility risk premium as the difference between implied and realized volatility. In this section, we turn to exploring the effect of Federal funds rate surprises on the volatility risk premium. Our interest in studying the response of the volatility risk premium to Federal funds rate surprises stems from identifying the effect of monetary policy on the volatility risk premium and, more generally, market-wide risk aversion.

Following Bollerslev, Tauchen and Zhou (2009) we define the volatility risk premium as the difference between implied and realized volatility:

$$VRP_t = IV_t - RV_t, \quad (11)$$

where IV_t denotes the level of implied volatility observed using the “model-free” VIX index and RV_t denotes the level of realized volatility. The effect of Federal funds rate surprises is studied using the same regression framework as (9):

$$VRP_t = \alpha + \beta^e \Delta i_t^e + \beta^u \Delta i_t^u + \varepsilon_t. \quad (12)$$

Panel A of Table 4 reports the results from estimating equation (12) using the surprise measures defined in equations (2), (3) and (4).

[Insert Table 4 here]

The results in Table 4 indicate that the Federal funds rate surprises significantly affect the volatility risk premium while the expected component of a target rate change does not. A positive surprise of 25 basis points leads to a drop (ranging from 1.1 to 3.7 percentage points) in the volatility risk premium.

Next, we explicitly relate macroeconomic news to the volatility risk premium by re-estimating equation (12) while including as regressors the surprise components of the employment, inflation and industrial production releases. Equation (12) is rewritten as:

$$VRP_t = \alpha + \beta^e \Delta i_t^e + \beta^u \Delta i_t^u + X_t' \beta + \varepsilon_t, \quad (13)$$

where the vector X_t is defined in the same manner as equation (10). The results from estimating equation (13), reported in Panel B of Table 4, indicate that, even when controlling for the macroeconomic factors, the effect of the Federal funds rate surprises on the volatility risk premium remains highly significant for the current month and one-month-ahead surprise measures. Furthermore, while the surprise component of non-farm payroll employment and industrial production significantly affect the volatility risk premium, the effect of the unexpected component of consumer price inflation is not significant.

The results in Table 2 suggest that Federal funds rate surprises tend to increase (the changes of) implied and realized volatility, while Table 4 points to a decrease in the volatility risk premium due to a monetary policy surprise. Whereas these findings may appear contradictory at first, we note the results from the volatility risk premium regression in equation (12) are consistent with those we obtain when the levels of volatility are used as dependent variables in equations (9). Furthermore, several studies (Bollerslev, Andersen, Diebold and Vega, 2003; Chulia, Martens and van Dijk, 2010) provide empirical evidence suggesting the presence of important asymmetries in the response of returns and realized volatility to the sign of macroeconomic and monetary policy news at the intra-daily level. To the extent that the response of the volatility risk premium to the sign of the Federal funds rate surprise exhibits similar asymmetries, this can shed further light on the dynamics of the volatility risk premium and contribute to a more complete understanding of the results in Tables 2 and 4.

Intuitively, the sign of the Federal funds rate surprise conveys important information to stock market participants regarding the monetary policy stance (expansionary or contractionary). A negative Federal funds rate surprise implies that the Fed decreased the target rate more than market participants expect (thus signalling expansionary monetary policy) and constitutes positive news to stocks due to the lower than expected discount rate used to value future cash flows (dividends). Conversely, a positive target rate surprise can be viewed as negative news to stocks.

We further modify equations (9) and (12) to account for possible asymmetries in the response of volatility and the volatility risk premium to the sign of Federal funds rate surprise by decomposing the surprise into positive and negative changes. More specifically, we estimate the following regression model:

$$y_t = \alpha + \beta^e \Delta i_t^e + \beta^{u-} \Delta i_t^u + \delta^u \Delta i_t^u D(\Delta i_t^u > 0) + \varepsilon_t, \quad (14)$$

where y_t is ΔIV_t , ΔRV_t or VRP_t , $D(\cdot)$ denotes an indicator (dummy) variable that takes the value one when the Federal funds rate surprise is positive and $\delta^u = \beta^{u+} - \beta^{u-}$. The coefficient β^{u-} gives the response of volatility (volatility risk premium) to negative surprises whereas the significance of the coefficient δ^u allows us to determine whether the response of the three variables exhibits asymmetries with respect to the sign of the surprise.

[Insert Table 5 here]

The results from estimating equation (14), presented in Table 5, reveal that realized volatility and the volatility risk premium exhibit a significant asymmetric response to the sign of the Federal funds rate surprise. In contrast, evidence of asymmetries in the response of implied volatility is weak at the daily level. A negative Federal funds rate surprise tends to decrease the

volatility risk premium and to increase realized and implied volatility. Bollerslev, Gibson and Zhou (2011) and Rosenberg and Engle (2002) show that the volatility risk premium positively correlates with market-wide risk aversion while Bekaert, Hoerova and Lo Duca (2010) argue that an expansionary monetary policy shock leads to a decrease in risk aversion. Our results are therefore consistent with Bekaert, Hoerova and Lo Duca (2010) and also suggest that expansionary monetary policy decreases risk aversion.

3.3 The leverage effect

An additional interesting feature of the results in Table 2 is the converse response of returns and volatility to Federal funds rate surprises. Although numerous studies establish each of these effects individually for returns and realized volatility (Bernanke and Kuttner, 2005; Chulia, Martens and van Dijk, 2010), our aim is to assess whether the effect of Federal funds rate surprises on volatility is due to its effect on returns.

The asymmetric relationship between stock market returns and volatility, referred to as the “leverage effect”, has been widely documented in the literature (Black, 1976; Christie, 1982; among others). Fleming, Ostdiek and Whaley (1995) demonstrate the presence of a similar asymmetric relationship between implied volatility and stock market returns. We build upon Fleming, Ostdiek and Whaley (1995) and investigate if accounting for the leverage effect diminishes the impact of Federal funds rate surprises on stock returns or volatility. To that end, the following two regressions are estimated:

$$r_{d,t} = \alpha + \beta^e \Delta i_{d,t}^e + \beta^u \Delta i_{d,t}^u + \beta_v \Delta V_{d,t} + \varepsilon_{d,t} \quad (15)$$

$$\Delta V_{d,t} = \alpha + \sum_{i=-2}^2 \beta_s r_{d+i,t} + \beta_{|s|} |r_{d,t}| + \beta^e \Delta i_{d,t}^e + \beta^u \Delta i_{d,t}^u + \varepsilon_{d,t} \cdot \quad (16)$$

Equation (15) relates stock market returns to the change in volatility and the expected and surprise components of a target rate change. Equation (16) employs Fleming, Ostdiek and Whaley's (1996) framework where the change in volatility is regressed onto two lags and leads of returns, the contemporaneous return and the absolute value of the contemporaneous returns. In addition to returns, we add the expected and surprise components of a target rate change to the regression.

Table 6 reports the results from estimating equations (15) and (16).

[Insert Table 6 here]

A number of observations emerge from these results. First, the negative correlation between implied volatility and returns found in previous studies is confirmed. Second, including implied volatility in equation (15) does not diminish the significance of the Federal funds rate surprise on returns while adding returns as an explanatory variable to equation (16) eliminates the effect of the surprise on volatility. Taken together, our findings point to the importance of the return channel in the effect of Federal funds rate surprises on implied volatility. A more complete investigation of the channels through which Federal funds rate surprises affect volatility would require a richer dynamic model that is beyond the scope of this study.¹²

3.3 The response of volatility to Federal funds rate surprises: monthly analysis

A regular time series regression, similar to equation (9), is employed to measure the effect of monthly Federal funds rate surprises on implied and realized volatility. Following Bandi and Perron (2006), monthly realized volatility is constructed from squared daily returns as:

¹² For example, the duration and the dynamics of the response of implied volatility to Federal funds rate surprises would be of great practical importance for both investors and policy makers. This can be studied using impulse response analysis in vector autoregressive models as in Gospodinov and Jamali (2011).

$$RV_{d,t} = \sqrt{\frac{1}{n_t} \sum_{d=1}^{n_t} r_d^2} \times 252, \quad (17)$$

where n_t denotes the number of trading days in month t and r_d denotes the continuously compounded returns on the S&P 500 index. In line with our daily analysis, we define the volatility risk premium to be the difference between implied and realized volatilities. Using our monthly dataset, the effect of Federal funds rate changes on implied or realized volatility is studied using the following regression:

$$\Delta V_t = \alpha + \beta \Delta i_t + \varepsilon_t. \quad (18)$$

The effects of the monthly surprise and expected components on volatility are investigated using the following regression:

$$\Delta V_t = \alpha + \beta^e \bar{\Delta i}_t^e + \beta^u \bar{\Delta i}_t^u + X_t' \beta + \varepsilon_t, \quad (19)$$

where X_t denotes a vector of macroeconomic variables. Equations (18) and (19) are also estimated with monthly returns on the S&P 500 index and the volatility risk premium as dependent variables. In light of the previous empirical evidence suggesting that macroeconomic news affect the volatility risk premium, we include in the vector X_t the growth rate of nonfarm employment, the growth rate of industrial production, and the consumer price inflation.

Panel A of Table 7 presents the results from estimating equation (18) for S&P 500 returns, changes in implied and realized volatilities and the volatility risk premium. The results from estimating equation (19) for all three variables are reported in Panel B of Table 7.

[Insert Table 7 here]

Similarly to the event study regressions (8) and (9), the results in Panel A of Table 7 indicate that an expected Federal funds rate change does not significantly affect returns, implied/realized

volatility or the volatility risk premium. In contrast, the monthly monetary surprise significantly decreases both the volatility risk premium and stock returns while it increases implied volatility. Realized volatility also increases, albeit insignificantly, due to the monetary policy surprise. More specifically, a percentage point monthly surprise decreases the volatility risk premium by 9.72 percentage points while it increases the change in implied (realized) volatility by 6.94 (6.19) percentage points. The monthly results agree with those obtained from the daily analysis in that the monthly monetary policy surprise decreases the volatility risk premium while increasing realized and implied volatility.

When the macroeconomic factors are added to the equations, the parameter estimates indicate a statistically significant increase in implied volatility of 7.23 percentage points due to a percentage point increase in the monthly surprise and a significant decrease of 11.10 percentage points in S&P 500 returns. The monthly surprise significantly increases implied volatility and bears similarity, in terms of the magnitude of the response, to the coefficient from the daily regressions. Also, while only the inflation rate has a statistically significant impact on realized volatility, both the inflation rate and industrial production growth enter significantly the monthly regressions for implied volatility. The significance of the macroeconomic variables in the monthly regressions provides suggestive evidence that the macroeconomic risks are priced in implied volatility and point again to the presence of a volatility risk premium.

4. CONCLUSION

This paper investigates the response of implied and realized volatility to Federal funds rate surprises. Our analysis takes into account market expectations, obtained from Federal funds futures contracts, in order to disentangle the expected and surprise elements of each Federal

funds target rate change. Implied volatility responds positively and significantly across various specifications to Federal funds rate surprises, while it does not respond to the expected component of a target rate change. In addition, our results suggest that larger than expected decreases in the Federal funds target rate tend to lower the volatility risk premium.

We perform a monthly analysis of the relationship between volatility and Federal funds rate surprises. Monthly surprises significantly affect returns, implied volatility and the volatility risk premium, while the effect of the expected component of monetary policy appears insignificant. These results continue to hold after controlling for macroeconomic announcements even though returns, implied volatility and volatility risk premium are shown to be significantly affected by some macroeconomic factors.

From an economic policy perspective, the results show that the volatility reaction to the Fed surprise rate changes is economically and statistically significant. A large literature in macroeconomics examines the effect of monetary policy transparency on the economy. A similar analysis might be of interest in our context. For instance, even though the FOMC became more transparent in the post-1994 period, this did not translate into Fed actions that do not affect stock market volatility. If lower volatility is a desirable outcome, then central banks should become more effective at communicating not only their current policy stand, but more importantly, their expected future course of action.

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Table 1

Descriptive statistics for daily and monthly data

<i>Panel A: Sample Means</i>				
	Daily Data			
	Full Sample	Positive Rate Change	No Rate Change	Negative Rate Change
Number of FOMC Meetings	116	31	64	21
Target Rate Change	1.50	29.83	0.00	-35.71
Current Month Surprise	-1.16	2.50	-0.96	-7.18
One-Month-Ahead Surprise	-1.18	1.45	-0.53	-7.07
Two-Months-Ahead Surprise	-1.42	-2.38	-0.12	-4.38
Returns on the S&P 500	0.29	0.24	0.20	0.65
Level of VIX	19.53	15.37	20.05	24.10
Change in VIX (Δ VIX)	-0.55	-0.33	-0.52	-0.98
Realized Volatility (RV)	15.33	12.23	15.88	18.21
Change in Realized Volatility (Δ RV)	-0.17	-0.20	0.04	-0.79

<i>Panel B: Standard Deviations and First-Order Autocorrelations</i>				
	Daily Data		Monthly Data	
	Standard Deviation	Autocorrelation	Standard Deviation	Autocorrelation
Returns on the S&P 500	1.16	0.00	4.05	0.00
Level of VIX	6.73	0.98	6.56	0.84
Change in VIX (Δ VIX)	1.28	0.00	3.67	-0.09
Realized Volatility (RV)	7.24	0.98	7.08	0.69
Change in Realized Volatility (Δ RV)	1.13	0.17	5.51	-0.28

Notes: The table provides summary statistics for the daily event study and monthly data for the period 1994 to 2007. Panel A reports the sample means of all the variables except for the number of FOMC meetings. Target rate changes and surprises are measured in basis points. Volatility and returns are measured in percent.

Table 2

Response of returns, implied and realized volatility to Federal funds rate surprises

<i>Panel A</i>		<i>Returns on S&P 500</i>					
<i>Independent Variables/Surprise</i>	<i>Current Month</i>		<i>One-Month-Ahead</i>		<i>Two-Months-Ahead</i>		
Constant	0.30*** (0.09)	0.17* (0.10)	0.30*** (0.09)	0.16 (0.10)	0.30*** (0.09)	0.16 (0.10)	
Target Rate Change	-0.73 (0.45)	-	-0.73 (0.45)	-	-0.73 (0.45)	-	
Expected Change	-	0.89* (0.49)	-	0.82 (0.48)	-	-0.11 (0.44)	
Surprise Change	-	-8.28*** (1.83)	-	-9.62*** (1.81)	-	-4.32** (1.76)	

<i>Panel B</i>		<i>ΔVIX</i>					
<i>Independent Variables/Surprise</i>	<i>Current Month</i>		<i>One-Month-Ahead</i>		<i>Two-Months-Ahead</i>		
Constant	-0.57*** (0.10)	-0.47*** (0.10)	-0.57*** (0.10)	-0.45*** (0.10)	-0.57*** (0.10)	-0.46*** (0.10)	
Target Rate Change	1.08* (0.56)	-	1.08* (0.56)	-	1.08* (0.56)	-	
Expected Change	-	-0.13 (0.44)	-	-0.13 (0.41)	-	0.60 (0.61)	
Surprise Change	-	6.74*** (2.12)	-	8.04*** (2.67)	-	2.80** (1.13)	

<i>Panel C</i>		<i>ΔRV</i>					
<i>Independent Variables/Surprise</i>	<i>Current Month</i>		<i>One-Month-Ahead</i>		<i>Two-Months-Ahead</i>		
Constant	-0.18* (0.09)	-0.08 (0.07)	-0.18* (0.09)	-0.08 (0.06)	-0.18* (0.09)	-0.03 (0.05)	
Target Rate Change	0.92 (0.60)	-	0.92 (0.60)	-	0.92 (0.60)	-	
Expected Change	-	-0.26 (0.29)	-	-0.15 (0.28)	-	0.05 (0.30)	
Surprise Change	-	6.41** (3.04)	-	7.08** (3.23)	-	1.48 (2.08)	

Notes: The table provides the results from estimating equations (8) and (9) using the three surprise measures defined in equations (2), (3) and (4). Newey and West (1987) Heteroskedasticity and Autocorrelation Consistent (HAC, 4 lags) standard errors in parentheses. * denotes significance at 10% level, ** at 5% level and *** at 1% level.

Table 3

The effect of Federal funds rate and macroeconomic surprises on volatility

<i>Panel A</i>		ΔVIX					
<i>Independent Variables/Surprise</i>	Current Month		One-Month-Ahead		Two-Months-Ahead		
Constant	-0.60*** (0.09)	-0.50*** (0.08)	-0.60*** (0.09)	-0.49*** (0.08)	-0.60*** (0.09)	-0.49*** (0.09)	
Target Rate Change	1.03* (0.53)	- -	1.03* (0.53)	- -	1.03* (0.53)	- -	
Expected Change	- -	-0.03 (0.47)	- -	-0.05 (0.43)	- -	0.54 (0.61)	
Surprise Change	- -	6.13*** (1.89)	- -	7.49*** (2.46)	- -	2.56*** (0.90)	
Employment Surprise	-0.04*** (0.00)	-0.03*** (0.00)	-0.04*** (0.00)	-0.03*** (0.00)	-0.04*** (0.00)	-0.04*** (0.00)	
Inflation Rate Surprise	4.12** (1.94)	2.51 (3.23)	4.12** (1.94)	3.38 (2.67)	4.12** (1.94)	3.52 (2.35)	
Industrial Production Surprise	-2.44* (1.27)	-2.88* (1.64)	-2.44* (1.27)	-2.93* (1.76)	-2.44* (1.27)	-2.37 (1.58)	
<i>Panel B</i>		ΔRV					
<i>Independent Variables/Surprise</i>	Current Month		One-Month-Ahead		Two-Months-Ahead		
Constant	-0.15* (0.09)	-0.04 (0.05)	-0.15* (0.09)	-0.03 (0.05)	-0.15* (0.09)	-0.00 (0.05)	
Target Rate Change	1.16* (0.66)	- -	1.16* (0.66)	- -	1.16* (0.66)	- -	
Expected Change	- -	-0.12 (0.31)	- -	0.01 (0.31)	- -	0.28 (0.28)	
Surprise Change	- -	7.32** (2.92)	- -	7.97*** (2.99)	- -	2.05 (1.93)	
Employment Surprise	0.02*** (0.00)	0.03*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	
Inflation Rate Surprise	0.11 (1.07)	-1.82 (2.46)	0.11 (1.07)	-0.65 (1.64)	0.11 (1.07)	-0.74 (1.72)	
Industrial Production Surprise	-3.32*** (0.57)	-3.85*** (0.91)	-3.32*** (0.57)	-3.83*** (0.95)	-3.32*** (0.57)	-2.90*** (0.90)	

Notes: The table provides the results from estimating equation (10) using the three surprise measures defined in equations (2), (3) and (4). Newey and West (1987) Heteroskedasticity and Autocorrelation Consistent (HAC, 4 lags) standard errors in parentheses. * denotes significance at 10% level, ** at 5% level and *** at 1% level.

Table 4

The effect of Federal funds rate and macroeconomic surprises on the volatility risk premium

<i>Panel A: Federal Funds Rate Surprises</i>			
	<i>Volatility Risk Premium</i>		
<i>Independent Variables/Surprise</i>	Current Month	One-Month-Ahead	Two-Months-Ahead
Constant	4.10** (0.48)	4.08** (0.48)	4.05** (0.48)
Expected Change	-1.96 (2.14)	-1.95 (1.98)	-2.75 (1.76)
Surprise Change	-12.73*** (5.73)	-14.83** (6.55)	-4.40 (4.39)

<i>Panel B: Federal Funds Rate and Macroeconomic Surprises</i>			
	<i>Volatility Risk Premium</i>		
<i>Independent Variables/Surprise</i>	Current Month	One-Month-Ahead	Two-Months-Ahead
Constant	4.02*** (0.47)	3.99*** (0.47)	3.99*** (0.47)
Expected Change	-2.49 (2.12)	-2.53 (1.95)	-3.47* (1.78)
Surprise Change	-14.59*** (5.43)	-16.76*** (6.41)	-6.06 (4.39)
Employment Surprise	-0.04*** (0.00)	-0.04*** (0.00)	-0.03*** (0.00)
Inflation Rate Surprise	-1.29 (7.66)	-3.06 (6.90)	-3.40 (6.06)
Industrial Production Surprise	14.17** (3.29)	14.22*** (3.32)	12.85*** (3.07)

Notes: The table provides the results from estimating equations (12) and (13) using the three surprise measures defined in equations (2), (3) and (4). Newey and West (1987) Heteroskedasticity and Autocorrelation Consistent (HAC, 4 lags) standard errors in parentheses. * denotes significance at 10% level, ** at 5% level and *** at 1% level.

Table 5

Asymmetries in the response of volatility and volatility risk premium to monetary policy shocks

<i>Panel A</i>			
ΔVIX			
<i>Independent Variables/Surprise</i>	Current Month	One-Month-Ahead	Two-Months-Ahead
Constant	-0.45*** (0.09)	-0.45*** (0.09)	-0.50 (0.12)
Expected Change	-0.12 (0.44)	-0.13 (0.41)	0.62 (0.62)
Surprise Change	7.02*** (2.44)	8.04*** (3.09)	2.28*** (0.78)
Surprise × Positive Surprise Dummy	-1.16 (5.31)	0.03 (7.00)	2.81 (3.83)

<i>Panel B</i>			
ΔRV			
<i>Independent Variables/Surprise</i>	Current Month	One-Month-Ahead	Two-Months-Ahead
Constant	0.20** (0.08)	0.19** (0.08)	0.04 (0.07)
Expected Change	-0.19 (0.39)	-0.23 (0.37)	0.00 (0.28)
Surprise Change	10.42*** (3.11)	10.89*** (3.36)	2.49 (2.35)
Surprise × Positive Surprise Dummy	-16.99*** (4.71)	-19.06*** (5.31)	-5.54* (3.10)

<i>Panel C</i>			
Volatility Risk Premium			
<i>Independent Variables/Surprise</i>	Current Month	One-Month-Ahead	Two-Months-Ahead
Constant	3.44*** (0.57)	3.44*** (0.61)	3.76*** (0.56)
Expected Change	-2.10 (1.98)	-1.76 (1.74)	-2.58 (1.71)
Surprise Change	-21.75*** (7.79)	-23.55** (9.57)	-7.98* (4.29)
Surprise × Positive Surprise Dummy	38.25** (15.81)	43.66** (20.82)	19.60 (12.34)

Notes: The table provides the results from estimating equation (14) using the three surprise measures defined in equations (2), (3) and (4). Newey and West (1987) Heteroskedasticity and Autocorrelation Consistent (HAC, 4 lags) standard errors in parentheses. * denotes significance at 10% level, ** at 5% level and *** at 1% level.

Table 6

Response of returns and implied volatility to Federal funds rate surprises controlling for the leverage effect

Independent Variables	Dependent Variable	
	<i>Returns on the S&P 500</i>	ΔVIX
Constant	-0.10 (0.07)	-0.34*** (0.11)
Expected Change	0.70* (0.39)	0.13 (0.06)
Surprise Change	-3.93** (1.88)	-0.33 (1.71)
Change in Volatility	-0.63*** (0.06)	- -
Two Day Lagged Return	- -	0.13** (0.06)
One Day Lagged Return	- -	-0.03 (0.07)
Contemporaneous Return	- -	-0.93*** (0.12)
Absolute Contemporaneous Return	- -	0.62 (0.41)
One Day Lead Return	- -	-0.07 (0.08)
Two Days Lead Returns	- -	-0.12 (0.07)

Notes: The table provides the results from estimating equations (15) and (16) using the current month surprise defined in equation (2). Newey and West (1987) Heteroskedasticity and Autocorrelation Consistent (HAC, 4 lags) standard errors in parentheses. * denotes significance at 10% level, ** at 5% level and *** at 1% level.

Table 7

Monthly response of returns, volatilities and the volatility risk premium to Federal funds rate and macroeconomic surprises

<i>Panel A : Monthly Monetary Surprises</i>								
<i>Dependent Variables</i>	<i>Independent variable</i>							
	<i>Returns on S&P 500</i>		<i>ΔVIX</i>		<i>ΔRV</i>		<i>VRP</i>	
Constant	0.69** (0.32)	0.47 (0.33)	0.04 (0.16)	0.16 (0.18)	0.04 (0.26)	0.08 (0.33)	4.34** (0.38)	4.21 (0.48)
Federal Funds Rate Change	-1.56 (1.19)	- (-)	1.31 (1.34)	- (-)	2.67 (2.25)	- (-)	-3.19 (2.38)	- (-)
Expected Change	- (-)	-0.17 (2.19)	- (-)	1.41 (1.64)	- (-)	4.38 (5.25)	- (-)	-4.02 (4.16)
Surprise Change	- (-)	-9.97** (3.93)	- (-)	6.94** (2.93)	- (-)	6.19 (6.55)	- (-)	-9.72* (4.98)

<i>Panel B: Monetary Surprises and Macroeconomic Factors</i>								
<i>Dependent Variables</i>	<i>Independent variable</i>							
	<i>Returns on S&P 500</i>		<i>ΔVIX</i>		<i>ΔRV</i>		<i>VRP</i>	
Constant	0.22 (0.58)	0.24 (0.58)	-0.30 (0.36)	-0.22 (0.35)	-0.56 (0.65)	-0.51 (0.60)	4.70*** (0.72)	4.68*** (0.67)
Federal Funds Rate Change	-3.63* (2.19)	- (-)	0.93 (1.65)	- (-)	2.29 (0.86)	- (-)	-3.56 (2.43)	- (-)
Expected Change	- (-)	-2.49 (3.01)	- (-)	0.26 (2.02)	- (-)	3.51 (6.45)	- (-)	-4.09 (3.84)
Surprise Change	- (-)	-11.10*** (3.80)	- (-)	7.23** (2.85)	- (-)	6.94 (6.24)	- (-)	-10.56* (4.60)
Employment Growth	10.12** (3.46)	8.96*** (3.44)	-2.06 (2.24)	-1.76 (2.13)	-2.21 (3.44)	-2.11 (4.05)	3.71 (3.99)	3.08 (3.80)
Inflation Rate	-1.70** (0.82)	-1.93** (0.81)	1.42*** (0.52)	1.54** (0.50)	3.11 (1.32)	3.19** (1.18)	-3.16** (1.10)	-3.33*** (1.00)
Industrial Production Growth	-1.66* (0.86)	-1.72** (0.86)	1.22** (0.62)	1.26** (0.63)	0.82 (0.88)	0.82 (0.89)	-0.52 (0.70)	-0.54 (0.71)

Notes: The table provides the results from estimating equations (18) and (19) using the monthly surprise measure defined in equation (6). Newey and West (1987) Heteroskasticity and Autocorrelation consistent standard errors (HAC, 4 lags) in parentheses. * denotes significance at 10% level, ** at 5% level and *** at 1% level.