The Effects of Central Bank Communications on Financial Markets

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Preliminary and incomplete. Please, do not quote.

27th March 2007

Abstract

This paper investigates the effects that statements and minutes published by the FOMC have on financial markets. Different definitions of volatility have been used to check this influence. The effects are examined by a data-analysis, the nonparametric Kruskal Wallis test and by estimating the size of the effects with the parametric ARFIMA model. The results show that FOMC statements significantly increase the volatility of the stock exchange index futures, and, long term and short term interest rate futures, while FOMC minutes only increase the volatility of the long term interest rate futures significantly.

1 Introduction

The reaction of financial markets to the arrival of new information has been analyzed in many studies by now (see for example Ederington & Lee (1993), Clare & Courtenay (2001) or Andersen, Bollerslev, Diebold & Vega (2003)). New information, or 'news', could be anything: natural events (or disasters), political events (a war or a terrorist attack), legal events (like a settlement of Microsoft trial), macroeconomic data releases (such as CPI), relevant government decisions, etc.

Why should markets respond to these 'news'? Well, if the market is rational than it will value the products it sells according to the net discounted value of the future returns from owning them. In the case of stocks, it is the net discounted value of the (infinite) stream of future dividends. For bonds, it is the stream of the future coupon payments until the bond expires. And so on. If the even in

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the 'news' affects the future value of the returns, than the current price of the financial product (or instrument) should react, depending on the magnitude of the effect on the returns. Hence, Microsoft stock will naturally react strongly to the settlement of Microsoft trial, while it may not react at all to the results of German elections. German bunt will react to the unemployment numbers in the Euro zone (and the elections), while it will hardly react to the news on Microsoft trial.

In this paper we will focus on a particular type of 'news' releases: on those made by central banks. More specifically, we focus on the effects that statements and minutes made and published by the Federal Reserve have on American bond and stock markets. At least eight times a year, the policy setting arm of the Federal Reserve - the Federal Open Market Committee (FOMC) - convenes and decides on the appropriate level of a short-term interest rate in America. This rate is then implemented in a short-term money market via sales or purchases of central bank money. The appropriate level of the policy rate is set from the viewpoint of meeting the Federal Reserve's objectives, that is "to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates." As the short-term interest rate does not affect inflation and GDP immediately, policy rate decisions reflect FOMC's expectations of the developments in about two-year time.

FOMC's decisions are communicated to the public immediately after the meeting adjourns. The statement consists of a very short justification for the decision on the basis of macroeconomic developments, the decision itself, the record of votes and, possibly, an indication of future policy moves. Three weeks after the meeting, FOMC releases the minutes, which contain an extensive account of relevant macroeconomic developments, a summary of discussions among FOMC members, the statement and the votes.

The way in which the FOMC brings information to the public has changed several times, moving in the direction of greater transparency (see for example Danker & Luecke (2005), Poole (2005a) or Poole & Rasche (2003)). Before 1994, no policy statements were released after the meetings. Financial markets had to guess policy decisions from the operations in the money market. Beginning in May 1999, FOMC statements also included description of the FOMC's views about prospective developments, the so-called "policy bias" , which was widely interpreted as hinting at future policy actions. The FOMC adopted a bias towards tightening if it felt that interest rates might rise in the inter-meeting period, a bias towards easing if interest rates may have to be lowered and no bias if no change seemed to be most appropriate. After January 2000, the bias was dropped from the statement in favor of a "balance-of-risks" assessment. While the bias was meant to refer to the inter-meeting period only, the balance-of-risks statement was intended to indicate the FOMC's assessment of the risks to the goals of price stability and economic growth over the foreseeable future. Along with the decision to adopt the balance-of-risks language, the Committee adopted the policy of providing a press release after every FOMC meeting. As of August 2003, the FOMC introduced a "forward-looking" language into the statements (see also Poole (2005b)).

To investigate the impact of the information released by the FOMC we will look at the volatility of three high-frequency futures' series: TBills (3-month paper), and TNotes (10-year bond) and S&P500. To see if the content of the statement matters, FOMC statements will also be split up in statements which contain a bias, a balance-of-risks and/or votes. We find that all the markets significantly react to the central bank communication. Additional information in the FOMC statements, going beyond the interest rate announcement, mutes the market reaction. The publication of the FOMC minutes has an effect only in the TNotes market. This can be explained by the fact that the minutes contain the FOMC analysis of the current situation and the outlook which are most relevant for longer term interest rates.

Our results are most closely related to Gürkaynak et al. (2005) and Clare & Courtenay (2001). Gürkaynak et al. (2005) find that FOMC interest rate 'path' news related to an unobserved factor that "corresponds to all aspects of FOMC announcements that move futures rates for the upcoming year without changing the current federal funds rate" (p. 78) significantly affect 2-year, 5-year and 10-year notes, while showing no impact on S&P500.[1] Clare & Courtenay (2001) find, using non-parametric methods, that Bank of England interest rate changes had significant effects on short sterling and long gilt markets, while the MPC minutes affected the long gilt and the FTSE-100.

The paper is organized as follows. In the next section we provide a description of the data, while, in section 3, we discuss methodology. Next, we carry out a non-parametric and parametric analysis of the effects of the 'news' on the markets - section 4. Finally, section 5 concludes.

2 Data description

This section gives a description of the various announcements we are interested in and the futures' timeseries used in this paper. Next an overview of the used definitions of volatility is given, which is followed by a graphical analysis of the different volatility series. Finally the volatility series will be sorted to get insights in the largest movements in the series.

Our financial markets' data consists of tick-by-tick observations of futures of the S&P500, TBills (3-month short interest rate) and TNotes (10-year long interest rate).[2] The high-frequency futures of the S&P500 are traded on the Chicago

[1]Using the same methodology, Brandt & Diebold (2006), find similar results for the Euro zone bond market.

[2]Purchased from Tickdata.com.

Mercantile Exchange (CME) from 8:30 AM to 3:15 PM (Eastern Standard Time minus 1 hour, (EST -1)). The TBills and the TNotes are traded on the Chicago Board of Trade (CBT) from 7:20 AM to 2:00 PM (EST -1).

The range of the sample is set to six years. The futures series of the S&P500 and the TNotes run from January 4, 1999 until December 31, 2004. The TBills series is shorter because it was not available for longer than from January 7, 1999 until September 8, 2003. For our analysis, the raw tick-by-tick data is transformed into series of three different frequencies: daily, hourly and 5-minute intervals.

The focus of our analysis is on the impact of the official announcements made by the Federal Reserve on financial markets. However, other authors, e.g. Ederington & Lee (1993) and Fleming & Remolona (1997), have shown that these markets react also to other important macro-economic news announcements, such as the publication of Consumer and Producer Price Indices and the Employment Situation. Hence, we have to control for the effects of macro-data releases.

The macro-news are published following a predetermined schedule, just as the Fed announcements are, at 7:30 AM (EST -1). The FOMC statements are published around 1:15 PM (EST -1) and the minutes are published at 1:00 PM (EST -1). Our sample, which covers the years 1999-2004, contains in total 216 macro-data releases and 49 FOMC statements. As we have explained in the introduction, the statements and minutes of the FOMC contain different kinds of information, next to the interest rate decision itself: a balance-of-risks statement (BoR), a bias or votes. These different element may affect the impact of FOMC announcements on the financial markets, hence we will also look at them separately. In the sample, we have 18 statements containing a bias, 42 statements with a balance-of-risks, and 23 with the votes. Table 1 presents the overview of the relevant 'news' together with the release times and the number of observations. Table 2 contains a structured description of the FOMC statements included in the sample.

3 Methodology

In our analysis we will employ a rather wide range of tools. We will carry out graphical analysis, non-parametric tests and we will estimate an ARFIMA model for the market volatility. In all cases, we will focus on the identification of the effects of Fed announcements.

This section contains the description of the methodology. However, before we get there, we will discuss different definitions of volatility used in the literature, together with their advantages and shortcomings. On the basis of that, we will motivate our choice of the definition to be used in the analysis.

3.1 Volatility

In this subsection we will examine four definitions of volatility. They make use of different parts of the available information, which in turn can lead to different results.

The most intuitive volatility estimator is realized volatility, which is a sum of squared intraday returns. This type of volatility is used in Martens (2002), Martens, van Dijk & de Pooter (2004), Andersen, Bollerslev, Diebold & Labys (2003) and Andersen et al. (2001), among others. The most popular form of realized volatility is the daily squared return. We will look at this type of volatility, with two different definitions for returns. The first is open-to-close volatility, which is based on squared open-to-close returns. It is defined as:

$$\sigma^2_{t,\,\mathrm{OC}} = (\ln(P_{\mathrm{C}t}) - \ln(P_{\mathrm{O}t}))^2 \tag{1}$$

where $P_{\mathrm{C}t}$ is defined as the closing price of interval t and $P_{\mathrm{O}t}$ is defined as the opening price of interval t. Recall, we have t equal to 5 minutes, 60 minutes and 1 day.

The second definition of volatility we use is close-to-close volatility, which is similar to open-to-close volatility but instead is based on the close-to-close returns. It is therefore defined as:

$$\sigma^2_{t,\,\mathrm{CC}} = (\ln(P_{\mathrm{C},t}) - \ln(P_{\mathrm{C},t-1}))^2 \tag{2}$$

where $P_{\mathrm{C}t}$ is defined as the price at the end of interval t.

Although the squared return is an unbiased estimator, it is contaminated by a measurement error. For example, when the closing price is close to the opening price the squared open-to-close return indicates low volatility. But when the futures prices have fluctuated substantially throughout the day, the volatility actually should be large. Therefore we also consider range-based volatility, which makes use of the highest and lowest price during a time interval. It is defined as:

$$\sigma^2_{t,\,\mathrm{RB}} = \frac{(\ln(P_{\mathrm{H}t}) - \ln(P_{\mathrm{L}t}))^2}{4\ln(2)} \tag{3}$$

where $P_{\mathrm{H}t}$ is the highest observed price during some interval, for example a day, and $P_{\mathrm{L}t}$ is the lowest price in that same interval (see also Parkinson (1980) and Garman & Klass (1980)).

Alizadeh, Brandt & Diebold (2002) discuss the advantages of using the range-based definition to measure volatility. They mention three reasons. First, range-based volatility is more efficient than the squared daily returns. Secondly, range-based volatility can be very well approximated as Gaussian, while this is not true for the daily squared returns. Finally, range-based volatility is robust to market microstructure effects, such as the bid-ask bounce.

However, daily realized volatility, as defined by Martens (2002), is still more efficient than range-based volatility.[3] Thus the fourth definition for daily volatility we use is realized volatility, defined as:

$$\sigma^2_{t,\,\mathrm{RV}} = (1+c)\sum_{d=1}^{D} r^2_{t,d} \tag{4}$$

where $r_{t,d}$ is the intraday return on day t for intraday period d. c is a positive constant such that the volatility measure corresponds to daily volatility. As we assume that the whole day consists of 98 5-minute intervals, of which 81 are observed during the floor trading, c is equal to 17/81 and $D = 81$.

Martens (2002) concludes that equation (4), the re-scaled sum of squared intraday trading returns, gives the best observation of the true volatility in absence of overnight trading. One of the reasons is that the squared intranight return is a noisy estimate of the volatility for the nontrading period, as is the daily squared return for the daily period. In fact, both daily range-based volatility and daily realized volatility make use of intraday data, but they process the available information in different ways.

3.2 Nonparametric methods

Following Ederington & Lee (1993) we will begin by examining graphically the daily and intraday pattern of volatility in the markets. We will also divide our series in two sub-samples: one sub-sample containing days when at least one of the announcements has been made and a sub-sample containing days when no announcement took place. This gives us first insights regarding the impact of the announcements on the financial markets.

Next we will identify the top 20 largest market moves, based on our volatility measures. We follow the approach by Fleming & Remolona (1997) and Bollerslev, Cai & Song (2000), meaning that the top 20 is identified out of all available observations and not only among observations around the announcements' time. This will allow us to carry another indirect test of the impact of the announcements on the market by observing what share of large market movements can be associated with the announcements we have identified, in particular the FOMC releases.

Finally, following the approach of Clare & Courtenay (2001), we will perform the Kruskal-Wallis tests to assess the statistical significance of the effects of the announcements.

[3] Andersen & Bollerslev (1998) show when range-based volatility is as efficient as realized volatility.

3.2.1 Kruskal-Wallis Test

Clare & Courtenay (2001) carry out an analysis on intraday data for the United Kingdom and make use of the Kruskal-Wallis test. Their investigation concentrates on the impact of a wide set of scheduled public news announcements, which also include the monetary policy announcements of the Bank of England, on a few futures contracts and exchange rates. The paper studies the differences in reaction to these announcements before and after the independence of the Bank of England in 1997. The conclusion they draw is that there may have been changes in the way that financial markets react to key economic announcements.

The sample period is split up into days when announcements occur and days when no announcements occur, as is done earlier for the graphical analysis in the previous section. Kruskal-Wallis statistic is used to test whether the volatilities of these sub-samples differ significantly. The idea behind the test is to sort the series from small to large and give the smallest value rank 1, the one after that a 2 and so on.[4] The test then compares the sum of the ranks from subgroup 1 to the sum of the ranks from subgroup 2. If the groups have the same median, the values should be similar. The test statistic is defined as:

$$KW = \frac{12}{N(N+1)} \sum_{j=1}^{J} \frac{S_j^2}{m_j} - 3(N+1) \tag{5}$$

J is the number of subgroups and since there are only two subgroups, announcements and non-announcements, $J = 2$. N is the total number of observations from both groups. m_j is the number of observations from group j and S_j is the rank sum for group j.

The test statistic is χ_{J-1} distributed under the null hypothesis of equal medians. The advantage of this test is that the underlying distribution does not have to be normal. To use this test however there have to be at least five observations in each group. The sign given to the test statistic is determined as follows: A plus sign is given when the mean rank of the announcement sample is larger than the mean rank of the sample with no announcements. This implies that we want to reject positive values of the Kruskal-Wallis tests, because this means that the announcement sample has larger values for the volatilities. Furthermore, in this setting, a positive reaction for the announcements released by the FOMC indicates that these announcements also contribute to higher volatility.

3.3 Parametric methods: the ARFIMA model

Many different models have been applied in the literature. The easiest approach is to estimate a dummy regression, which is done in Fleming & Remolona

[4] When 2 or more observations have the same value the ranks are summed and divided between the observations. For example, if 2 observations are equal and they should have got rank 5 and 6 they both get rank 5.5.

(1997) for 5-minute data and in Galati & Ho (2001) for daily data. Another method often applied is estimating some sort of GARCH model (for daily data see Bomfim (2000) and Jones, Lamont & Lumsdaine (1998), for 5-minute data see Bollerslev, Cai & Song (2000)). Other approaches are to estimate a factor model, as is done in e.g. Balduzzi, Elton & Green (1999). Most of these models are estimated on squared returns. However, we will use the realized volatility series, since this definition shows most evident results and it can be modeled directly through standard time series techniques, while exploiting the intraday high-frequency data. Moreover, we will show that our log realized volatility series exhibits long memory. Hence we will use a model which accommodates this feature of the data.

The leading class of parametric models able to describe the long memory property is the AutoRegressive Fractionally Integrated Moving Average (ARFIMA) models. The discrete time series representation of a fractionally integrated process has been introduced by Granger & Joyeux (1980) and Hosking (1981).

The simplest fractionally integrated time series model is defined as:

$$(1-L)^d y_t = \varepsilon_t \tag{6}$$

where L is the lag operator, ε_t is a white noise process and the fractionally differencing filter $(1-L)^d$ has the following binomial expansion:

$$(1-L)^d = 1 - dL + \frac{d(d-1)L^2}{2!} - \frac{d(d-1)(d-2)}{3!} + \cdots \tag{7}$$

This series shows that y_t can be described by an AR polynomial of infinite length. Obviously, the series becomes one for $d = 0$ and $(1-L)$ for $d = 1$. In the ARFIMA model the order of integration d is allowed to take real values. When $0 < d < 0.5$, the timeseries is said to have long memory, and when $0.5 \leq d < 1$ it is non-stationary.

Because the descriptive statistics of our series are comparable to those found in Martens, van Dijk & de Pooter (2004) we will use the same type of model, augmented with dummies for the announcement days. The Autoregressive Fractionally Integrated (ARFI) model for the log realized volatility, $y_t = \log(\sigma^2_{t,\text{ RV}})$, with $\sigma^2_{t,\text{ RV}}$ given in equation (4), is defined as:

$$\phi(L)(1-L)^d(y_t - \mu_t) = \varepsilon_t \tag{8}$$

where ε_t is a white noise process and $\phi(L) = 1 - \phi_1 L - \ldots - \phi_p L^p$ is a lag polynomial with all roots outside the unit circle. The standard approach is to set μ_t equal to a constant. However, to capture the announcement and day-of-the-week effects, announcement and daily dummy variables are added in the mean equation. This implies the following equation for μ_t:

$$\begin{aligned}\mu_t \;=\; & \mu + \gamma_1 D_{\text{state.},t} + \gamma_2 D_{\text{empl.},t} + \gamma_3 D_{\text{min.},t} + \gamma_4 D_{\text{cpi},t} + \gamma_5 D_{\text{ppi},t} + \\ & \delta_1 D^*_{1,t} + \delta_2 D^*_{2,t} + \delta_4 D^*_{4,t} + \delta_5 D^*_{5,t}\end{aligned} \tag{9}$$

The announcement dummies: $D_{\text{state.},t}$, $D_{\text{empl.},t}$, $D_{\text{min.},t}$, $D_{\text{cpi},t}$ and $D_{\text{ppi},t}$, are 1 on the days when the announcements are made and zero otherwise. The daily dummies are centered around Wednesdays. This implies that, $D^*_{j,t}$, with $j =$ 1(Monday), 2(Tuesday), 4(Thursday), 5(Friday), are defined as $D^*_{j,t} = D_{j,t} - D_{3,t}$, with $D_{j,t} = 1$ when t corresponds with day j and zero otherwise.

To estimate the model parameters, we rewrite the ARFI model in an infinite order AR representation:

$$\pi(L)(y_t - \mu_t) = \varepsilon_t \tag{10}$$

with

$$\pi(L) = 1 - \pi_1 L - \pi_2 L^2 - \pi_3 L^3 - \cdots = \phi(L)(1-L)^d \tag{11}$$

π are a function of ϕ and d, and can be computed by using the binomial expansion for the differencing operator $(1-L)^d$, given in equation (7).

In the estimation, the approximate maximum likelihood estimator of Beran (1995) for invertible and possibly nonstationary ARFIMA models (thus $d > -0.5$) is applied. In fact this means we can just minimize the sum of squared residuals:

$$\sum_{t=1}^{T} e_t^2(\theta) \tag{12}$$

where T is the sample size and θ is the parameter vector: $\theta = (d, \mu, \phi, \gamma_1, \gamma_2, \gamma_3, \gamma_4,$ $\gamma_5, \delta_1, \delta_2, \delta_4, \delta_5)$. The residuals $e_t(\theta)$ can be computed as:

$$e_t(\theta) = (y_t - \mu_t) - \sum_{i=1}^{t+p-1} \pi_i (y_{t-i} - \mu_{t-i}) \tag{13}$$

If the errors are normally distributed, the approximate maximum likelihood estimator is asymptotically efficient. Under less restrictive conditions it is asymptotically normal and $\sqrt{n}$ consistent.

3.3.1 Forecasting

To further evaluate the estimated ARFI models we will check their forecasting performance. The forecasts are constructed by dividing the sample into an in-sample period, which runs from January 4, 1999 until December 31, 2002, and an out-of-sample period, which runs from January 2, 2003 until December 31, 2004. The first prediction is based on the model estimated on the in-sample data. For the second forecast the in-sample is enlarged by one extra data point and the model is re-estimated before the forecast is made.

The volatility forecasts for one day ahead are constructed by using the truncated form of the infinite order AR representation of the ARFI models given in equation (13). Rewriting this equation gives:

$$y_t = \hat{\mu}_t + \sum_{i=1}^{p^*} \pi_i (y_{t-i} - \mu_{t-i}) + e_t \tag{14}$$

where $p^* = 162$. The one step ahead forecast can be obtained using the above result. The forecasts are made for the dependent variable in the ARFI models, which is the logarithmic realized volatility series.[5]

Several out-of-sample forecasting criteria are considered to evaluate and compare the models. The following accuracy statistics for each model are computed:

$$\begin{aligned}
\text{Mean Squared Prediction Error: MSPE} &= \frac{1}{m}\sum_{j=1}^{m}(\hat{y}_{t+j|t+j-1} - y_{t+j})^2 \\
\text{Mean Absolute Prediction error: MAPE} &= \frac{1}{m}\sum_{j=1}^{m}|\hat{y}_{t+j|t+j-1} - y_{t+j}| \\
\text{Heteroscedasticity-adjusted MSPE: HMSPE} &= \frac{1}{m}\sum_{j=1}^{m}\left(\frac{\hat{y}_{t+j|t+j-1} - y_{t+j}}{\hat{y}_{t+j|t+j-1}}\right)^2 \\
\text{Mean Error: ME} &= \frac{1}{m}\sum_{j=1}^{m}(\hat{y}_{t+j|t+j-1} - y_{t+j})
\end{aligned}$$

To decide whether the squared prediction errors of two alternative models, say model $\mathcal{M}_1$ and $\mathcal{M}_2$, are significantly different, Diebold-Mariano (DM) tests are performed. Diebold & Mariano (1995) developed a statistic which compares the absolute magnitudes of the prediction errors by testing whether the average so-called loss differential is significantly different from zero. The loss differential is defined as:

$$d_j = e^2_{t+j|t+j-1,\mathcal{M}_1} - e^2_{t+j|t+j-1,\mathcal{M}_2} \tag{15}$$

where $e_{t+j|t+j-1,\mathcal{M}_1}$ and $e_{t+j|t+j-1,\mathcal{M}_2}$ are the forecast errors at time $t+j$ from model $\mathcal{M}_1$ and $\mathcal{M}_2$, respectively. The test statistic is given by:

$$DM = \frac{\bar{d}}{\sqrt{\nu}} \sim N(0,1) \tag{16}$$

with $\bar{d} = \frac{1}{m}\sum_{j=1}^{m} d_j$ and ν is the variance of the average difference $\bar{d}$.

4 Results

In this section we will review our results, starting with the graphical analysis and ending with the checking the forecasting performance of our ARFIMA model.

[5]One could also produce forecasts for the realized variance and realized standard deviation. However, the results for these series are similar and therefore not shown here.

4.1 Nonparametric analysis

Figure 1 presents the different volatility measures for all three series at the daily frequency.[6] It is clear to note that different definitions of volatility lead to different patterns. The open-to-close and close-to-close volatility series look quite similar, at least in the case of the S&P500 and the TNotes futures. They also produce higher volatility, alternated with more large volatility peaks, than the range-based and realized definitions. The volatility of the TBills shows a different pattern: the definitions produce quite different series, whereby a relatively low volatility is alternated with large peaks.

Figures 4 and 3 present the intraday volatility pattern, based on the close-to-close and range-based definitions.[7] The figures show the volatility of the S&P500 and the TNotes at 5-minute intervals during the trading day (i.e. from 8:30 AM to 3:15 PM for the S&P500 and from 7:20 AM to 2:00 PM for the TNotes).[8][9] Contrary to daily data, now we observe that the overall pattern of both series is similar, although the range-based volatility shows relatively larger peaks. Both measures indicate that the TNotes futures exhibit a large volatility peak at the interval 7:30 until 7:35 and the peak at approximately 9:00 in the TNotes.[10] The S&P500 futures show rising volatility starting at 12:15, lasting until approximately 15:00.

Next, we look at the series split into days when at least one of the announcements has been made and days when no announcement took place. Figures 4 and 5 show the results. The TNotes futures clearly show that the volatility peaks in figures 2 and 3 arose from the effects of announcements, as there are no peaks in volatility at 7:35 and around 13:15 in the non-announcement sample. The panels for S&P500 futures also show that the jump in volatility at 13:15 disappears in the non-announcement sample, while it is clearly present in the announcement sample.

Finally, we analyze the effects of different information content of the FOMC statements on the financial markets (figure 6). In the top panel, the non-announcement days are plotted against the FOMC statements' days; in the bottom panel the statements' days are further split into days when statements

[6] The daily realized volatility is shown only for the TNotes and the S&P500, since there are too few 5-minute observations for the TBills series to construct the daily realized volatility numbers.

[7] The open-to-close intraday volatility is similar to the close-to-close volatility. Realized volatility is only a daily series and therefore not shown here.

[8] Again, we do not show the results for the TBills, due to data missing at the 5-minute frequency. For this series, we limit the analysis to the hourly and daily frequency.

[9] The timestamp for each interval represents the data of the period ending immediately prior to the timestamp. For example, the 8:35 bar contains data from 8:30:00 to 8:34:59.

[10] Also documented by e.g. Ederington & Lee (1993) and Bollerslev, Cai & Song (2000). The peak at 9:00 (EST -1) is caused by several macroeconomic announcements, which we will not investigate in this paper.

contained the balance-of-risks, votes or bias. We can cleary see that statements containing the balance of risks or bias, that is: information about the future, have a stronger impact on the S&P500 futures than other information. In section 4.1.2 below we will perform a more formal analysis to determine whether the above findings are statistically significant.

4.1.1 Top-20 volatilities

The next step in the analysis is to identify the top 20 largest market moves, based on our volatility measures, for the daily data and for the 5-minute intervals. The results are given in tables 3 and 4. The column "Ann." identifies the announcement that was released at the time when the peak was recorded.

The first observation is that different definitions of volatility lead to different top 20's: no more than five observations are identical in corresponding rankings. The top announcement days also depend on the volatility definition.

Regarding the impact of announcements, the S&P500 daily ranking includes the largest number of announcement days when the close-to-close volatility is considered.[11] Three (out of 8) announcements are FOMC statement releases, all with the balance of risk statements. In case of the TNotes most announcements make it to the top 20 when volatility is defined as realized volatility. A clear majority of announcements are the Employment Situation releases. Four announcemnets are related to monetary policy: three statements and one release of FOMC minutes. For the TBills, the open-to-close volatility shows the highest number of announcements days, of which a clear majority (8 out of 11) are announcements made by the FOMC (four are FOMC statements and four are FOMC minutes).[12]

The top 20 rankings are much more consistent on an intraday basis. For the 5-minute top 20's, half of all episodes are the same, regardless of volatility definitions. Interestingly, a substantially larger share of episodes occur on announcement days, up to 100% in the case of the TNotes open-to-close volatility. The highest number of annuncements for the S&P500 now arises under the range-based definition, with a clear majority of FOMC statements (9 out of 14 announcements). The top 20's for the TNotes again include mostly Employment Situation releases.[13]

To see which announcements have a statistically significant effect on market volatilities Kruskal-Wallis tests will be performed in the next section.

[11]The ranking includes almost only observations from the years 2000-2002. This can also be seen in figure 1, which shows clearly that at the end of the sample the daily S&P500 volatility series have less large peaks.

[12]The top 20 open-to-close TBills volatility ranking contains only days in 1999, 2000 and 2001. When volatility is defined as range-based or based on open-to-close returns, the rankings differ by just five days.

[13]The overwhelming presence of employment news in the 5-minute top 20 for the TNotes is also found in Fleming & Remolona (1997) and Bollerslev, Cai & Song (2000).

4.1.2 Kruskal-Wallis Test

The results of the Kruskal-Wallis tests are given in tables 5 through 10. The tests are performed on daily, hourly and 5-minute data. For the TBills the tests are only performed at the daily and hourly frequency because the 5-minute data were not available, as explained above.

The first rows ("All") refer to all announcements and show the test results when the sample is split into days when no announcements are made and days when at least one of the five announcements are made. Rows two through six report the test results for particular announcements, i.e. when the announcement sub-sample contains only the observations with the particular announcement. We report the test statistics and the corresponding P values for the equality of the volatility in the two sub-samples. When the null hypothesis is rejected at a significance level of 5% the P value is printed bold. If the null hypothesis is rejected at 10% the P value is printed in italic.

Table 5 presents the results for the daily data. While S&P500 volatility seems to be significantly affected only by PPI news and the FOMC statements, the TNotes futures show significant reaction to (almost) all types of announcements we analyze, except when close-to-close volatility is used. In the case of the TBills, two definitions indicate that volatility is higher on days when the Employment Situation and the FOMC statements are published. A methodological observation is that the null hypothesis is rejected most often when we look at daily volatility which makes use of the intraday data.

When we compare the top 20 rankings in table 3 with the results of the Kruskal-Wallis test, we see a large correspondence. The Kruskal-Wallis tests produce the highest test statistic for the FOMC statements for the S&P500, the Employment Situation for the TNotes and the Employment Situation and the FOMC statements for the TBills, that is: the announcements which are most often seen in the top 20's.

Next, we present the results on an hourly basis (table 6). We now include only those announcements that had significant effects on the markets at the daily frequency. This is done because when the null hypothesis is not rejected at the daily level it is not rejected at the hourly level, either. The test for the S&P500 indicate that volatility is significantly higher on announcement days between 8:30 and 9:30 and again at 12:30 until 14:30.[14] The range-based volatility indicates that the morning high volatility is due to the PPI releases (published before CME opens, at 7:30 AM), while all definitions clearly show that the FOMC statements (published around 1:15 PM) are associated with the afternoon peaks. On days when FOMC statements are published the volatility remains higher until the exchange closes, which was also visible in figure 6. For the TNotes, the hourly test shows that volatility is higher exactly at times when the corresponding

[14]The given time stamps indicate the observations which occurred until that time. For example, the time stamp 9:30 contains the information from 8:30:00 until 9:29:59.

announcements are published. In the case of PPI, Employment Situation or the FOMC statements, volatility remains higher for one or even two hours later. The TNotes is the only series that indicates a higher volatility on days when the minutes of the FOMC are published. The TBills series shows that volatility stays higher for one hour on days when the Employment Situation is published and for two hours following the FOMC statement. No other announcement has significant effects on the volatility of short interest rate futures.

Finally we investigate market reaction when the FOMC statements have different information content by again looking at four different parts in the statements (table 7). First we test if volatility differs on days when the interest rate decision was changed or when the interest rate was left unchanged. The results in table 7 show that the markets did not react differently to different decisions. Only the short interest rate futures (TBills) display a significantly higher volatility on days when the interest rate is changed. The second test we performed looks if the FOMC statements including votes cause higher volatility than the statements without. For the TBills no significant difference in market reaction can be detected, while for the S&P500 the reaction is significantly smaller if the votes are published (in the case of range-based volatility even for three hours), while for the TNotes volatility is increased by the publication of votes (at the 5% significance level for range-based volatility). The latter effect can be explained by the fact that the division of votes can interpreted by the markets as indicative of Federal Reserve future policy intentions. As the bias has similar informational content, the results regarding the presence of the bias in the statement are quite similar. Finally, we test for the effect of the balance-of-risks part. The S&P500 volatility is significantly reduced by the presence of the balance-of-risks statements, while the TNotes and the TBills show hardly significant effects of the balance-of-risks statements.

Now we turn to the tests performed at the 5-minute intervals (tables 8, 9 and 10).[15] Both series exhibit higher volatility around announcement times in the afternoon, beginning at 1:15 PM. This reaction can almost certainly be attributed to the FOMC announcements as it is unlikely that any other announcements are made on these days at these times. The TNotes also exhibit a significant reaction to macroeconomic news as the volatility becomes significantly higher at 7:30 and remains significant until 9:00. The results for specific announcements, presented in table 9, give us additional interesting insights. For example, we observe that for the S&P500 the sign of the test statistic is negative prior to the publication of the FOMC statements. This could be explained by the fact that the market is anxiously waiting for the statement to be released. Then the reaction to the announcement takes place, which is illustrated by the largest positive test statistic value at 13:20. Volatility stays higher until the exchange closes (as was also shown

[15]In tables 9 and 10 we present only the results for the range-based volatility, as the results based on the other definitions are similar.

for the hourly data). The same significant volatility increase due to the statement release is shown for the TNotes. Moreover, the TNotes exhibit a clear reaction to the publication of the FOMC minutes the highest significant test statistic is obtained for the interval 13:05, which contains the publication time of these minutes.

The effects of different elements of the statements at the 5-minute frequency are comparable to those at the hourly frequency (see table 10).

Summarizing the most important findings, the presented test results show that the FOMC statements have a significant effect on volatility for the futures of the TBills, TNotes and S&P500. Only the short interest rate futures (TBills) display a significantly higher volatility on days when the interest rate is changed, relative to the days without a change in rates. The publication of votes increases the volatility of the TNotes, possibly because the division of votes can interpreted by the markets as indicative of Federal Reserve future policy intentions. As the bias has similar informational content, the results regarding the presence of the bias in the statement are quite similar. The votes, the bias and the balance-of-risks statements all have significant effects on the S&P500: all significantly reduce the S&P500 futures' volatility around the time they are published. Finally, the publication of FOMC minutes has a significant effect on the volatility of the TNotes. This is because the minutes contain macroeconomic analysis which is most relevant for the medium-term outlook for interest rates.

4.2 Parametric results

In this section we estimate a model to quantify the size of the effects of the announcements we are interested in. As we have seen in the previous sections most evident results emerged when realized or range-based volatility were used. Hence, we will estimate a model on the realized volatility series. Several studies document the properties of realized volatility, constructed from high-frequency data (see e.g. Andersen, Bollerslev, Diebold & Labys (2003) and Martens, van Dijk & de Pooter (2004)), many of them showing that log realized volatility exhibits long memory. Hence before we estimate the model we investigate the distributional characteristics of the S&P500 volatility.[16]

4.2.1 Distributional characteristics of realized volatility

Figure 7 presents the daily realized volatility, standard deviation and log volatility for the S&P500 futures. The descriptive statistics of the plots are reported in table 11, together with the descriptive statistics for the realized daily

[16]The results for the distribution of the log realized volatility series for the TNotes are similar.

returns, r_t. Realized daily returns are defined as:

$$r_t = \sum_{d=1}^{D} r_{t,d} \tag{17}$$

where $r_{t,d}$ is the intraday return defined below equation (4). Although we do not have the intranight data at our disposal, the given results are similar to those in Martens, van Dijk & de Pooter (2004). The standard deviation of the realized volatility is 1.6234, which is smaller than that of the squared returns, 2.6893. This shows that the daily squared returns are noisier estimates of the true volatility than the standard deviation of the realized volatility. The skewness of the realized daily volatility and the realized daily standard deviation are much larger than zero, while the log realized daily volatility is much less skewed ($S = 0.2138$). The kurtosis of the log realized daily volatility is around 3.

To give an indication about the normality of the log realized volatility in figure 8 we plot the estimated kernel density together with a normal distribution function. This figure indicates that log realized volatility is approximately normally distributed (right panel). We can also see that the realized daily standardized returns are also approximately normally distributed (left panel in figure 8).

Besides the normality property of the log realized volatility, Andersen, Bollerslev, Diebold & Labys (2003) show that the series also posses long memory. Figure 9 presents the sample autocorrelation functions for the squared realized returns, the log realized volatility, realized standard deviation and realized volatility. The figure indeed confirms that the three realized volatility series display a slow decay in the autocorrelation, which is a sign of long memory in the data. We test for the presence of long memory with the nonparametric short memory test of Leybourne, Harris & McCabe (2003). The test is based on the rate of decay of the autocovariance function. The null hypothesis of the test is that the time series possesses short memory. This implies that $\sum_{i=0}^{\infty} |\gamma_i| < \infty$, where γ_i is the autocovariance of the timeseries at lag i. The short memory test is based on the idea that the difference between long and short memory can be found via knowledge of the rate at which $\gamma_i \to 0$ as $i \to \infty$. The short memory test statistic is defined as:

$$S_{k,T} = \frac{\sqrt{T}\hat{\gamma}_{k_T}}{\hat{\sigma}_{\infty}} \tag{18}$$

where $\hat{\sigma}^2_{\infty} = \hat{\gamma}^2_0 + 2\sum_{i=1}^{l_T} \hat{\gamma}^2_i$, $\hat{\gamma}_i = \frac{1}{T}\sum_{t=i+1}^{T} y_t y_{t-i}$, y_t is taken demeaned and k_T and l_T are chosen such that $k_T, l_T \to \infty$ when $T \to \infty$ and $k_T/l_T \to 0$. Furthermore, $k_T = 5.5\sqrt{T}\ \ln T$ and $l_T = 4\sqrt[4]{T/100}$, as suggested by Leybourne, Harris & McCabe (2003). Under the null hypothesis of short memory $S_{k_T} \to N(0,1)$. The test statistic for the S&P500 takes the value 3.9747, which gives a P value of 0.0001. Therefore the null hypothesis is clearly rejected, which confirms our conclusions regardiong the long memory.

4.2.2 ARFIMA results

The estimation results for the log realized volatility series of the S&P500 and the TNotes are given in tables 12 and 13, respectively. The first model in table 12, model $\mathcal{M}_{SP1}$, assumes $\mu_t = \mu$. The best fit appears to be the ARFI model with $\phi(L)$ of order 1. The estimated d parameter is 0.5578. The value for d commonly found in the literature is 0.4, which is based on an ARFI model with no AR structure to capture the short term dynamics. If the short term dynamics are accounted for, the order of integration d we find is $0.5578 - 0.1588 = 0.3990$. This implies that the model still can be regarded as stationary. The serial correlation test given in the last three rows of the table indicates that the model is correctly specified in the sense that there is no serial correlation present in the residuals. The second model $\mathcal{M}_{SP2}$ assumes that μ_t is composed of a constant and the centered daily dummies only. This model indicates that day-of-the-week effects are present. Volatility is significantly lower on Monday, and significantly higher on Thursday and Friday.

Next we estimate model $\mathcal{M}_{SP3}$ with μ_t containing only a constant and the five announcement dummies. This model indicates that the volatility is significantly higher on the days when four of the five announcements are published: the FOMC statements, the Employment Situation, the FOMC minutes and the PPI data. Only the parameter for the CPI dummy is not significant.

However, when we estimate the full model as given in equation (9), i.e. model $\mathcal{M}_{SP4}$ combining the day-of-the-week effects and the announcement effects, only the parameters for the FOMC statements and the Employment Situation remain significant. The Friday effect, which was significant when μ_t included a constant plus the daily dummies, has disappeared in the full model. This is due to the fact that the Employment Situation news is always published on Friday. The Friday effect we first found seems to be entirely caused by the publication of the Employment Situation news. Thus, we find that the FOMC statements and the Employment Situation news significantly increase the volatility of the S&P500. The effect of the FOMC statements is larger than that of the employment news' releases.

The results for the TNotes are presented in table 13. The best model for the TNotes this appears to be an ARFI model with $\phi(L)$ of order 2. For the TNotes series we also find that the day-of-the-week effects are present (model $\mathcal{M}_{TN2}$): on Monday and Tuesday log realized volatility is lower and at the end of the week volatility is higher. The parameter estimates in column 4 and 5 of table 13 show that the central bank releases increase the volatility significantly. The effect of the FOMC statements is larger than the effect of the FOMC minutes. Other macroeconomic news also contribute significantly to higher volatility (as was also indicated by the Kruskal Wallis test). Our results for the TNotes are in line with other studies. Jones, Lamont & Lumsdaine (1998) also find a significant positive effect for the PPI and the employment news. The largest effect on volatility given by our ARFIMA model estimations is due to the Employment Situation. Such result is also documented in Fleming & Remolona (1997). The findings of Bollerslev, Cai & Song (2000) also indicate significant effects of the employment news, PPI, FOMC meetings and CPI.

Finally, we investigate the effect of the different contents of the FOMC statements. The FOMC statements are again split up into days when the statements contained votes, the balance-of-risk statement and the bias. For the S&P500 futures only the parameter of the dummy for statements which contained the balance-of-risks was significant (model $\mathcal{M}_{SP5}$ in table 12). Including balance-of-risks into the FOMC statements had a calming effect on the volatility of the S&P500. This can be seen by the large parameter for the dummy of the FOMC statements without the balance-of-risks in it. The parameter is approximately twice as large as for the FOMC statements with the balance-of-risks. The TNotes show that both the inclusion of the balance-of-risks and the bias in the FOMC statements have a significant effect on volatility (model $\mathcal{M}_{TN5}$ in table 13). The calming effect which was present for the S&P500 is not as large for the TNotes, although the volatility rises less when a bias or balance-of-risks part is added to the FOMC statement.

4.2.3 Forecasting

The most complete models, $\mathcal{M}_{SP4}$, $\mathcal{M}_{SP5}$ and $\mathcal{M}_{TN4}$, which include the daily centered dummies and the significant announcement dummies, have the best fit in terms of the AIC, SIC and the residual standard deviation (see tables 12 and 13). We will now look if the daily and announcement dummies contribute to better forecasting performance of these models.

The forecasting results for both series are presented in table 14. In the case of the S&P500 (the upper part), model $\mathcal{M}_{SP4}$, which includes the daily dummies and the FOMC statement and Employment Situation dummies, shows the smallest MSPE and the ME.[17] The Diebold-Mariano tests for model $\mathcal{M}_{SP4}$ shows only positive values (column 9) which indicates that this model is more accurate than the other four models, including model $\mathcal{M}_{SP5}$, where the FOMC statements are split up into statements with and without balance-of-risks. However, the DM-statistics.indicate that the differences in forecasting accuracy of different S&P500 models are not significant.

The forecasting results for the TNotes are shown in the lower part of table. The forecasting results in terms of the MSPE, MAPE, and HMSPE, are best for model $\mathcal{M}_{TN4}$, which includes the daily dummies and all the announcement dummies. The DM-statistics indicate that model $\mathcal{M}_{TN4}$ produces significantly better forecasts than the models $\mathcal{M}_{TN1}$, $\mathcal{M}_{TN2}$ and $\mathcal{M}_{TN3}$. Again the DM-statistic favors model $\mathcal{M}_{TN4}$ over $\mathcal{M}_{TN5}$.

[17]The HMSPE is not presented for the S&P500, because due to a few observations this accuracy statistic gave unclear results.

The estimation results in subsection 4.2.2 showed a very large parameter for the employment dummy. To verify that this is not the only important dummy, we assess the forecasting performance of models $\mathcal{M}_{TN6}$ and $\mathcal{M}_{TN7}$, which include only the Employment Situation dummy. The results show that the employment dummy is important, but the full models produce significantly better forecasts at the 5% significance level.

Still, we are mainly interested in the importance of the central bank communication dummies. Therefore, we estimated and tested the forecasting performance of models $\mathcal{M}_{TN8}$ and $\mathcal{M}_{TN9}$, which contain only the macro news' and daily dummies. The Diebold Mariano tests comparing the model with central bank communication and macro news' dummies versus only macro news dummies shows a significant negative DM statistic of -2.8952, indicating that the model containing the central bank communication dummies produces significantly better forecasts at the 5% significance level. The same is true when the daily dummies are included in both models.

5 Conclusions

We have carried out an analysis of the effect of the 'news' releases on three different financial markets in the United States: S&P500, TBills (3-month short interest rate) and TNotes (10-year long interest rate). Our focus was to isolate the effects of the releases made by the central bank: i.e. the FOMC statements and minutes, having controlled for other important information releases (like the CPI, the PPI and the Employment Situation) and volatility patterns (like long memory and day-of-the-week effects).

Our first, methodological, conclusion is that the definition of volatility influences the significance of the results. In general volatility definitions which exploit the information of the high-frequency data show more 'news' effects.

At the daily frequency, the most responsive market are the TNotes futures. They show significantly higher volatility on the days when all announcements are made. S&P500 and TBills futures react selectively. S&P500 reacts significantly to the FOMC statements and the PPI releases, while TBills react to the FOMC statements and the Employment Situation releases. Notably, we register a significant response to the FOMC statement releases in all markets.

The effects of the FOMC communication are clearer when we look at the markets on an hourly basis. The release of the FOMC statements (at around 1:15 PM) creates afternoon surges in the S&P500 volatility, with the volatility remaining higher until the exchange closes. Similarly for the TNotes and the TBills: the volatility remains significantly elevated for two hours after the FOMC release. Finally, and not surprisingly, the TNotes futures show a significant reaction to the publication of the FOMC minutes: after all the minutes contain the FOMC analysis of the current situation and the outlook, which are more relevant for the medium-term and longer-term outlook for interest rates. However, contrary to the statements, this reaction does not stay significant at the daily level.

The publication of votes had no significant effect on the TBills, while it increased the volatility of TNotes. This effect can be explained by the fact that the division of votes can be interpreted by the markets as indicative of Federal Reserve future policy intentions. As the bias has similar informational content, the results regarding the presence of the bias in the statement are quite similar. Interestingly, the short and in particular the long interest rate futures showed significant reaction to the publication of the balance-of-risks statement. Finally, the S&P500 registered a significantly lowered volatility if any of this additional information was included in the FOMC statements.

Finally, our ARFIMA model estimations allow us to assess the relative strength of the news' impact on the three markets. The results are as follows. The FOMC statements and the Employment Situation releases are the two announcements that significantly increase the volatility of the S&P500, with the statements having a larger impact. If the statement contained the balance-of-risks, the market reaction was relatively smaller. All the news significantly contributed to the volatility in the TNotes futures market, with the strongest effects of the Employment Situation and then the FOMC statements. The publication of the FOMC minutes had the smallest, but still statistically significant, effect on the volatility. When controlling for the contents, we observe that the market volatility was relatively lower when the bias and/or the votes were published with the statement.

Hence we can conclude that the three markets significantly react to central bank communication. The FOMC statements containing the interest rate decision cause significant response in the S&P500, the TBills and the TNotes futures' markets. However, incorporating additional forward-looking elements into the statements (the votes, the bias or the balance-of-risks) had a significantly calming effect on the market reaction. These results could be interpreted as an encouragement for other central banks to include such information in their releases. An increase in market volatility due to policy rate statements' releases is most likely unavoidable. So if a central bank cares about the stability in the markets, it can reduce the volatility effects of its own communication by providing more explanation with the releases.

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United States	obs.	time
CPI	72	7:30 AM (EST -1)
PPI	72	7:30 AM (EST -1)
Employment Situation	72	7:30 AM (EST -1)
Minutes of FOMC meetings	49	1:00 AM (EST -1)
FOMC statements	49	1:15 AM (EST -1)

Table 1: Overview of the news over the period 1999-2004.

Meeting date	**Interest rate**	**Bias**	**Balance of risks**	**Extra information**
29/30 June 1999	+0.25%	No bias	*NA*	First time statement with rate target & bias
24 August 1999	+0.25%	Symmetrical	*NA*	
5 October 1999		Tight	*NA*	
16 November 1999	+0.25%	Symmetrical	*NA*	
21 December 1999		Symmetrical	*NA*	
1/2 February 2000	+0.25%	*NA*	*I*	
21 March 2000	+0.25%	*NA*	*I*	
16 May 2000	+0.50%	*NA*	*I*	
27/28 June 2000		*NA*	*I*	
22 August 2000		*NA*	*I*	
3 October 2000		*NA*	*I*	
15 November 2000		*NA*	*I*	
19 December 2000		*NA*	*E*	
3 January 2001	-0.50%	*NA*	*E*	Unscheduled
30/31 January 2001	-0.50%	*NA*	*E*	
20 March 2001	-0.50%	*NA*	*E*	
18 April 2001	-0.50%	*NA*	*E*	Unscheduled
15 May 2001	-0.50%	*NA*	*E*	
26/27 June 2001	-0.25%	*NA*	*E*	
21 August 2001	-0.25%	*NA*	*E*	
17 September 2001	-0.50%	*NA*	*E*	Unscheduled
2 October 2001	-0.50%	*NA*	*E*	
6 November 2001	-0.50%	*NA*	*E*	
11 December 2001	-0.25%	*NA*	*E*	
29/30 January 2002		*NA*	*E*	
19 March 2002		*NA*	*B*	First time votes included
7 May 2002		*NA*	*B*	
25/26 June 2002		*NA*	*B*	
13 August 2002		*NA*	*E*	
24 September 2002		*NA*	*E*	Two dissents for easing
6 November 2002	-0.50%	*NA*	*B*	
10 December 2002		*NA*	*B*	
28/29 January 2003		*NA*	*B*	
18 March 2003		*NA*	No B-o-R	
6 May 2003		*NA*	*E*	
24/25 June 2003	-0.25%	*NA*	*D*	One dissent for a larger cut
12 August 2003		*AM*	*D*	Bias reappears
16 September 2003		*AM*	*D*	
28 October 2003		*AM*	*D*	
9 December 2003		*AM*	Inflation/deflation risks equal	
27/28 January 2004		*P*	Inflation/deflation risks equal	
16 March 2004		*P*	Inflation/deflation risks equal	
4 May 2004		*MP*	Risks roughly balanced	
29/30 June 2004	+0.25%	*MP*	Risks roughly balanced	
10 August 2004	+0.25%	*MP*	*R*	
21 September 2004	+0.25%	*MP*	*R*	
10 November 2004	+0.25%	*MP*	*R*	
14 December 2004	+0.25%	*MP*	*R*	Quicker release of minutes

Table 2: Overview of the FOMC statements and their content over the period 1999-2004.

Notes: I refers to 'Heightened inflation pressures' balance of risks.E refers to 'Economic weakness'. D refers to 'Risk of inflation becoming undesirably low'.B refers to 'Balanced risks with respect to the prospects for both goals'. R refers to 'Risks roughly equal'. AM refers to 'Policy accommodation can be maintained for a considerable period'. P refers to 'Committee believes that it can be patient in removing its policy accommodation'. MP refers to 'Policy accommodation can be removed at a pace that is likely to be measured'.

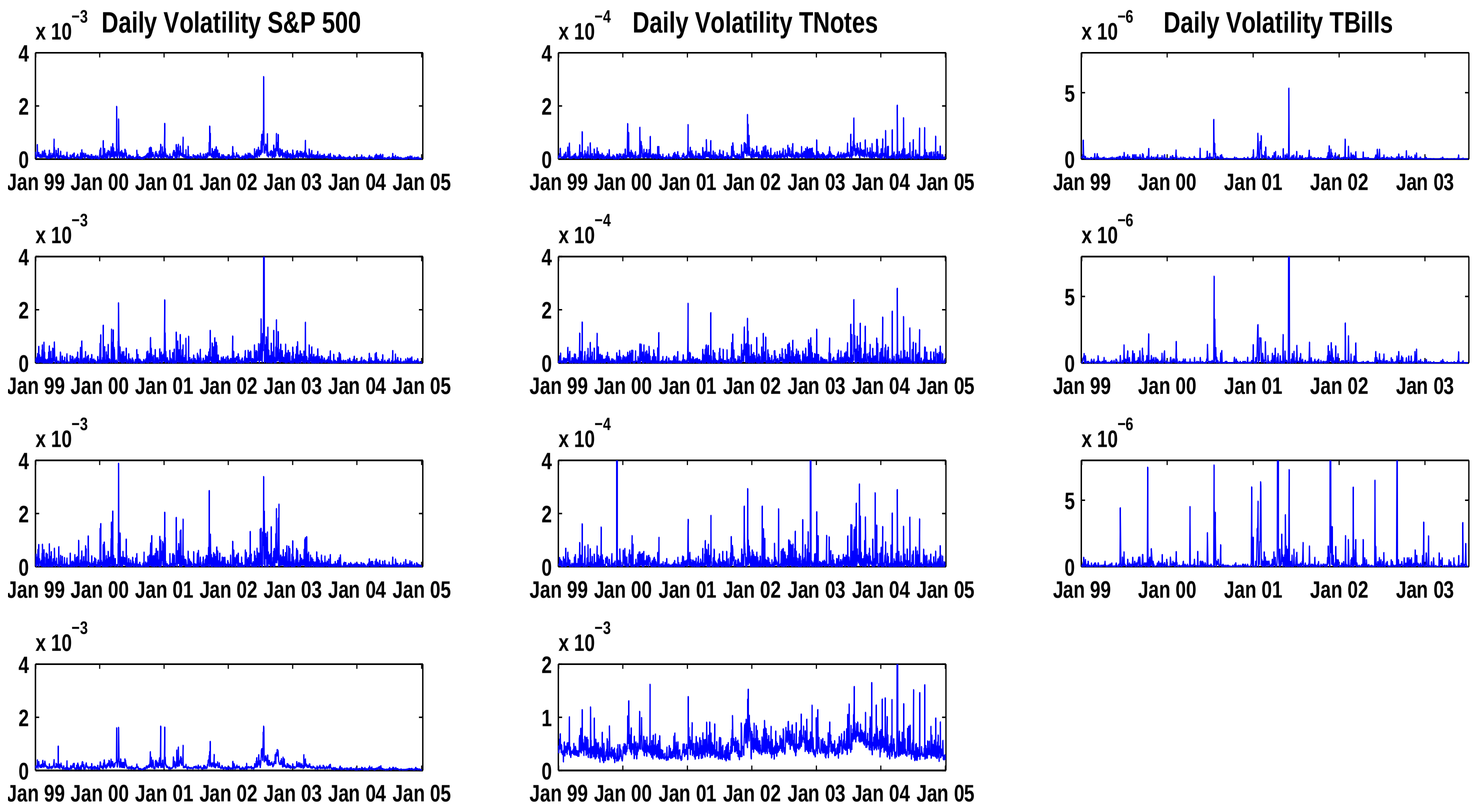

Figure 1: Daily volatilities, first row range-based volatility, second row open-to-close volatility, third row close-to-close volatility and last row realized volatility.

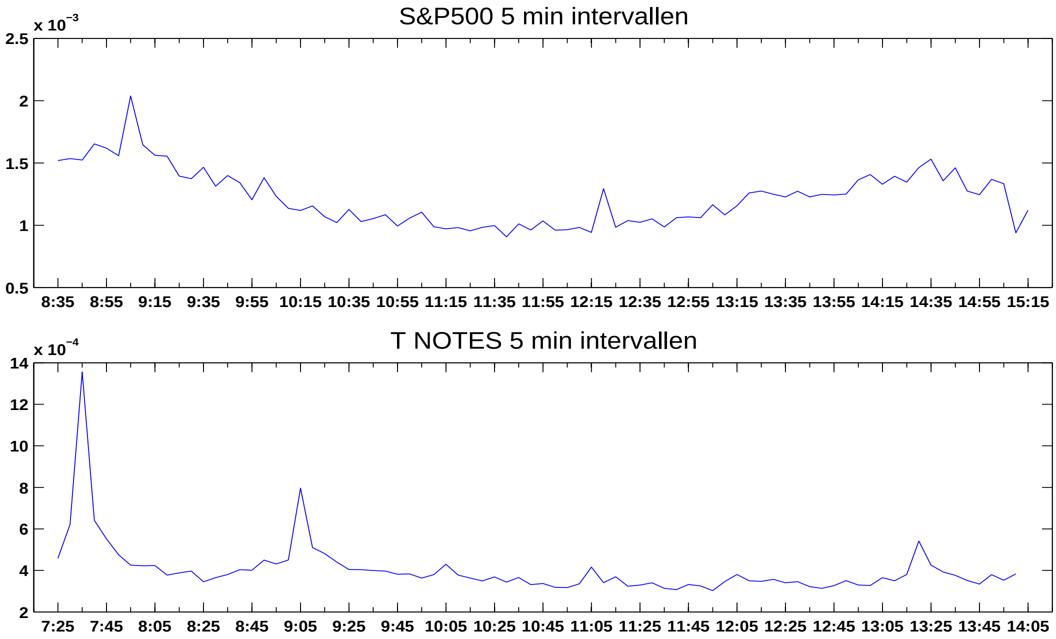

Figure 2: Mean of the close-to-close volatilities.

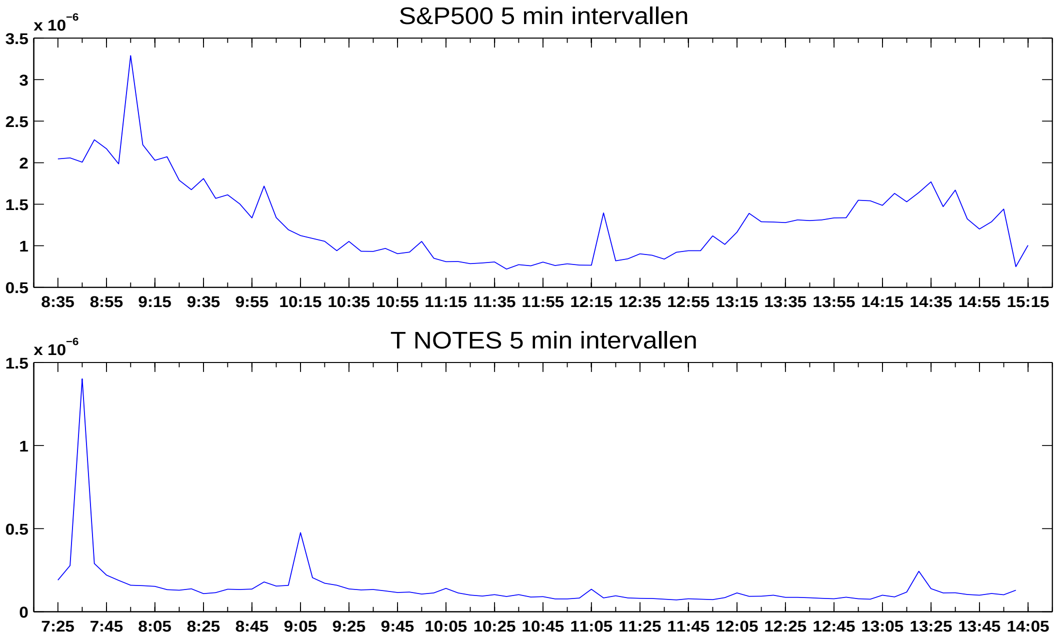

Figure 3: Mean of the range-based volatilities.

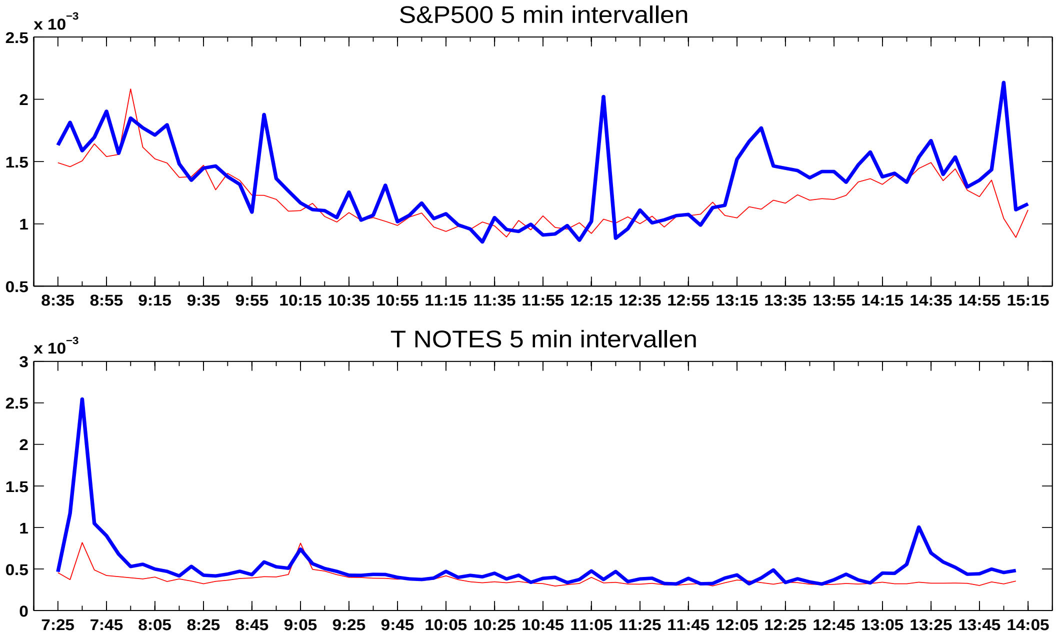

Figure 4: Mean of the close-to-close volatilities, fat solid line is days when at least one announcement is made, thin solid line is days when non of these announcements are made.

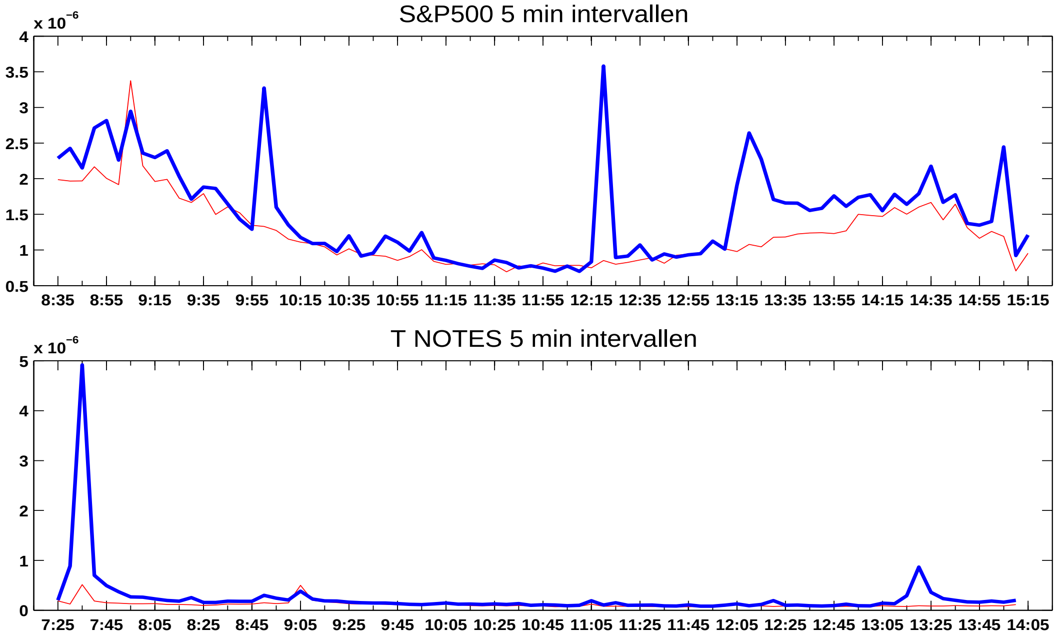

Figure 5: Mean of the range-based volatilities, fat solid line is days when at least one announcement is made, thin solid line is days when non of these announcements are made.

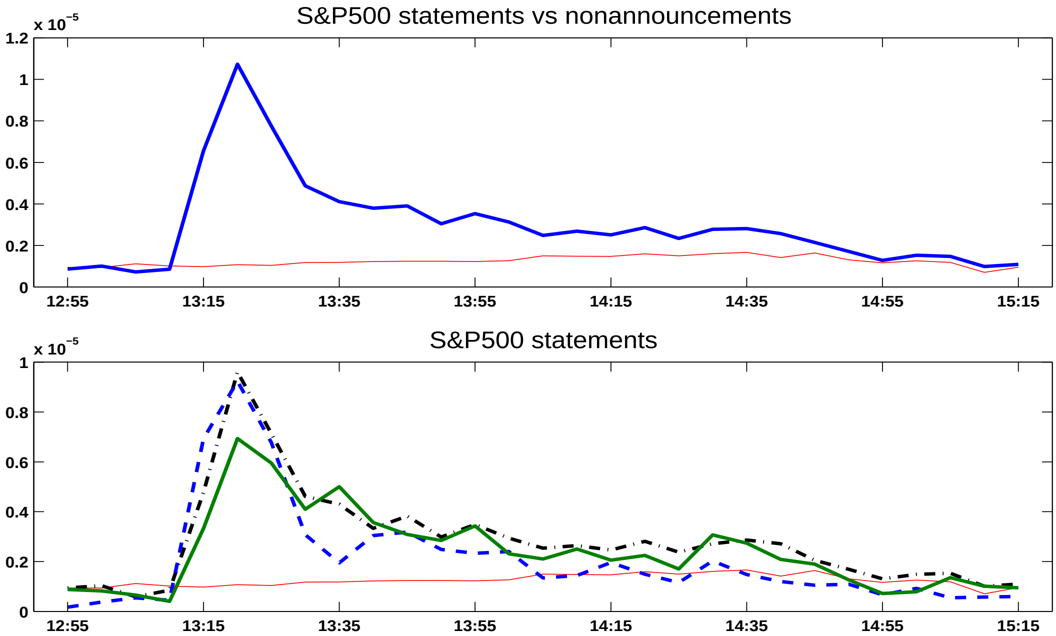

Figure 6: Mean of the range-based volatilities, top: statements (fat) vs non-announcement days, bottom: statements split in balance-of-risks (fat dashed-dotted line), bias (fat dashed line) and votes (fat solid line) versus non announcements days (thin solid line).

SP500	Close-to-Close	Ann.	Open-to-Close	Ann.	Range-Based	Ann.	Realized	Ann.
1	04/14/2000	CPI	07/24/2002		07/24/2002		07/24/2002	
2	07/24/2002		01/03/2001	State.*	04/04/2000		12/08/2000	Empl.
3	09/17/2001	State.*	04/14/2000	CPI	04/14/2000	CPI	01/03/2001	State.*
4	10/15/2002		07/10/2002		01/03/2001	State.*	04/14/2000	CPI
5	10/01/2002		10/01/2002		09/19/2001		04/04/2000	
6	03/16/2000	PPI	03/17/2003		07/22/2002		07/25/2002	
7	07/29/2002		01/24/2000		09/21/2001		07/22/2002	
8	01/03/2001	State.*	08/14/2002		10/01/2002		07/23/2002	
9	03/12/2001		03/07/2000		08/14/2002		09/21/2001	
10	10/11/2002	PPI	03/16/2000	PPI	07/25/2002		04/18/2001	State.*
11	04/18/2001	State.*	09/17/2002		07/15/2002		05/12/1999	
12	03/09/2000		09/21/2001		10/10/2002		03/22/2001	Minutes*◇
13	01/07/2000	Empl.	10/10/2002		04/18/2001	State.*	04/17/2000	
14	09/03/2002		03/12/2001		04/19/1999		07/15/2002	
15	07/10/2002		01/05/2001	Empl.	03/17/2003		10/04/2002	Empl.
16	01/04/2000		07/18/2002		01/24/2000		07/11/2002	PPI
17	07/05/2002	Empl.	04/03/2001		07/10/2002		03/14/2001	
18	04/05/2001		04/17/2000		07/23/2002		10/09/2002	
19	04/03/2001		01/07/2000	Empl.	09/17/2001	State.*	10/08/2002	
20	05/08/2002		01/29/2002		10/04/2002	Empl.	09/19/2001	
TNOTES	**Close-to-Close**	**Ann.**	**Open-to-Close**	**Ann.**	**Range-Based**	**Ann.**	**Realized**	**Ann.**
1	11/29/1999		04/02/2004	Empl.	04/02/2004	Empl.	04/02/2004	Empl.
2	11/27/2002		07/31/2003		12/05/2001		11/07/2003	Empl.
3	08/29/2003		01/03/2001	State.*	05/07/2004	Empl.	06/02/2000	Empl.
4	12/05/2001		03/05/2004	Empl.	07/31/2003		09/03/2004	Empl.
5	04/02/2004	Empl.	05/11/2001	PPI	01/28/2000		08/01/2003	Empl.
6	11/26/2003		05/07/2004	Empl.	12/07/2001		12/07/2001	
7	08/13/2003		01/09/2004	Empl.	01/03/2001	State.*	07/02/2004	Empl.
8	11/15/2001		12/05/2001		04/04/2000		08/06/2004	Empl.
9	02/28/2002		05/14/1999	CPI	09/03/2004	Empl.	01/03/2001	State.*
10	05/31/2002		09/05/2003	Empl.	08/06/2004	Empl.	01/28/2004	State.*◇⋆
11	01/02/2003		07/15/2003		03/05/2004	Empl.	12/05/2001	
12	03/05/2004	Empl.	10/03/2003	Empl.	01/28/2004	State.*◇⋆	01/09/2004	Empl.
13	05/11/2001	PPI	11/16/2001	CPI	05/14/1999	CPI	07/31/2003	
14	09/05/2003	Empl.	06/15/2004	CPI	02/03/2000	Minutes◇⋆	03/05/2004	Empl.
15	10/03/2003	Empl.	01/02/2003		07/15/2003		02/03/2000	Minutes◇⋆
16	06/15/2004	CPI	08/06/2004	Empl.	12/31/2001	PPI	05/07/2004	Empl.
17	08/06/2004	Empl.	12/07/2001		11/05/2000	Empl.	07/03/2003	Empl.
18	01/03/2001	State.*	07/20/2000		06/02/2000	Empl.	12/05/2003	Empl.
19	10/15/2002		04/30/1999		08/01/2003	Empl.	12/06/2002	Empl.
20	09/02/2003		03/07/2002		01/09/2004	Empl.	06/30/1999	State.*
TBILLS	**Close-to-Close**	**Ann.**	**Open-to-Close**	**Ann.**	**Range-Based**	**Ann.**		
1	09/13/2001		04/18/2001	State.*	04/18/2001	State.*		
2	03/08/2001		05/31/2000		05/31/2000			
3	05/29/2002		06/02/2000	Empl.	12/22/2000			
4	05/31/2000		11/06/2001	State.*	01/05/2001	Empl.		
5	09/09/1999		12/26/2000		11/06/2001	State.		
6	04/18/2001	State.*	12/22/2000		01/13/1999			
7	03/01/2002		09/14/1999		01/02/2001			
8	01/04/2001	Minutes*◇	03/27/2001		06/02/2000	Empl.		
9	11/29/2000		11/16/2001	CPI	12/26/2000			
10	12/05/2001		01/02/2001		01/03/2001	State.*		
11	01/05/2001	Empl.	01/05/2001	Empl.	09/07/2001	Empl.		
12	12/26/2000		12/31/1999		11/16/2001	CPI		
13	02/25/2000		12/21/2000	Minutes*◇	01/23/2001			
14	06/02/1999		01/03/2001	State.*	04/04/2000			
15	06/05/2000		01/04/2001	Minutes*◇	09/14/1999			
16	04/04/2001		01/23/2001		01/04/2001	Minutes*◇		
17	10/15/2002		06/28/2001	Minutes*◇	03/27/2001			
18	06/10/2003		09/17/2001	State.*	09/17/2001	State.*		
19	09/19/2001		12/13/2001	PPI, Minutes*◇	03/13/2002			
20	12/21/2000	Minutes*◇	05/08/2000		03/20/2002			

Table 3: Top 20 largest volatilities for the daily series, State. are the FOMC statements, Empl. is the Employment Situation and Minutes are Minutes of the FOMC meetings. An $*$ indicates that there were balance-of-risks statements, a $\diamond$ indicates that there were votes available and a $\star$ indicates there was bias available.

	SP500		Ann.			Ann.			Ann.
	Close-to-Close	**Time**		**Open-to-Close**	**Time**		**Range-Based**	**Time**	
1	12/08/2000	15:05	Empl.	12/08/2000	15:05	Empl.	01/03/2001	12:20	State.*
2	01/03/2001	12:20	State.*	01/03/2001	12:20	State.*	04/18/2001	10:00	State.*
3	04/18/2001	10:00	State.*	04/18/2001	10:00	State.*	12/08/2000	15:05	Empl.
4	05/12/1999	08:50		05/12/1999	08:50		05/12/1999	08:50	
5	06/30/1999	13:20	State.*	03/07/2003	09:15	Empl.	09/17/2001	08:50	State.*
6	03/07/2003	09:15	Empl.	06/30/1999	13:20	State.*	03/07/2003	09:15	Empl.
7	04/04/2000	11:55		04/04/2000	11:55		05/12/1999	08:55	
8	04/04/2000	12:10		04/14/2000	14:55	CPI	06/30/1999	13:20	State.*
9	04/14/2000	14:55	CPI	11/06/2002	13:35	State.	09/17/2001	08:55	State.*
10	12/08/2000	15:10	Empl.	10/12/2001	10:50	PPI	04/04/2000	11:55	
11	05/12/1999	08:55		11/13/2002	09:50		01/03/2001	12:35	State.*
12	11/13/2002	09:50		12/04/2000	10:45		04/14/2000	14:55	CPI
13	10/12/2001	10:50	PPI	05/12/1999	08:55		11/06/2002	13:35	State.$^{*\diamond}$
14	12/04/2000	10:45		10/29/2002	09:05		07/03/2003	09:40	Empl.
15	04/04/2000	11:45		03/07/2003	09:20	Empl.	10/05/1999	13:15	State.*
16	11/06/2002	13:35	State.*	07/24/2002	10:35		09/17/2001	09:00	State.*
17	10/29/2002	09:05		07/25/2002	14:35		12/08/2000	15:10	Empl.
18	04/04/2000	12:30		09/17/2001	08:50	State.*	11/13/2002	09:50	
19	07/25/2002	14:35		04/04/2000	12:30		09/21/2001	09:45	
20	07/24/2002	09:30		07/25/2002	14:20		10/12/2000	09:00	
	TNOTES		**Ann.**			**Ann.**			**Ann.**
	Close-to-Close	**Time**		**Open-to-Close**	**Time**		**Range-Based**	**Time**	
1	04/02/2004	07:35	Empl.	04/02/2004	07:35	Empl.	04/02/2004	07:35	Empl.
2	09/03/2004	07:35	Empl.	11/07/2003	07:35	Empl.	09/03/2004	07:35	Empl.
3	11/07/2003	07:35	Empl.	06/02/2000	07:35	Empl.	01/09/2004	07:35	Empl.
4	01/09/2004	07:35	Empl.	01/09/2004	07:35	Empl.	02/06/2004	07:35	Empl.
5	08/06/2004	07:30	Empl.	08/06/2004	07:30	Empl.	11/07/2003	07:35	Empl.
6	06/02/2000	07:35	Empl.	03/05/2004	07:35	Empl.	06/02/2000	07:35	Empl.
7	03/05/2004	07:35	Empl.	12/05/2003	07:35	Empl.	08/06/2004	07:30	Empl.
8	06/30/1999	13:20	State.*	05/07/2004	07:35	Empl.	03/05/2004	07:35	Empl.
9	05/07/2004	07:35	Empl.	06/30/1999	13:20	State.*	12/05/2003	07:35	Empl.
10	12/05/2003	07:35	Empl.	09/03/2004	07:30	Empl.	05/07/2004	07:35	Empl.
11	09/03/2004	07:30	Empl.	07/02/2004	07:30	Empl.	01/28/2004	13:20	State.$^{*\diamond\star}$
12	12/06/2002	07:35	Empl.	12/06/2002	07:35	Empl.	05/04/2004	13:20	State.$^{*\diamond\star}$
13	07/02/2004	07:30	Empl.	02/06/2004	07:35	Empl.	01/03/2001	12:20	State.*
14	02/06/2004	07:35	Empl.	11/05/2004	07:30	Empl.	11/05/2004	07:35	Empl.
15	11/05/2004	07:30	Empl.	10/03/2003	07:35	Empl.	08/06/2004	07:35	Empl.
16	10/03/2003	07:35	Empl.	01/10/2003	07:35	Empl.	10/03/2003	07:35	Empl.
17	07/02/2004	07:35	Empl.	07/02/2004	07:35	Empl.	04/29/2004	07:35	
18	03/05/1999	07:35	Empl.	01/03/2001	12:20	State.*	09/03/2004	07:30	Empl.
19	07/31/2003	07:35		10/30/2003	07:35	Minutes$^{*\diamond\star}$	04/02/2004	07:30	Empl.
20	08/06/1999	07:45	Empl.	01/28/2004	13:20	State.$^{*\diamond\star}$	05/07/1999	07:35	Empl.

Table 4: Top 20 largest movements for the 5-minute series, State. are the FOMC statements, Empl. is the Employment Situation and Minutes are Minutes of the FOMC meetings. An $*$ indicates that there were balance-of-risks Statements, a $\diamond$ indicates that there were votes available and a $\star$ indicates that there was bias available.

S&P500	Close-to-Close		Open-to-Close		Range-Based		Realized	
Ann.	KW	Pvalue	KW	Pvalue	KW	Pvalue	KW	Pvalue
All	6.2259	**0.0126**	1.8492	0.1739	7.3518	**0.0067**	6.4238	**0.0113**
CPI	0.4214	0.5162	-0.0273	0.8687	1.0565	0.3040	0.0722	0.7882
PPI	2.9550	*0.0856*	2.4327	0.1188	3.7213	*0.0537*	0.4474	0.5036
Employment	1.7137	0.1905	-0.1060	0.7447	0.0708	0.7901	2.4380	0.1184
Minutes	0.9236	0.3365	-0.0355	0.8505	3.7213	0.4078	1.2010	0.2731
Statements	0.8050	0.3696	0.6172	0.4321	7.2947	**0.0069**	7.6558	**0.0057**
TNOTES	Close-to-Close		Open-to-Close		Range-Based		Realized	
Ann.	KW	Pvalue	KW	Pvalue	KW	Pvalue	KW	Pvalue
All	20.7963	**0.0001**	38.0497	**0.0001**	139.6157	**0.0001**	166.4335	**0.0001**
CPI	1.3669	0.2423	4.2167	**0.0400**	25.2107	**0.0001**	30.7033	**0.0001**
PPI	6.4011	**0.0114**	7.5939	**0.0059**	27.6612	**0.0001**	33.5720	**0.0001**
Employment	20.9389	**0.0001**	36.0891	**0.0001**	102.2309	**0.0001**	111.3145	**0.0001**
Minutes	1.7358	0.1877	2.5118	0.1130	15.7048	**0.0001**	18.3712	**0.0001**
Statements	1.8877	0.1695	3.9088	**0.0480**	17.7815	**0.0001**	29.4799	**0.0001**
TBILLS	Close-to-Close		Open-to-Close		Range-Based			
Ann.	KW	Pvalue	KW	Pvalue	KW	Pvalue		
All	0.9465	0.3306	6.8097	**0.0091**	9.2437	**0.0024**		
CPI	0.0001	0.9964	0.1945	0.6592	0.0940	0.7591		
PPI	0.0699	0.7914	0.4397	0.5072	0.7975	0.3718		
Employment	0.5767	0.4476	3.7011	*0.0544*	6.1426	**0.0132**		
Minutes	-0.0289	0.8650	0.9205	0.3374	2.2357	0.1349		
Statements	2.4460	0.1178	6.4013	**0.0114**	8.7063	**0.0032**		

Table 5: Results of the Kruskal-Wallis tests for the daily data.

S&P500 Ann.	Time	Close-to-Close KW	Close-to-Close Pvalue	Open-to-Close KW	Open-to-Close Pvalue	Range-Based KW	Range-Based Pvalue
All	9:30	3.8499	**0.0497**	3.4899	**0.0497**	6.3035	**0.0121**
	10:30	-0.2157	0.6423	-0.2860	0.5928	0.0239	0.8772
	11:30	0.1342	0.7141	0.1098	0.7404	0.0398	0.8419
	12:30	0.3812	0.5370	0.4925	0.4828	0.0965	0.7561
	13:30	0.1522	0.6964	0.1721	0.6783	4.4998	**0.0339**
	14:30	0.4260	0.5139	0.3687	0.5437	6.0258	**0.0141**
	15:30	0.8257	0.3635	0.8972	0.3435	2.2020	0.1378
PPI	9:30	1.4966	0.2212	1.4966	0.2212	6.4265	**0.0112**
	10:30	-0.0712	0.7896	-0.1245	0.7242	0.6306	0.4271
	11:30	1.8214	0.1771	2.5219	0.1123	2.4760	0.1156
Statements	13:30	6.7882	**0.0092**	6.6698	**0.0098**	36.0412	**0.0001**
	14:30	22.3304	**0.0001**	22.1704	**0.0001**	48.0311	**0.0001**
	15:30	10.8906	**0.0010**	9.3539	**0.0022**	13.6304	**0.0002**

TNOTES Ann.	Time	Close-to-Close KW	Close-to-Close Pvalue	Open-to-Close KW	Open-to-Close Pvalue	Range-Based KW	Range-Based Pvalue
All	8:20	65.9810	**0.0001**	65.9810	**0.0001**	201.7036	**0.0001**
	9:20	4.6488	**0.0311**	3.2947	*0.0695*	19.2515	**0.0001**
	10:20	0.6921	0.4054	0.5347	0.4646	7.9343	**0.0049**
	11:20	5.6064	**0.0179**	6.5312	**0.0106**	21.0435	**0.0001**
	12:20	0.5874	0.4434	0.4437	0.5053	5.5133	**0.0189**
	13:20	2.9938	*0.0836*	2.2298	0.1354	20.3356	**0.0001**
	14:20	5.4893	**0.0191**	6.6914	**0.0097**	28.3636	**0.0001**
CPI	8:20	30.3685	**0.0001**	30.3685	**0.0001**	68.2386	**0.0001**
	9:20	1.2334	0.2667	0.3360	0.5622	4.2944	**0.0382**
	10:20	1.5390	0.2148	1.6316	0.2015	7.6237	**0.0058**
	11:20	9.0971	**0.0026**	8.5268	**0.0035**	15.1287	**0.0001**
PPI	8:20	94.4638	**0.0001**	25.7754	**0.0001**	25.7754	**0.0001**
	9:20	14.9641	**0.0001**	3.6811	*0.0550*	3.9881	**0.0458**
	10:20	-0.0546	0.8153	-0.8151	0.3666	-0.9564	0.3281
	11:20	10.7009	**0.0011**	5.4087	**0.0200**	3.2365	*0.0720*
Employment	8:20	76.7657	**0.0001**	76.7657	**0.0001**	171.1158	**0.0001**
	9:20	7.4807	**0.0062**	5.7945	**0.0161**	20.4878	**0.0001**
	10:20	5.4819	**0.0192**	4.6352	**0.0313**	17.2938	**0.0001**
	11:20	0.9413	0.3319	2.6889	0.1011	6.5210	**0.0001**
Minutes	13:20	4.8351	**0.0279**	3.6611	*0.0557*	14.4567	**0.0001**
	14:20	2.5574	0.1098	2.6184	0.1056	7.1879	**0.0001**
Statements	13:20	20.5623	**0.0001**	17.1116	**0.0001**	73.2012	**0.0001**
	14:20	41.3728	**0.0001**	38.1724	**0.0001**	112.9247	**0.0001**

TBILLS Ann.	Time	Close-to-Close KW	Close-to-Close Pvalue	Open-to-Close KW	Open-to-Close Pvalue	Range-Based KW	Range-Based Pvalue
All	8:20	1.7038	0.1918	1.7038	0.1918	2.9083	*0.0881*
	9:20	0.1123	0.7375	-1.5491	0.2133	-0.8243	0.3639
	10:20	1.7430	0.1868	0.6275	0.4283	1.9260	0.1652
	11:20	2.9273	*0.0871*	0.1684	0.6815	0.3356	0.5624
	12:20	4.9581	**0.0260**	10.4167	**0.0012**	10.7039	**0.0012**
	13:20	8.4638	**0.0036**	1.6340	0.2011	1.8207	0.1772
	14:20	-0.0023	0.9618	-0.0136	0.9072	-0.0021	0.9637
Employment	8:20	5.4070	**0.0201**	5.4070	**0.0201**	9.5732	**0.0020**
	9:20	0.0226	0.8804	-0.6524	0.4193	-0.5442	0.4607
	10:20	1.4462	0.2291	-0.1614	0.6879	0.0903	0.7638
	11:20	1.9338	0.1643	0.3064	0.5799	0.7518	0.3859
Statements	13:20	26.7961	**0.0001**	24.7944	**0.0001**	23.1753	**0.0001**
	14:20	5.2532	**0.0219**	7.2024	**0.0073**	5.7767	**0.0162**

Table 6: Results of the Kruskal-Wallis tests for the hourly data.

S&P500	Time	Close-to-Close		Open-to-Close		Range-Based	
Ann.		KW	Pvalue	KW	Pvalue	KW	Pvalue
Decision	13:30	-0.1296	0.7188	-0.3136	0.5755	0.3136	0.5755
	14:30	0.1936	0.6599	0.1444	0.7039	0.2304	0.6312
	15:30	-0.7056	0.4009	-0.7744	0.3789	-0.1936	0.6599
Votes	13:30	-2.1387	0.1436	-1.5427	0.2142	-8.4381	**0.0037**
	14:30	-1.3971	0.2372	-1.2586	0.2619	-2.6986	0.1004
	15:30	-4.0940	**0.0430**	-4.7657	**0.0451**	-8.4381	**0.0037**
Bias	13:30	-0.7953	0.3725	-0.6882	0.4068	-1.6533	0.1985
	14:30	-1.9888	0.1585	-1.6533	0.1985	-5.2994	**0.0213**
	15:30	-4.0940	**0.0202**	-4.8327	0.0279	-14.8800	**0.0001**
BoR	13:30	-4.0000	**0.0455**	-4.2318	**0.0397**	-9.3461	**0.0022**
	14:30	0.4702	0.4929	0.3265	0.5677	-0.0131	0.9090
	15:30	-0.9437	0.3313	-1.1176	0.2904	-0.6865	**0.0382**
TNOTES	Time	Close-to-Close		Open-to-Close		Range-Based	
Statements		KW	Pvalue	KW	Pvalue	KW	Pvalue
Decision	13:20	-0.1369	0.7114	-0.2209	0.6383	0.4096	0.5222
	14:20	0.0895	0.7648	-0.0665	0.7964	0.0895	0.7648
Votes	13:20	0.4504	0.5021	0.8309	0.3620	4.2578	**0.0391**
	14:20	1.9406	0.1636	5.7806	**0.0162**	3.9881	**0.0295**
Bias	13:20	5.1104	**0.0238**	4.1310	**0.0421**	11.5682	**0.0007**
	14:20	13.8889	**0.0002**	8.8889	**0.0029**	2.3510	0.1251
BoR	13:20	-0.4702	0.4929	-0.1380	0.7103	-0.5102	0.4751
	14:20	-2.0908	0.1482	0.0019	0.9651	0.0941	0.7591
TBILLS	Time	Close-to-Close		Open-to-Close		Range-Based	
Ann.		KW	Pvalue	KW	Pvalue	KW	Pvalue
Decision	13:20	6.1611	**0.0131**	4.0774	**0.0435**	4.0774	**0.0435**
	14:20	0.5052	0.4772	1.1775	0.2779	1.0935	0.2957
Votes	13:20	-1.8264	0.1766	-0.0507	0.8218	-0.0507	0.8218
	14:20	-0.8996	0.3429	-0.2412	0.6234	-0.1993	0.6553
Bias	13:20	-1.4386	0.2304	-1.1721	0.2790	-1.4248	0.2326
	14:20	3.0341	*0.0815*	-1.8044	0.1792	-1.8044	0.1792
BoR	13:20	1.5635	0.2111	0.6182	0.4317	0.7941	0.3729
	14:20	-3.5710	*0.0588*	2.5062	0.1134	2.5062	0.1134

Table 7: Results of the Kruskal-Wallis tests; testing for differences in statements in the hourly data.

S&P500	Close-to-Close		Open-to-Close		Range-Based	
Time	KW	Pvalue	KW	Pvalue	KW	Pvalue
8:35	2.1572	0.1419	2.1572	0.1419	6.9128	**0.0086**
8:40	3.2193	*0.0728*	1.9076	0.1672	2.4846	0.1150
8:45	1.3281	0.2491	1.5169	0.2181	4.0209	**0.0449**
8:50	0.0010	0.9749	0.0444	0.8332	1.5876	0.2077
8:55	2.8730	*0.0901*	2.1576	0.1419	8.6146	**0.0033**
9:00	0.2349	0.6279	0.7113	0.3990	2.2882	0.1304
9:05	-2.8214	0.0930	-4.7955	**0.0285**	-2.0641	0.1508
12:55	1.9553	0.1620	1.2814	0.2576	0.0151	0.9023
13:00	-0.0231	0.8792	-0.3073	0.5794	0.5331	0.4653
13:05	-0.9357	0.3334	-0.5977	0.4394	-0.0012	0.9726
13:10	1.8400	0.1750	0.9387	0.3326	0.3286	0.5665
13:15	5.5888	**0.0181**	6.7701	**0.0093**	9.7615	**0.0018**
13:20	3.0096	*0.0828*	2.5806	0.1082	12.9542	**0.0003**
13:25	16.1132	**0.0001**	16.6649	**0.0001**	21.4325	**0.0001**
13:30	0.8925	0.3448	0.6895	0.4063	5.2809	**0.0216**
13:35	7.5925	**0.0059**	3.6692	*0.0554*	8.9334	**0.0028**
13:40	7.1656	**0.0074**	5.9546	**0.0147**	9.0570	**0.0026**
13:45	2.2112	0.1370	1.7509	0.1858	4.0129	**0.0452**
13:50	4.7639	**0.0291**	6.3520	**0.0117**	9.1231	**0.0025**
13:55	7.6899	**0.0056**	7.3628	**0.0067**	13.5252	**0.0002**
14:00	0.1193	0.7298	0.0260	0.8719	7.4458	**0.0064**
14:05	0.7966	0.3721	1.2011	0.2731	2.1930	0.1386

TNOTES	Close-to-Close		Open-to-Close		Range-Based	
Time	KW	Pvalue	KW	Pvalue	KW	Pvalue
7:25	0.9214	0.3371	0.9214	0.3371	2.6928	0.1008
7:30	16.1024	**0.0001**	30.9804	**0.0001**	59.2799	**0.0001**
7:35	127.1407	**0.0001**	152.4325	**0.0001**	271.0179	**0.0001**
7:40	85.5397	**0.0001**	80.6430	**0.0001**	204.7819	**0.0001**
7:45	68.9381	**0.0001**	63.1971	**0.0001**	174.5154	**0.0001**
7:50	38.6851	**0.0001**	32.2824	**0.0001**	134.7411	**0.0001**
7:55	36.6105	**0.0001**	29.4049	**0.0001**	115.8619	**0.0001**
8:00	23.2551	**0.0001**	22.6310	**0.0001**	97.6232	**0.0001**
8:05	22.9772	**0.0001**	17.3979	**0.0001**	82.2267	**0.0001**
8:10	10.8739	**0.0010**	1.7822	0.1819	54.0057	**0.0001**
8:15	20.5366	**0.0001**	22.9095	**0.0001**	68.2036	**0.0001**
8:20	15.5149	**0.0001**	17.9680	**0.0001**	89.2366	**0.0001**
8:25	18.6929	**0.0001**	10.7367	**0.0011**	55.3767	**0.0001**
8:30	9.5763	**0.0020**	6.2747	**0.0122**	47.4400	**0.0001**
8:35	12.2668	**0.0005**	8.3150	**0.0039**	42.1399	**0.0001**
8:40	17.7097	**0.0001**	11.6904	**0.0006**	34.3188	**0.0001**
8:45	3.3238	*0.0683*	10.1036	**0.0015**	33.2942	**0.0001**
8:50	10.2508	**0.0014**	12.1507	**0.0005**	38.3812	**0.0001**
8:55	7.4790	**0.0062**	5.6427	**0.0175**	35.3375	**0.0001**
9:00	10.6222	**0.0011**	11.0793	**0.0009**	34.2639	**0.0001**
9:05	-0.3560	0.5507	-1.5192	0.2177	-0.1045	0.7466
12:55	0.4469	0.5038	5.3716	**0.0205**	5.5736	**0.0182**
13:00	0.5161	0.4725	4.8997	**0.0269**	7.8065	**0.0052**
13:05	-0.1304	0.7181	1.0260	0.3111	2.4976	0.1140
13:10	2.0708	0.1501	-0.0151	0.9021	1.4286	0.2320
13:15	4.6242	**0.0312**	9.1439	**0.0025**	17.4189	**0.0001**
13:20	5.8388	**0.0157**	22.6875	**0.0001**	17.0674	**0.0001**
13:25	11.1724	**0.0008**	9.5781	**0.0020**	22.9532	**0.0001**
13:30	7.3648	**0.0067**	7.3486	**0.0067**	18.4971	**0.0001**
13:35	12.8193	**0.0003**	4.3575	**0.0368**	6.2423	**0.0125**
13:40	3.0520	*0.0806*	5.4287	**0.0198**	16.4484	**0.0001**
13:45	3.9779	**0.0461**	8.6639	**0.0032**	15.5181	**0.0001**
13:50	6.6389	**0.0100**	14.0515	**0.0002**	29.9922	**0.0001**
13:55	2.3737	0.1234	2.7506	*0.0972*	14.2319	**0.0002**
14:00	5.8325	**0.0157**	0.7444	0.3883	23.3446	**0.0001**

Table 8: Results of the Kruskal-Wallis tests; testing "all" announcements versus no announcements for the 5-minute data.

S&P500	PPI		Statements		TNOTES CPI		PPI		Employment		Minutes		Statements	
Time	KW	Pvalue	KW	Pvalue	KW	Pvalue	KW	Pvalue	KW	Pvalue	KW	Pvalue	KW	Pvalue
7:25					0.0027	0.9582	0.0049	0.9443	9.8739	**0.0017**				
7:30					13.8247	**0.0002**	15.6132	**0.0001**	92.0304	**0.0001**				
7:35					95.7599	**0.0001**	130.1717	**0.0001**	163.9274	**0.0001**				
7:40					53.2250	**0.0001**	80.7707	**0.0001**	161.6212	**0.0001**				
7:45					41.2375	**0.0001**	68.6865	**0.0001**	144.2161	**0.0001**				
7:50					35.8035	**0.0001**	49.2216	**0.0001**	122.6647	**0.0001**				
7:55					35.2893	**0.0001**	43.1896	**0.0001**	109.9123	**0.0001**				
8:00					21.8999	**0.0001**	30.1675	**0.0001**	107.7377	**0.0001**				
8:05					21.3214	**0.0001**	29.7576	**0.0001**	94.9770	**0.0001**				
8:10					5.7359	**0.0166**	18.0132	**0.0001**	101.7207	**0.0001**				
8:15					9.6190	**0.0019**	18.9037	**0.0001**	83.0989	**0.0001**				
8:20					35.8211	**0.0001**	44.0115	**0.0001**	63.4430	**0.0001**				
8:25					15.2921	**0.0001**	18.5778	**0.0001**	55.5236	**0.0001**				
8:30					10.5930	**0.0011**	18.7083	**0.0001**	39.6400	**0.0001**				
8:35	2.3094	0.1286			15.3295	**0.0001**	12.3575	**0.0004**	46.9626	**0.0001**				
8:40	3.6371	*0.0565*			15.0201	**0.0001**	3.5436	*0.0598*	45.4359	**0.0001**				
8:45	1.0643	0.3022			10.4528	**0.0012**	7.9295	**0.0049**	49.4376	**0.0001**				
8:50	5.0952	**0.0240**			14.6587	**0.0001**	27.2601	**0.0001**	33.7252	**0.0001**				
8:55	1.4978	0.2210			9.6333	**0.0019**	28.0799	**0.0001**	15.4188	**0.0001**				
9:00	2.9032	*0.0884*			9.9971	**0.0016**	12.7816	**0.0004**	33.4446	**0.0001**				
9:05	-0.6797	0.4097			-8.4900	**0.0036**	0.2013	0.6537	8.0447	**0.0046**				
9:10	2.7951	*0.0946*			1.7286	0.1886	6.6524	0.0099	11.6162	**0.0007**				
9:15	0.7979	0.3717			4.2669	**0.0389**	3.0076	*0.0829*	13.9803	**0.0002**				
9:20	4.9282	**0.0264**			8.8417	**0.0029**	4.4231	**0.0355**	17.9062	**0.0001**				
9:25	3.0877	*0.0789*			12.3037	**0.0005**	3.5098	*0.0610*	18.8263	**0.0001**				
9:30	2.1407	0.1434			6.5033	**0.0108**	0.9626	0.3265	14.1867	**0.0002**				
9:35	6.5566	**0.0104**			7.3473	**0.0067**	1.0049	0.3161	9.1475	**0.0025**				
12:55			-3.9793	**0.0461**							6.4313	**0.0112**	0.8366	0.3604
13:00			-1.5468	0.2136							10.1582	**0.0014**	1.4808	0.2237
13:05			-5.7670	**0.0163**							26.6466	**0.0001**	0.1519	0.6967
13:10			-1.8646	0.1721							16.4951	**0.0001**	13.1024	**0.0003**
13:15			24.1122	**0.0001**							16.6986	**0.0001**	67.1656	**0.0001**
13:20			100.1521	**0.0001**							10.3205	**0.0013**	119.4711	**0.0001**
13:25			97.6249	**0.0001**							8.2516	**0.0041**	111.5344	**0.0001**
13:30			71.4343	**0.0001**							3.8652	**0.0493**	111.2516	**0.0001**
13:35			64.7099	**0.0001**							8.5405	**0.0157**	101.8780	**0.0001**
13:40			56.2175	**0.0001**							4.3838	**0.0363**	92.4983	**0.0001**
13:45			43.4012	**0.0001**							5.7866	**0.0161**	83.3485	**0.0001**
13:50			47.4375	**0.0001**							8.2676	**0.0040**	91.2123	**0.0001**
13:55			53.5756	**0.0001**							5.1701	**0.0230**	78.4941	**0.0001**
14:00			37.3855	**0.0001**							3.2360	*0.0720*	60.2102	**0.0001**
14:05			21.4299	**0.0001**										

Table 9: Results of the Kruskal-Wallis tests based on range-based volatility for the 5-minute data.

S&P500	Votes		Bias		BoR	
Time	KW	Pvalue	KW	Pvalue	KW	Pvalue
12:55	-2.2575	0.1330	-19.5135	**0.0001**	0.0522	0.8192
13:00	-4.2578	**0.0391**	-10.0864	**0.0015**	-0.8890	0.3458
13:05	-5.4939	**0.0191**	-4.6520	**0.0310**	-5.0947	**0.0240**
13:10	-7.3144	**0.0068**	-4.3875	**0.0362**	-2.0408	0.1531
13:15	-13.5877	**0.0002**	-6.6133	**0.0101**	-4.1151	**0.0425**
13:20	-4.8562	**0.0275**	-1.7617	0.1844	-2.0408	0.1531
13:25	-3.7762	*0.0520*	-2.2920	0.1300	-2.3804	0.1229
13:30	-2.9683	*0.0849*	-8.0727	**0.0045**	-1.2416	0.2652
13:35	-2.5686	0.1090	-11.7097	**0.0006**	0.0008	0.9772
13:40	-6.3716	**0.0116**	-4.1308	**0.0421**	-6.7600	**0.0093**
13:45	-1.5929	0.2069	-5.1101	**0.0238**	2.2931	0.1300
13:50	-0.8127	0.3673	-1.7617	0.1844	-1.3722	0.2414
13:55	-2.3795	0.1229	-3.8817	**0.0488**	-0.8359	0.3606
14:00	-5.5882	**0.0181**	-2.6843	0.1013	-3.0376	*0.0814*
14:05	-2.2575	0.1330	-10.0684	**0.0015**	-0.1600	0.6892
TNOTES	Votes		Bias		BoR	
Time	KW	Pvalue	KW	Pvalue	KW	Pvalue
12:55	0.5204	0.4707	0.9106	0.3400	-0.0204	0.8864
13:00	3.3971	*0.0653*	2.3554	0.1249	0.4319	0.5111
13:05	-1.6638	0.1971	0.5878	0.4433	-0.4713	0.4924
13:10	-3.0411	*0.0812*	-0.3556	0.5510	-0.0258	0.8724
13:15	0.2352	0.6277	6.4222	**0.0113**	-1.4696	0.2254
13:20	6.3913	**0.0115**	10.8957	**0.0010**	0.7938	0.3730
13:25	4.7407	**0.0295**	1.9756	0.1599	2.3520	0.1251
13:30	3.1135	*0.0776*	1.9755	0.1599	-0.3944	0.5300
13:35	6.8155	**0.0090**	2.6195	0.1056	0.1333	0.7150
13:40	0.6313	0.4269	1.5787	0.2090	-0.1333	0.7150
13:45	7.0327	**0.0080**	7.2000	**0.0073**	0.3586	0.5493
13:50	6.7082	**0.0096**	0.9184	0.3379	0.6931	0.4051
13:55	1.2651	0.2607	2.8304	*0.0925*	-2.0908	0.1482
14:00	0.2557	0.6131	1.3719	0.2415	-0.7426	0.3888

Table 10: Results of the Kruskal-Wallis tests; testing for differences in statements in the 5-minute data.

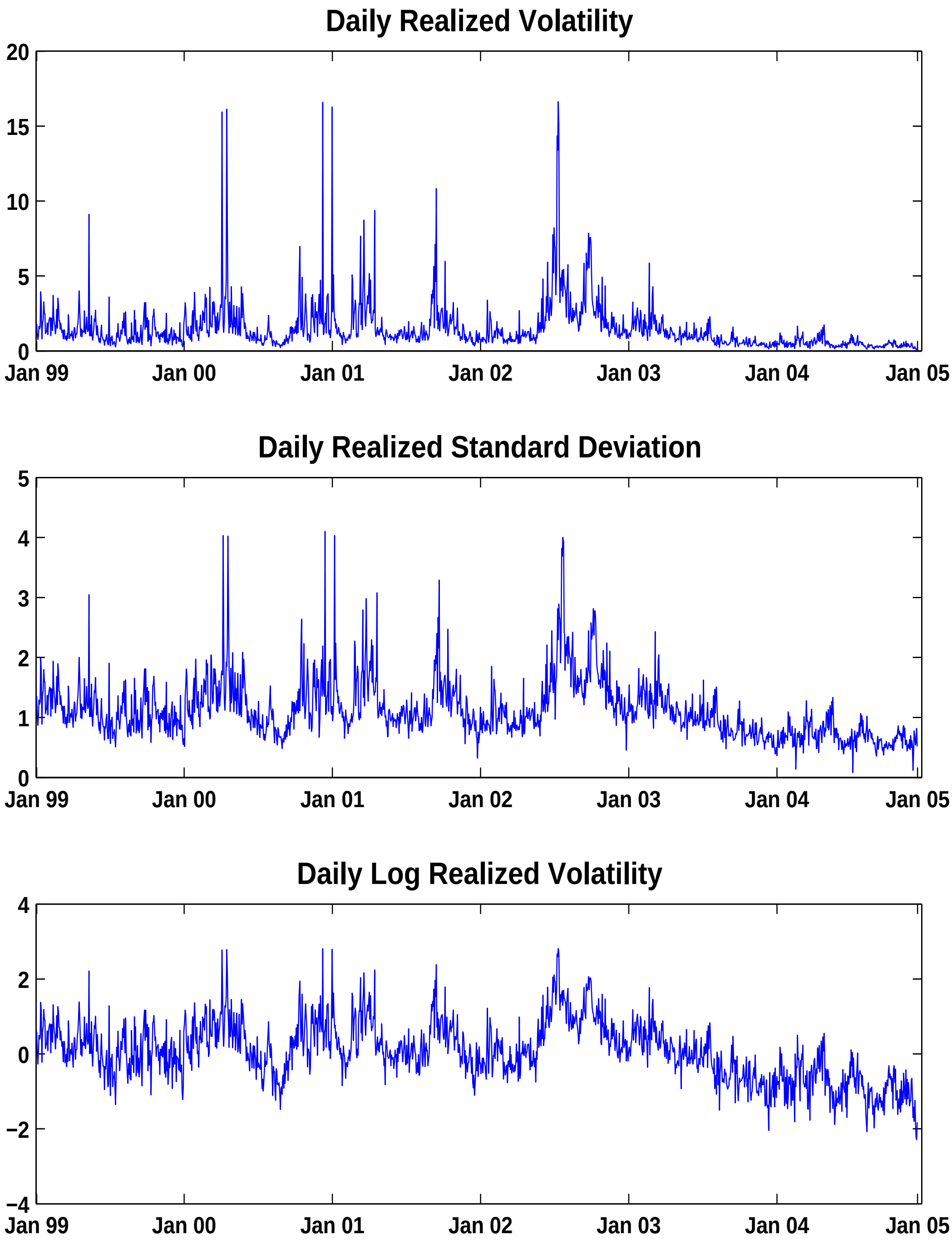

Figure 7: Realized volatilities for S&P500.

	Mean	Min	Max	Std.dev	Skew	Kurt
Realized returns	-0.0325	-4.2828	7.9711	1.1170	0.2041	5.6690
Squared returns	1.2480	0	63.5384	2.6893	10.3076	202.8537
Standardized returns	-0.0071	-3.0595	3.0475	0.9437	0.0383	2.9458
Realized volatility	1.4897	0.1016	16.6225	1.6234	4.6599	35.4996
Realized standard deviation	1.1238	0.0819	4.1020	0.4905	1.8511	9.3405
Log realized volatility	0.0646	-2.2864	2.8108	0.7892	0.2138	3.2834

Table 11: Descriptive statistics for the realized returns and volatility.

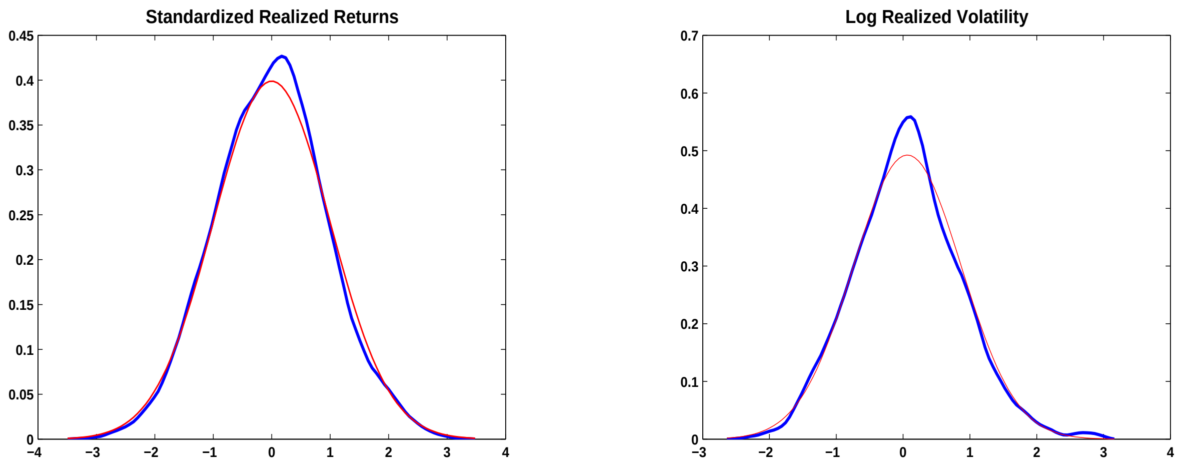

Figure 8: Kernel for standardized returns (fat line) and the standard normal density (thin line), left graph, and the kernel for log realized volatility (fat line) with normal density (thin line), right graph, for S&P500.

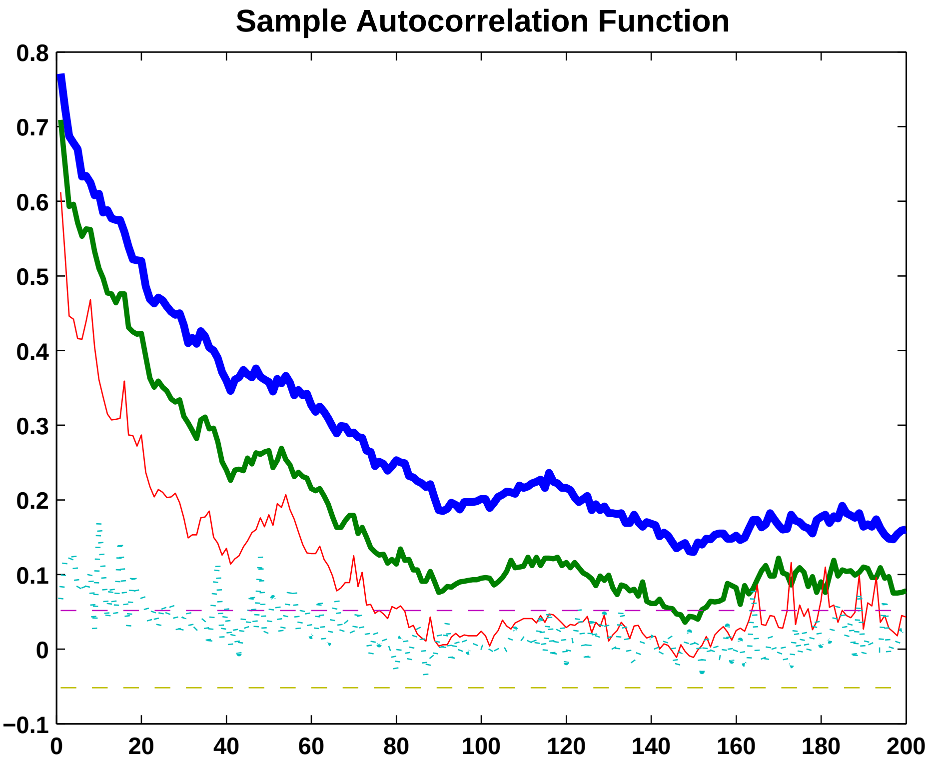

Figure 9: Sample autocorrelation function for the log realized volatilities (upper fattest solid line), realized standard deviation (fat solid line), realized volatility (thin solid line) and squared realized returns (fat dotted line) for S&P500. The 2 horizontal dashed lines are the confidence bounds, defined as $\pm 2/\sqrt{N}$, where N is the number of observations in the sample.

Model	$\mathcal{M}_{SP1}$	$\mathcal{M}_{SP2}$	$\mathcal{M}_{SP3}$	$\mathcal{M}_{SP4}$	$\mathcal{M}_{SP5}$
d	0.5578	0.5748	0.5547	0.5708	0.5705
	(0.0301)	(0.0348)	(0.0353)	(0.0354)	(0.0355)
μ	-0.1580	-0.1797	-0.1866	-0.1897	-0.1784
	(0.3513)	(0.3846)	(0.3463)	(0.3841)	(0.3762)
γ_1			0.3494	0.3177	
			(0.0721)	(0.0726)	
γ_2			0.2545	0.2118	0.2114
			(0.0574)	(0.0618)	(0.0618)
γ_3			0.1448		
			(0.0539)		
γ_4			0.0697		
			(0.0495)		
γ_5			0.1157		
			(0.0495)		
$\gamma_{1,1}$					0.2763
					(0.0744)
$\gamma_{1,2}$					0.7497
					(0.2367)
δ_1		-0.1471		-0.1369	-0.1269
		(0.0203)		(0.02040	(0.0204)
δ_2		-0.0220		-0.0364	-0.0390
		(0.0195)		(0.0204)	(0.0204)
δ_4		0.0472		0.0673	0.0674
		(0.0192)		(0.0193)	(0.0193)
δ_5		0.0518		0.0230	0.0230
		(0.0200)		(0.0214)	(0.0214)
ϕ_1	-0.1588	-0.1741	-0.1223	-0.1453	-0.1416
	(0.0445)	(0.0447)	(0.0451)	(0.0451)	(0.0453)
σ_ε	0.4416	0.4317	0.4333	0.4248	0.4239
AIC	-1.6307	-1.6703	-1.6711	-1.6994	-1.7022
SIC	-1.6190	-1.6430	-1.6398	-1.6642	-1.6632
$\text{LM}_{\text{SC}}(1)$	0.8210	0.9159	0.8169	0.9335	0.8564
$\text{LM}_{\text{SC}}(6)$	0.1626	0.4713	0.1503	0.4170	0.4844
$\text{LM}_{\text{SC}}(12)$	0.6166	0.8133	0.5640	0.7874	0.8317

Table 12: Estimation results for the ARFI models of the S&P500, covering the period January 4, 1999 - December 31, 2004. The table shows the parameter estimates, diagnostic measures and P values for the serial correlation tests. The numbers in parentheses express the heteroscedastic standard errors for the parameters. $\gamma_{1,1}$ is the parameter estimate for the FOMC statement dummy which is 1 on days with statements containing balance-of-risks and zero otherwise. $\gamma_{1,2}$ represents the parameter for the FOMC statement dummy which is 1 on days FOMC statements were published without balance-of-risks and zero otherwise.

Model	$\mathcal{M}_{TN1}$	$\mathcal{M}_{TN2}$	$\mathcal{M}_{TN3}$	$\mathcal{M}_{TN4}$	$\mathcal{M}_{TN5}$
d	0.3690	0.3966	0.3896	0.4065	0.4057
	(0.0332)	(0.0357)	(0.0356)	(0.0376)	(0.0374)
μ	1.4183	1.4135	1.3471	1.3560	1.3565
	(0.0659)	(0.0747)	(0.0686)	(0.0749)	(0.0745)
γ_1			0.3171	0.3023	
			(0.0487)	(0.0497)	
γ_2			0.6753	0.6044	0.6043
			(0.0504)	(0.0526)	(0.0528)
γ_3			0.2043	0.1085	0.1059
			(0.0397)	(0.0416)	(0.0418)
γ_4			0.2158	0.1723	0.1700
			(0.0326)	(0.0323)	(0.0328)
γ_5			0.2384	0.1623	0.1622
			(0.0314)	(0.0330)	(0.0329)
$\gamma_{1,1}$					0.2302
					(0.0509)
$\gamma_{1,2}$					0.2019
					(0.0878)
$\gamma_{1,3}$					0.3208
					(0.0489)
δ_1		-0.2152		-0.1584	-0.1590
		(0.0144)		(0.0141)	(0.0141)
δ_2		-0.0370		-0.0252	-0.0244
		(0.0144)		(0.0143)	(0.0142)
δ_4		0.0813		0.1019	0.1014
		(0.0139)		(0.0137)	(0.0137)
δ_5		0.1717		0.0540	0.0534
		(0.0186)		(0.0159)	(0.0159)
ϕ_1	-0.2082	-0.2019	-0.1137	-0.1398	-0.1388
	(0.0453)	(0.0454)	(0.0466)	(0.0475)	(0.0477)
ϕ_2	-0.0972	-0.0594	-0.0968	-0.0597	-0.0618
	(0.0330)	(0.0345)	(0.0325)	(0.0340)	(0.0341)
σ_ε	0.3399	0.3106	0.2931	0.2794	0.2796
AIC	-2.1528	-2.3276	-2.4415	-2.5316	-2.5268
SIC	-2.1373	-2.2965	-2.4065	-2.4812	-2.4686
$\text{LM}_{\text{SC}}(1)$	0.0032	0.1571	0.0006	0.0567	0.0664
$\text{LM}_{\text{SC}}(6)$	0.0001	0.0023	0.0002	0.0133	0.0090
$\text{LM}_{\text{SC}}(12)$	0.0001	0.0187	0.0001	0.0074	0.0033

Table 13: Estimation results for the ARFI models of the TNotes, covering the period January 4, 1999 - December 31, 2004. The table shows the parameter estimates, diagnostic measures and P values for the serial correlation tests. The numbers in parentheses express the heteroscedastic standard errors for the parameters. $\gamma_{1,1}$ ($\gamma_{1,2}$) is the parameter estimate for the FOMC statement dummy which is 1 on days with statements containing balance-of-risks (bias) and zero otherwise. $\gamma_{1,3}$ represents the parameter for the FOMC statement dummy which is 1 on days FOMC statements were published without balance-of-risks or bias and zero otherwise.

Model	S&P500	MSPE	MAPE	ME		$\mathcal{M}_{SP2}$	$\mathcal{M}_{SP3}$	$\mathcal{M}_{SP4}$	$\mathcal{M}_{SP5}$				
$\mathcal{M}_{SP1}$	μ	0.1601	0.3181	-0.0527		0.8714	1.0268	0.8782	0.2675				
$\mathcal{M}_{SP2}$	μ,day	0.1571	0.3135	-0.0521			0.1348	0.3437	-0.3186				
$\mathcal{M}_{SP3}$	μ,ann	0.1565	0.3173	-0.0488				0.1308	-0.4699				
$\mathcal{M}_{SP4}$	μ,γ_1,γ_2, day	0.1561	0.3156	-0.0487					-0.8246				
$\mathcal{M}_{SP5}$	$\mu,\gamma_{1,1},\gamma_{1,2},\gamma_2$, day	0.1586	0.3162	-0.0496									
Model	TNotes	MSPE	MAPE	ME	HMSPE	$\mathcal{M}_{TN2}$	$\mathcal{M}_{TN3}$	$\mathcal{M}_{TN4}$	$\mathcal{M}_{TN5}$	$\mathcal{M}_{TN6}$	$\mathcal{M}_{TN7}$	$\mathcal{M}_{TN8}$	$\mathcal{M}_{TN9}$
$\mathcal{M}_{TN1}$	μ	0.1323	0.2693	-0.0083	0.0763	**4.5513**	**5.7382**	**6.2615**	**5.9453**	**4.6640**	**5.5728**	**5.0361**	**5.7938**
$\mathcal{M}_{TN2}$	μ,day	0.1132	0.2485	-0.0084	0.0650		**4.1779**	**5.7576**	**5.2032**	**2.7340**	**4.8926**	**3.2853**	**5.1555**
$\mathcal{M}_{TN3}$	μ,ann	0.0866	0.2260	-0.0065	0.0565			**2.0450**	1.2786	**-3.5457**	-0.4143	**-2.8952**	0.1359
$\mathcal{M}_{TN4}$	μ,ann,day	0.0819	0.2171	-0.0070	0.0506				-1.0595	**-3.8869**	**-2.9387**	**-3.4286**	**-2.3985**
$\mathcal{M}_{TN5}$	μ,ann*,day	0.0832	0.2180	-0.0075	0.0511					**-3.0425**	-1.6565	**-2.5074**	-1.1091
$\mathcal{M}_{TN6}$	μ,γ_2	0.0958	0.2390	-0.0067	0.0637						**2.7295**	1.8936	**3.1088**
$\mathcal{M}_{TN7}$	μ,γ_2,day	0.0880	0.2271	-0.0071	0.0546							-1.6477	1.5813
$\mathcal{M}_{TN8}$	μ,macro	0.0928	0.2325	-0.0068	0.0597								**2.5864**
$\mathcal{M}_{TN9}$	μ,macro,day	0.0815	0.2192	-0.0003	0.0539								

Table 14: Forecast results of the various models for the S&P500 and the TNotes. The forecast evaluation period covers January 1, 2003 - December 31, 2004. The final eight columns denote the DM test statistic of equal forecast accuracy. Negative values indicate that the model on the left hand side is more accurate. day denotes the daily dummies $(\delta_1, \delta_2, \delta_4, \delta_5)$, ann all the announcements dummies, ann* all the announcement dummies except the FOMC statements, in this case the FOMC statements are split up into statements containing bias, balance-of-risks and no bias and balance-of-risks, empl the employment dummy, state the FOMC statement dummy, macro the macro announcement dummies $(\gamma_2,\gamma_4$ and $\gamma_5)$.