The High-Frequency Response of the EUR-US$ Exchange Rate to ECB Monetary Policy Announcements

Christian Conrad* and Michael J. Lamla

First draft: February 2007

Preliminary and Incomplete

Abstract

We investigate the effects of the European Central Bank's (ECB) interest rate decisions on the level and volatility of the EUR-US Dollar (EUR-$) exchange rate. Interest rate decisions are made publicly available via a press release launched at 13.45 CET and explained by the ECB's president in a press conference scheduled for 14.30 CET. As market participants follow both events carefully, it is valuable to analyze how they are digested. The analysis is conducted using intra-day data from 12/1998–10/2006. We carefully model the apparent intraday seasonality pattern of the EUR-$ exchange rate returns by suggesting a new method based on nonparametric kernel smoothing techniques. On the filtered returns series we estimate an AR-FIGARCH specification with exogenous variables in the mean and variance. We find that the press release has a significant impact on the level and volatility of the EUR-$ exchange rate. Unexpected monetary policy tightening results in an immediate appreciation of the EUR-$ exchange rate. The effect on the volatility is most pronounced on days of unexpected interest rate changes. The content of the introductory statement impacts the mean and the volatility. Pessimistic statements concerning the future outlook induce a depreciation of the EUR-$ within the hour during the press conference. If the EUR-$ exchange rate is commented on as undervalued this results in a significant appreciation during the five-minute period following the statement.

Keywords: ECB communication, exchange rate, expectations, long memory GARCH processes.

JEL Classification: C22, E58.

*We thank Helge Berger, Jan-Egbert Sturm and the participants of the Macroeconomic Research Meeting (Zurich, 2007) for their helpful comments and suggestions. The usual disclaimer applies. Address for correspondence: Christian Conrad, Chair of Applied Macroeconomics, ETH Zürich WEH D4, Weinbergstrasse 35, 8092 Zürich, Switzerland. E-mail: conrad@kof.ethz.ch, tel: +41 (0)44 632 53 44, fax: +41 (0)44 632 12 18.

1 Introduction

In this article we investigate the high-frequency impact of the European Central Bank's (ECB's) monetary policy announcements on the EUR-$ exchange rate during the 89 meeting days of the ECB governing council in the period 01/1999 – 10/2006. A meeting day consists of the announcement of the next key interest rate at 13.45 CET and a detailed assessment of the economic situation and future prospects starting at 14.30 CET in the introductory statement.[1] Both events are of major importance. First, the reaction of the market participants to the pure interest rate announcement depends on how well they anticipated the policymakers decision, and therefore on how successful the policymaker guided market expectations. Second, the assessment of the policymakers communication in the introductory statement by market participants is of great importance since the interpretation of central bank action matters most for the response of the exchange rate. An econometric approach which allows to distinguish between the effects of the pure announcement released at 13.45 and the press conference starting at 14.30 requires two ingredients: an appropriate modeling of the intraday high-frequency movements of the EUR-$ exchange rate and a meaningful quantification of the ECB's presidents verbal statements.

The building blocks of our analysis are derived from two strands of existing literature. One strand is concerned with the high-frequency modeling of exchange rate returns with a particular emphasis on the movements in the second conditional moment. In a seminal article Andersen and Bollerslev (1997) showed that high-frequency exchange rate returns are characterized by a strong intraday periodicity in their conditional variance. From their study it is evident, that the "estimation and extraction of the intraday periodic component is both feasible and indispensable for a meaningful intraday dynamic analysis" (Andersen and Bollerslev, 1997, p. 116). Along these lines Andersen and Bollerslev (1998) analyze high-frequency Deutsche Mark-Dollar returns and reveal that the volatility process can be naturally separated into three components: (i) a deterministic periodic component (including day-of-the week and calender effects), (ii) announcement effects and (iii) ARCH effects. Following the articles of Andersen and Bollerslev (1997) and Andersen and Bollerslev (1998) it has become a standard approach to estimate the deterministic periodic component by assuming that the intraday volatility pattern is best described by a flexible Fourier form (FFF). Announcement effects are either estimated directly by including dummy variables in the FFF regression or in a two step procedure by investigating the filtered return series, i.e. the original return series divided by the FFF estimated seasonal component. This second approach is employed by e.g. Baillie et al. (2000) or Han (2004). Finally, Andersen et al. (2003) shift the focus of attention to the reaction of the conditional mean of exchange rate returns in response to macroeconomic announcements. While the volatility is at least partly driven by the pure fact that an announcement is released, the conditional mean reacts to surprise news only, i.e. a deviation of the released figures from what market participants expected. In particular, the impact of monetary policy announcements concerning interest rate decisions on exchange rates has recently received great attention. Among oth-

[1] Throughout the article all dates are reported as Central European Time (CET).

ers, the recent studies of Faust et al. (2006) and Kearns and Manners (2006) point towards a positive relationship between exchange rate movements and unexpected interest rate changes, i.e. exchange rates react to monetary tightening (easing) by appreciating (depreciating).

The second strand of literature focuses on the instrument of central bank communication. At the heart of this literature is the attempt to measure the quantitative implications of central bank communication on exchange rates, interest rates etc. Jansen and de Haan (2005a) discuss the role of the ECB statements to speak up the Euro and discover only a volatility effect using daily exchange rate data. Switching to high frequency, Jansen and de Haan (2005b) find both a mean and a volatility effect. However, the mean effect is comparatively small and rather short lived. Fratzscher (2004) provides evidence that oral interventions effect the mean as well as the volatility and reports that oral interventions during actual interventions reduce volatility while direct interventions increase the movement of exchange rates. Similarly, Beine et al. (2004) deliver some support that comments during official exchange rate interventions were partially effective. Ehrmann and Fratzscher (2005a) compare the effectiveness of the different communication strategies of the Federal Reserve, the Bank of England and the ECB in the inter-meeting period and argue that central bank communication is a statistically and economically important driver of financial markets. All these studies support the idea that communication provides an important channel for central banks to impact exchange rates. Despite this research effort, there are rarely any studies which test the impact of the ECB key communication instrument, i.e. the press conference on the interest rate decision announcement day, on the EUR-$ exchange rate. This is especially surprising as the introductory statements received considerable attention recently (see for instance Heinemann and Ullrich (2005), Lamla and Rupprecht (2006)).

Our analysis contributes to the existing literature in several ways. We test the impact of the interest announcement as well as the introductory statement on the mean and the volatility of the EUR-$ exchange rate by employing a long time span (12/1998–10/2006) of high-frequency intraday data. The major advantage of employing high frequency rather than daily data is that we can directly monitor the impact of central bank communication on the market in real time. Hence there is no identification problem whether the movement in the exchange rate is driven by other factors than monetary policy announcements. The usage of such intraday data requires an econometric methodology which allows to separate the announcements effects from the typical intraday patterns and volatility persistence. Following Andersen and Bollerslev (1997) we deseasonalize in a first step the high-frequency returns using a control sample containing non-announcement days from which the seasonal pattern is extracted. Second, the filtered absolute returns show a clear pattern of long memory and persistence and hence a model for the conditional variance of the exchange rate should take into account this property. We therefore estimate a AR-FIGARCH specification for the filtered five-minutes returns whereby we control for the interest change announcement, the content of the press conference and the surprises inherent in both in the mean and variance. Our surprise measure for the interest change is taken from the Reuter business surveys. To assess the impact of the press conference we rely on the Berger-DeHaan-Sturm (BHS) communication indicator as discussed in Berger et al. (2006). This index measures on a scale ranging from -3 to +3 the risk to price stability.[2] We show that interest rate announcements effect the level and volatility of the EUR-$ exchange rate at 13.50 and at 14.35 and the following hour. Especially, surprises in the interest announcement eventuate in a significant movement in the exchange rate. In addition, explicit statements on the assessment of the current developments of the exchange rate effect the mean as well as the volatility. Finally, the content of ECB's introductory statements affects the mean and volatility. Hence, both the ECB's policy decision on the target interest rate as well as the communication of this impact the EUR-$ exchange rate in an order of magnitude which statistically and economically important.

The remainder of the article is organized as follows. Section 2 briefly discusses the linkages between interest rate decisions and exchange rate movements. In Section 3 we analyze the times series properties of the five-minute EUR-$ exchange rate data and suggest a new methodology for extracting the intraday seasonal pattern. Moreover, we introduce the Reuters data on market expectations and the BHS index of ECB communication. Section 4 lays out the properties of the FIGARCH model which is the workhorse for our empirical analysis which follows in Section 5. Section 6 contains conclusions and suggestions for further research.

2 ECB Announcement Days and Exchange Rate Movements

Figure 1 displays the timing of the press release and the press conference during ECB announcement days. At 13.45 the interest rate decision is announced via the press release. At 14.30 the introductory statement is given by the ECB's president which is then followed by the questions and answers session.

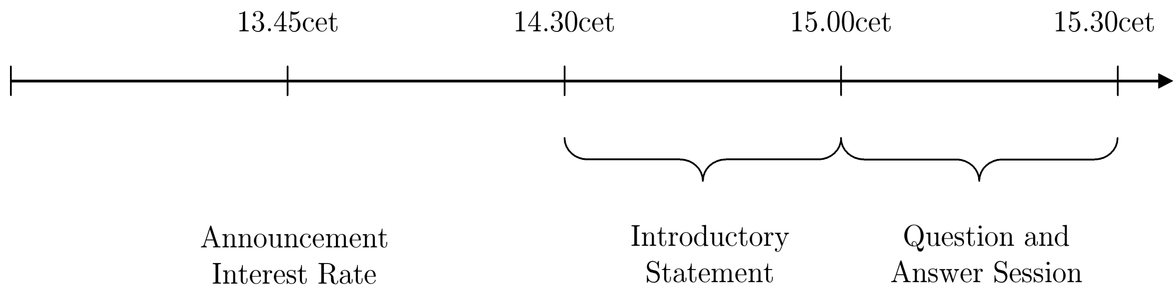

Figure 1: Timing of press release and press conference during ECB announcement days.

[2]Since the impact of communication is often driven by the so-called "reading between the lines" this index does not count a bunch of signal words, but portrays an overall sentiment driven by discussed risks in the real, the monetary and the price developments. For a discussion concerning different types of wording indicators used in recent papers see also Lamla and Rupprecht (2006) and Fratzscher (2005).

Interest rate parity and arbitrage opportunities imply an appreciation of the home currency due to an unexpected monetary tightening. Hence, the announcement of an increasing interest should lead to an appreciation of the home currency relative to the foreign currency. However, this need not necessarily to be the case.[3] One reason for a movement in the exchange rate that does not match this classical pattern are expectations about future developments. As Ehrmann and Fratzscher (2005b) argue an unexpected easing of monetary policy might signal to the public an economic upturn associated with high economic activity as well as rising asset prices in the future and consequently imply that the home currency appreciates and not depreciates. Another explanation can be located in technical trading. Agents might bet in front of central bank statements against or in favor of an exchange rate movement which might swamp the effect of the announced interest rate movement afterwards.

The linkage between the ECB press conference and the interest rate has not been tackled explicitly in the economic literature. As noted earlier the interpretation matters. This is true for exchange rate interventions as discussed in Beine et al. (2004) as well as announced interest rate changes as put forward by Ehrmann and Fratzscher (2005b). Notably, no study so far dwelled on this topic empirically for the press conference. The press conference comprises the assessment of the central bank officials concerning their risks to price stability. Hence, a statement that signals higher risks to price stability should lead to a depreciation, while communicated lower risk to prices should lead to an appreciation.

Moreover, central banks can justify respectively explain their interest rate movement in several fashions. Financial analysts often categorize central bank statements as being "hawkish" or "dovish". "Hawkish" speeches imply a more aggressive statement concerning the intention to establish price stability while "dovish" speeches are much less so. One should expect that unexpected dovish statements may lead to a depreciation of the exchange rate since they may cast doubt on the willingness to fight inflation in this economic situation while unexpected hawkish statements might signal greater ambitions to achieve price stability.

3 Data

3.1 Exchange Rate Data

Since all ECB announcement days are Thursdays and it is well known that the intraday volatility pattern varies across the days of the week we employ for our event study only high-frequency EUR-$ exchange rate data stemming from Thursdays.[4] Our original sample consists of irregularly spaced tick-by-tick quotes of the EUR-$ exchange rate for all 417 Thursdays in the period January 1999 to October 2006 obtained from Olsen and Associates. Each quote contains a bid and an ask price along with the time to the nearest second. Taking the immediately preceding and following quotation at the end of each five

[3] One aspect are for instance differences in the reaction in the short to medium and long-term horizon driven by, e.g. Dornbush's overshooting model.

[4] There are only three exceptions to this rule.

minute interval we obtain the log price by linearly interpolating the average of the log bid and the log ask at each five-minute mark. Five-minute returns are then constructed as the change in these five-minute log prices. The returns are denoted by $R_{k,n}$, $k = 1, \ldots, K$ and $n = 1, \ldots, N$, where K is the number of days in our sample and $N = 288$ is the number of five-minute intervals per day. Among all Thursdays there are 89 ECB monetary policy decision days. The standard summary statistics (not reported) for ECB announcement days and non-announcement days are virtually identical. The sample mean of the five-minute returns is indistinguishable from zero at any standard significance level. While the skewness is not significantly different from zero, there is evidence for excess kurtosis significantly larger than three. Hence, the five-minute return distribution is symmetric around zero but non Gaussian which is also confirmed by the Jarque-Bera statistic. As often reported for high-frequency data, there is some evidence of serial correlation for low lags in the five-minute EUR-$ returns, possibly due to microstructure effects. In sharp contrast, the squared and absolute returns are highly correlated even for long lags. In the following we will analyze these intertemporal dependencies in the simple and absolute returns in more detail.

Figure 2 displays the average five-minute EUR-$ returns over the 288 intervals of one trading day (left) and the corresponding sample autocorrelation function (right). The visual impression that the average returns are centered around zero with no evidence for a systematic appreciation or depreciation within the trading day cycle is confirmed by the sample autocorrelations which – apart from a view rare exceptions – are small and resemble the realizations of a white noise process.

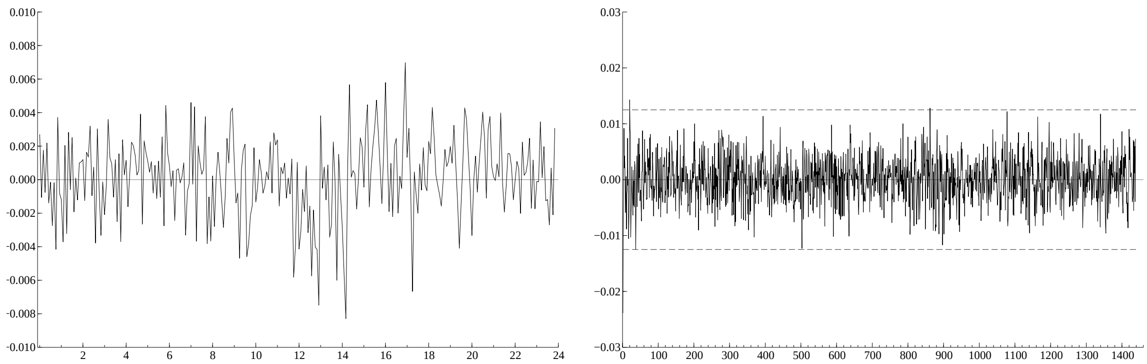

Figure 2: Intraday average five-minute EUR-$ returns (left) and five days sample autocorrelation function with 95% confidence bands (right).

The average absolute returns over the 5-minutes intervals for the 328 non-announcement days (solid) and the 89 announcement days (dashed) are shown in Figure 3. From the figure it is clear that the return series displays a pronounced intraday volatility pattern. At 1.00 volatility begins to increase with the opening of the Singapore and Hong Kong markets which are followed by the Tokyo market one hour later and by the Sydney market two hours later.[5] The decline in volatility around 4.00 to 5.30 reflects

[5]In comparison to using Greenwich Mean Time (GMT) this approach has the advantage that we do not have to worry

the lunch hour in the Tokyo and Hong Kong markets. Volatility then sharply increases with the opening of the European markets around 8.00 and tails off again with European lunch time around 12.00. The U.S. markets open at 14.00. Between 14.00 and 16.00 both the European and American markets are open simultaneously and volatility is highest during the day. Finally, after the closing of the European markets around 17.00 volatility starts to decline monotonically back to the level associated with the Pacific segment. The solid line reveals two volatility spikes during the trading day. A first one at 14.35 and a second one at 16.05. Both time points correspond to major macroeconomic news announcements in the US (see Andersen et al., 2003). The dashed line which is associated with the announcement days reveals an intraday volatility pattern which is almost identical to the one of the non-announcement days for most of the trading day. However, exactly at the timing of the ECB press release and during the press conference one can observe distinctive differences. Since neither in the U.S. nor in Europe any other macroeconomic news is released at 13.45, the dramatic increase in volatility at 13:50 must reflect how market participants process the news associated with the ECB's monetary policy decision launched by the press release. This increase in volatility clearly has no counterpart on the non-announcement days. Although the size of the increase in volatility at 14.30 is about the same as for the non-announcement days, the increase sustains for at least half an hour reflecting the whole time period of the press conference.

Figure 4 allows for a more detailed view on the important time period between 13.00 – 16.00. The line represents the difference between the average absolute five-minute EUR-$ returns on announcement and non-announcement days. Clearly, we observe a sharp increase in volatility at 13.50. Surprisingly, at 14.35 the difference is basically zero, i.e. announcement days and non-announcement days behave similar at that time at which major US macroeconomic announcements are released. The increase in volatility at 14.45 can be traced back to the ECB press conference and has no counterpart on non-announcement days.

Figure 5 shows the autocorrelation function of the absolute return series for one (left) and five (right) trading days. The figures provide overwhelming evidence for systematic movements in the daily volatility pattern. The autocorrelation function is highest for absolute returns separated by multiples of 288 observations, i.e. multiples of entire trading days, and decreases in between with a minimum of correlation at $144+j\cdot 288$, $j=0,1,\ldots$, lags, i.e. between observations separated by a half, one and a half, etc. trading days. Similarly, as observed by Andersen and Bollerslev (1997) and Andersen and Bollerslev (1998), the sample autocorrelations are characterized by a "distorted U-shape" behavior induced by the strong intraday pattern observed in Figure 3 for the average absolute returns. Hence, as argued in Andersen and Bollerslev (1997) it is indispensable for any meaningful analysis employing the intraday returns to first estimate and extract the intraday periodic component of return volatility.

about daylight savings time effects.

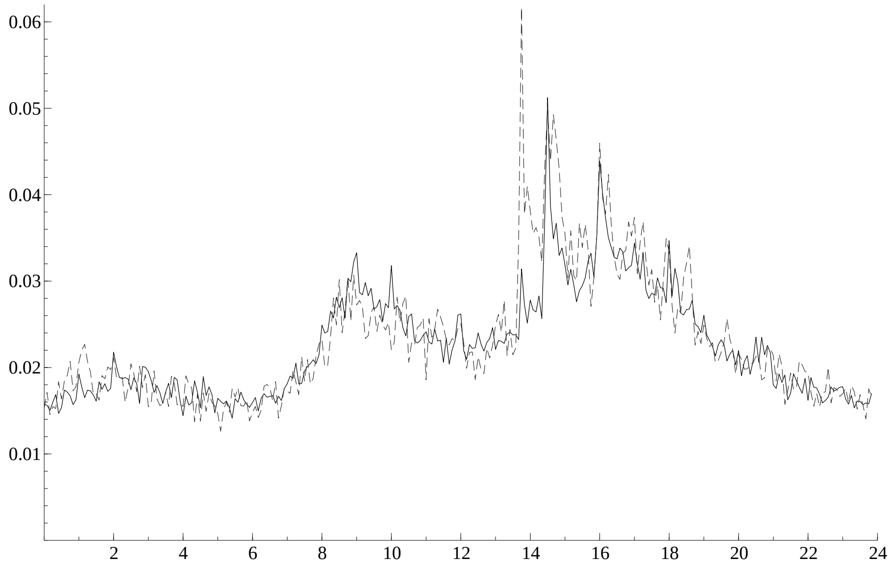

Figure 3: Average absolute five-minute EUR-$ returns for each five minute interval during the trading day. Solid: all non-announcement days, dashed: announcement days.

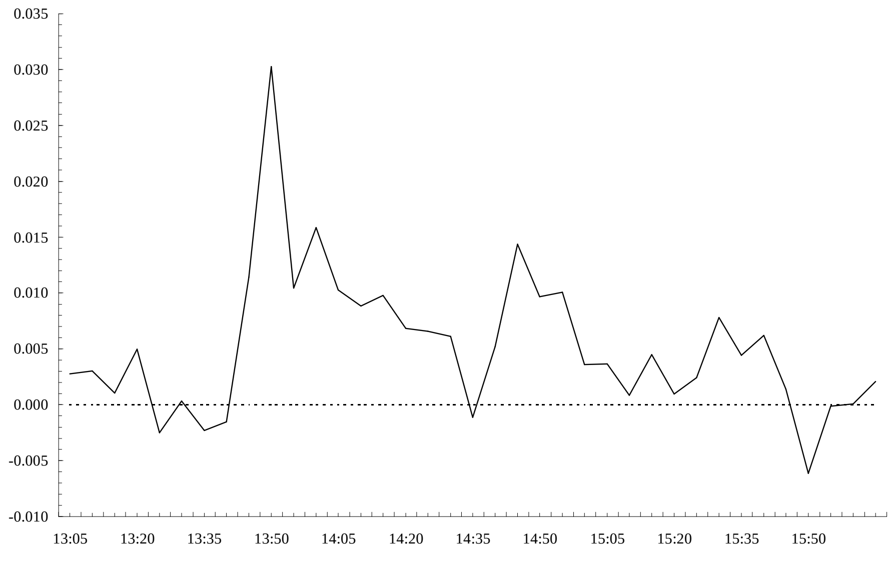

Figure 4: The figure plots the difference between the average absolute five-minute EUR-$ returns on announcement and non-announcement days in the time period 13:00 – 16:00.

3.2 Modeling the periodic intraday pattern

In this section we propose a new method for filtering out the periodic intraday seasonal component from the high-frequency return series. The procedure is based on a nonparametric kernel estimate of

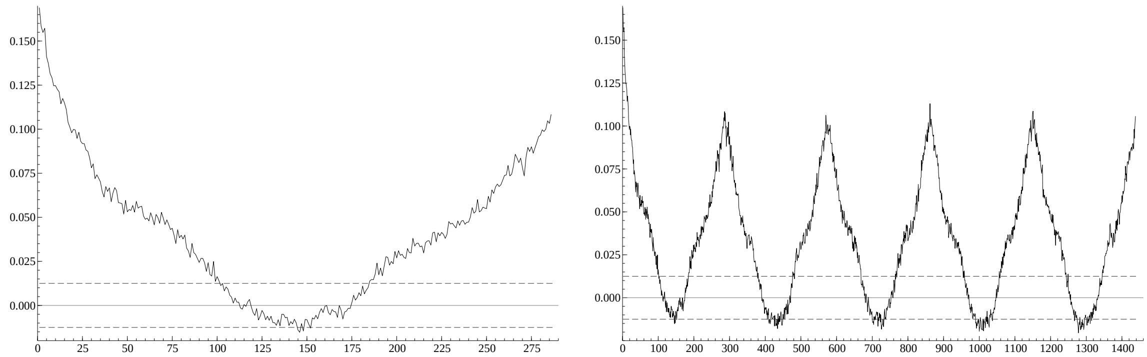

Figure 5: Sample autocorrelation functions of five-minute absolute EUR-$ returns for one day (left) and five days (right). Dashed lines are 95% confidence bands.

the intraday volatility pattern and requires no subjective choice of possibly important points in time as previous approaches. The non-announcement days – which have the same intraday seasonal pattern as that of the announcement days apart from the effects of the announcements themselves – serve as control days from which we extract the typical pattern of a Thursday. In this way, the proposed procedure takes into account intraday seasonality but at the same time ensures that we do not explain away what we are actually interested in.

As in Andersen and Bollerslev (1997), we assume the following structure for the intraday returns

$$R_{k,n} = \mathbf{E}(R_{k,n}) + \frac{\sqrt{h_k} s_n Z_{k,n}}{\sqrt{N}}, \tag{1}$$

where $\mathbf{E}(R_{k,n})$ denotes the unconditional expectation of the five-minute returns, h_k is the conditional variance of day k and s_n a deterministic periodic component for the n-th intraday interval. The innovations $Z_{k,n}$ are assumed to be independently and identically distributed (*i.i.d.*) with mean zero and unit variance. Moreover, we assume that $Z_{k,n}$ are independent of h_k. Note, that Andersen and Bollerslev (1997) allow the periodic component s_n also to depend on day k. While this is important when one has to deal with day-of-the-week effects, it is unnecessary in our context, since we consider only Thursdays.

Next, the aim is to obtain an estimate of the seasonal component s_n. As suggested by Andersen and Bollerslev (1998) we estimate the season component from a regression using a log-transformation of equation (1) which is more robust to extreme outliers in the five-minute return series than a regression in terms of, say $R^2_{k,n}$. Equation (1) can be rewritten as

$$r_{k,n} \equiv 2\log(|R_{k,n} - \mathbf{E}(R_{k,n})|) - \log(h_k) + \log(N) = \log(s_n^2) + \log(Z^2_{k,n}) \tag{2}$$

$$= f(n) + u_{k,n}, \tag{3}$$

with *i.i.d.* mean zero error term $u_{k,n} \equiv \log(Z^2_{k,n}) - \mathbf{E}(\log(Z^2_{k,n}))$. An estimable version of equation (3) is obtained by replacing $\mathbf{E}(R_{k,n})$ and h_k by suitable estimates. While $\mathbf{E}(R_{k,n})$ can be naturally estimated with the sample mean of the five-minute returns, there are several possible candidates for an estimate

$\widehat{h}_k$ of h_k. Andersen and Bollerslev (1997) estimate a GARCH model on the daily return series and then substitute h_k by the fitted conditional variance series. However, this approach has the disadvantage that the daily conditional variance is modeled as a slowly varying function of past residuals and past conditional variances. Hence, it captures sharp increases in volatility only with some time lag, i.e. a sudden increase in volatility on a certain day will not effect the GARCH estimated conditional variance for that day, but for the following day and onwards. We therefore estimate h_k by the realized volatility of the respective day, i.e. by $\widehat{h}_k = N^{-1} \sum_{n=1}^{N} R_{k,n}^2$, which exploits contemporaneous intraday information. Moreover, in contrast to the fitted conditional variances from a GARCH model, the realized volatility does not suffer from a generated regressor problem (see Andersen and Bollerslev (1998)).

Replacing $\mathbf{E}(R_{k,n})$ and h_k by their estimates leads to a generated $\widehat{r}_{t,n}$ series. The Andersen and Bollerslev (1997) approach assumes that $f(n)$ can be approximated by a parametric function $f(n|\theta)$ which is specified as a flexible Fourier form with trigonometric terms that obey a strict periodicity of one day and additional dummy variables capturing calender, day-of-the-week and announcement effects. In this framework an estimate of the seasonal component can be obtained by regressing $\widehat{r}_{k,n}$ on $f(n|\theta)$ by ordinary least squares. This in particular requires first a subjective election of possibly important announcements (to keep the number of dummies small) and second the knowledge of the exact timing of each particular announcement. Moreover, one has to specify for how long a particular announcement effects the conditional variance.

We suggest an alternative approach based on nonparametric kernel smoothing. To obtain an estimate of the seasonal component we regress $\widehat{r}_{k,n}$ non-parametrically on a grid $x = 1, \ldots, N$ of 5-minute intervals over the trading day. This can be naturally done by using a Naradaya-Watson kernel estimator of $f(x)$ which is given by

$$\widehat{f}_b(x) = \frac{\sum_{k=1}^{K} \sum_{n=1}^{N} K_b(n-x)\widehat{r}_{k,n}}{K \sum_{n=1}^{N} K_b(n-x)}, \tag{4}$$

where $K_b(\cdot) = b^{-1}K(\cdot/b)$ with K being a kernel function and bandwidth parameter b. If one is only interested in obtaining a filtered return series without any calender, day-of-the-week or announcement effects, this can be achieved by locally choosing the bandwidth parameter as e.g. suggested in Schucany (1995). While this approach does not require any subjective input by the researcher as the choice of the dummies in the Andersen and Bollerslev (1997) approach, it does not allow to *explain* such effects by exogenous variables. Since the main purpose of our research is to explain the movements in the volatility of the EUR-$ exchange rate by exogenous variables we apply the procedure to the non-announcement days only. Thereby, we extract only the shape of the *typical* seasonal component of a Thursday but not the effects due to ECB announcements. Those will be explained in a second step. Figure 6 graphs the fit $\widehat{f}(x)$ across the 24-hour trading day in comparison to the average absolute returns.[6]

[6] To compare the estimates with the absolute returns we have to convert the intraday seasonality pattern through the transformation

$$|R_{k,n} - \mathbf{E}(R_{k,n})| = \frac{\sqrt{h_k}\exp\left(f(n)/2\right)\exp\left(u_{k,n}/2\right)}{\sqrt{N}}.$$

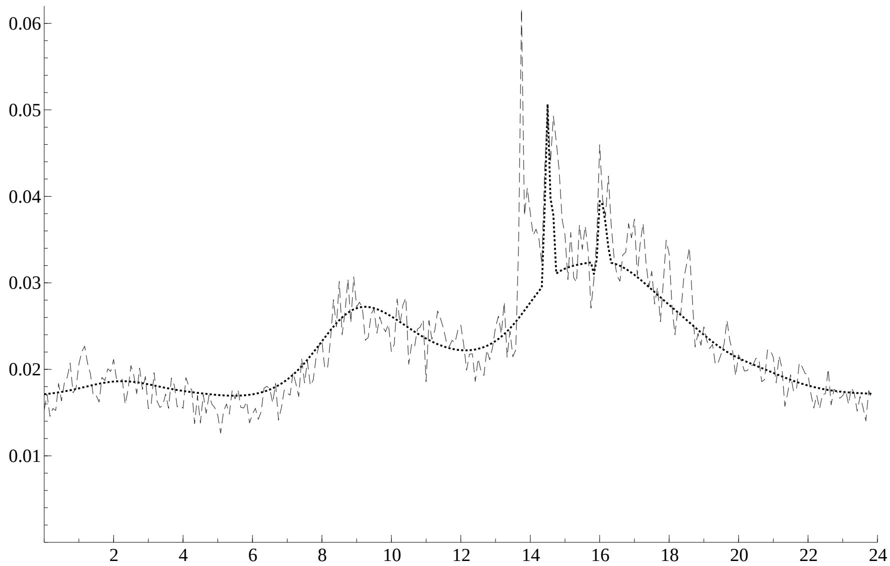

Figure 6: The figure graphs the nonparametric fit to the intraday seasonality of all Thursdays in the sample (dotted line) together with the average absolute returns for all announcement days (dashed line).

Finally, the filtered 5-minutes returns are obtained as $\widetilde{R}_{k,n} \equiv R_{k,n}/\widehat{s}_n$, whereby the $\widehat{s}_n$ are standardized such that $1/N \sum_{n=1}^{N} \widehat{s}_n = 1$. In order to examine their autocorrelation properties in comparison to the autocorrelation properties of the raw returns we plot in Figure 7 the autocorrelation function of the filtered series. Obviously, the proposed procedure does a very well job, resulting in a dramatic reduction in the periodic pattern with only some slight periodicity remaining. Interestingly, the autocorrelations of the absolute values of the filtered series first decay rapidly, but are then characterized by an extremely slow rate of decay. This type of decay is typical for long memory processes associated with autocorrelations decaying as j^{2d-1}, where d denotes the order of fractional integration. To illustrate this point we run the regression $\log(\hat{\rho}_j) = c_0 + c_1 \log(j) + u_j$, $j = 5, 6, \ldots, 1440$, where $\hat{\rho}_j$ denotes the sample autocorrelation of the absolute filtered five-minute returns (see Andersen and Bollerslev, 1998). Figure 7 shows that the rate of hyperbolic decay implied by the estimated persistence parameter of $\widehat{d} = (\widehat{c}_1 - 1)/2 = 0.42$ fits very well with the autocorrelations of the absolute filtered returns. Hence, an appropriate model for the conditional variance must allow for such long memory behavior. This requirement clearly rules out the class of stationary GARCH models which are characterized by exponentially decaying autocorrelations.

3.3 Reuters Data on Surprises

Concerning the ECB announcement data we construct several dummy variables controlling for changes in the interest rate.[7] Obviously, we also control for the real change that is announced. As news matter most

[7]Dummy interest change, positive interest change, negative interest change

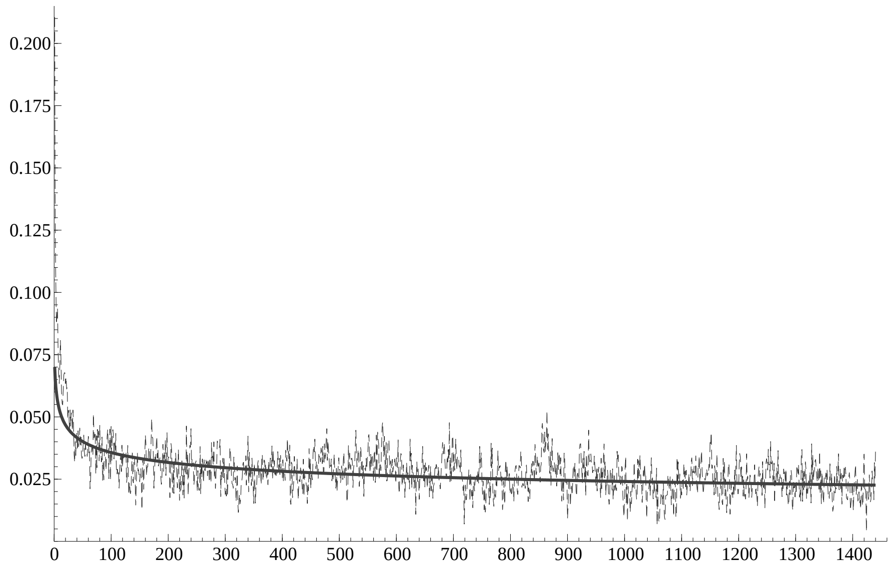

Figure 7: Sample autocorrelation function of the filtered absolute return series (dashed) and fitted hyperbolic decay (bold).

we try to capture the surprise that is transmitted with the announcement. Zettelmeyer (2004) as well as Kearns and Manners (2006) propose using the change in the 1-month respectively 3-month treasury bill interest rates. Clearly, this is an indirect measure of a surprise to the markets but should have enough explanatory power to tell wether ECB statements today change expectations of 3-month ahead interest rates. If the interest rate decision was correctly anticipated they should not move significantly. If there was indeed new information a re-adjustment should take place. To follow this approach we use the difference of the 1-month as well as 3-month EURIBOR rates. EURIBOR interest rates are interbank lending rates settled daily at 11.00 CET. The are available at maturities from one week to twelve months.[8]

In addition, we employ another more explicit instrument to control for a surprise in the interest rate announcement. One week ahead of the governing council meeting Reuters asks up to 100 financial analysts about their expectations concerning the key interest rate resulting after the central bank meeting. Out of this questionnaire a monetary policy surprise is calculated alternatively as the mean or median of the difference between the interest rate announced in the press release on the meeting day and the ex-ante expectations of the analysts. We devote this latter surprise measure more attention as it is a more direct way to assess this issue. However, a correlation coefficient of roughly 0.5 for the median and 0.7 for the mean suggests that the change in the EURIBOR interest rates as well as the explicit Reuters survey seem to measure something similar. Overall, among the 89 ECB announcement days there were 45 mean surprise days. On 32 days we observed a positive surprise, whereby the average positive surprises was 0.019, while on 13 days a negative surprise was observed with a slightly lower average of -0.015.

[8]For more details see: www.euribor.org

3.4 BHS Data on ECB Communication

To assess the impact of the content of the ECB press conference we employ the BHS communication indicator as introduced in Berger et al. (2006). This index and its subcomponents measure the risk associated to price stability communicated by the ECB. The index is measured on a scale from -3 to +3 where increasing values imply increasing risks to price stability. An appealing feature of this index is that it really measures the content of the press conference and is not generated by counting and valuing signal words as done in earlier studies.

Most of the empirical studies focus on the impact of communication events such as central bankers speeches or central bank statements. Mostly, binary proxies are used (i.e. if there was a statement or not). This, however, only allows to analyze the effect of a statement, no matter what the content is. In reality financial markets closely watch central bankers lips and analyze their speeches thoroughly. Therefore, a measure that allows us to quantify *contents* of these statements is of major importance.

Some recent studies like Heinemann and Ullrich (2005) and Rosa and Verga (2005) identify "code words" from ECB statements or publications to construct indicators for "hawkishness" in ECB statements. The advantage of such approaches is that they are relatively mechanical in quantifying ECB communication and are therefore in principle reproducible. Financial market agents, especially the so called "ECB Watchers", however, exactly analyze the statements and pay particular attention to the content of these statements. This is especially important as Berger et al. (2006) for example find that these sub-indicators weight differently in the overall assessment of the ECB. Hence, there is no distinction of whether a "code word" such as "upside risk" is related to developments in the real economy, in prices or in money growth. This, however, might be important, as the interpretation of the ECB on developments in one sector may be more or less expected by financial markets, whereas interpretations on other sectors might come as a surprise and thus – if considered to be important – significantly affect expectations about future interest rates. The mechanical quantification by only counting certain expressions therefore disregards too much information relevant for our purpose. Incorporating the entire content and allow for "reading between the lines" – as is done by Berger et al. (2006) – seems to be more appropriate in our case.[9]

Thus, the advantage of the BHS indicator is that it uses both subjective measurements of content of introductory statements of the ECB's monthly press conference and that also each of the statements are

[9]The indicator is constructed on the basis of the information communicated in the ECB's introductory statement at the press conference following an interest rate meeting. The introductory statements play a crucial role as the ECB itself highlights them as the most important communication device besides the monthly bulletin. This approach accounts of the fact that the ECB follows the collegial communication approach, as discussed by Ehrmann and Fratzscher (2005a), as the content of these statements reflect the views of *all* members of the council. These statements should therefore also contain important information for interest rate expectations. Indeed, Ehrmann and Fratzscher (2005c) find that the predictability of interest rates for financial markets significantly improves when analyzing communication that does not reflect dispersion across council members' opinions but rather their consensus.

quantified separately with regards to (1) price developments p, (2) the real economy ec, (3) the monetary sector m, and finally (4) the overall conclusively assessment of the current situation ag are quantified.[10]

3.5 A closer look at the data

Table 1 visualizes the movement in the absolute five-minute returns during the time span of interest (13.40–15.30). If we concentrate on the highest volatility at each point in time in comparison to the other samples the surprise sample dominates all other samples' movements nearly over the whole time span. Especially at the announcement time of the interest rate decision – 14.50 denotes the window 14.45 to 14.50 – the absolute return is nearly ten times larger than in our control sample. Even compared to the non-surprise announcement days it is five times larger. This result corresponds with our expectations. Unexpected changes should lead to reactions and adjustments by the market participants leading to a significant adjustment in the exchange rate. Moreover, this increased volatility remains at a high level until 14.30. However, looking at the time window 14.40 to 14.50 the surprise sample's volatility is dominated by the sample controlling for comments on the exchange rate. In several introductory statements the ECB comments on the value of the EURO which seem to yield a market reaction. This was especially, but not exclusively, the case in the first years of operation and is a clear indication how carefully markets listen to the introductory statements.[11]

Comparing the movement over the relevant time window between days when the central bank acts with our control sample where no central bank action took place, at no point in time the control sample's volatility exceeds the announcement days counterparts. Although we can observe that at 14.30 there is more movement within this row than at other times probably a reaction to news coming from the U.S. (8.30 eastern time) the average reaction on announcement days is higher. Notably, as discussed in the previous section, this seasonal pattern will be accounted for in our regressions. Overall, this eyeballing suggests that central bank announcements play an important role in the development and the volatility of the exchange rate. Moreover, there is clear evidence for the outstanding role of interest surprises in comparison to usual announcement days. In the next section we will capture this effect applying FIGARCH estimations.

[10] Independent economists read the ECB introductory statements and rated each month's statement on prices and price developments, the real economy, the monetary sector and the overall conclusively assessment of the current situation using a scale from -3 to +3. Despite their economic background, these junior researchers are on purpose non-experts in the field of monetary economics, i.e. they are not biased by actual and past policy discussions in this field.

[11] Usually the introductory statements start with an general assessment followed by comments on prices, the real economy and monetary aggregates. Hence, it seems reasonable that the volatility becomes more pronounced somewhere in the mid-end of the statement.

Table 1: Mean absolute value of five-minute EUR-$ returns.

	CD	AD	NS	SD	CE
13.40	0.024	0.022	0.022	**0.025**	0.023
13.45	0.024	0.035	0.032	**0.056**	0.026
13.50	0.028	0.062***	0.043	**0.213*****	0.068***
13.55	0.025	0.038	0.035	**0.063**	0.045
14.00	0.025	0.041	0.035	**0.085***	0.056*
14.05	0.023	0.038	0.036	**0.059**	0.055
14.10	0.024	0.036	0.033	**0.054**	0.047
14.15	0.023	0.036	0.030	**0.086****	0.047
14.20	0.027	0.035	0.032	**0.061**	0.048
14.25	0.027	0.032	0.029	**0.055**	0.037
14.30	0.041**	0.043	0.043	**0.046**	**0.046**
14.35	0.046***	0.050**	0.049***	**0.056**	0.050
14.40	0.035*	0.044	0.044	0.045	**0.064****
14.45	0.033	0.049*	0.048**	0.056	**0.068*****
14.50	0.041**	0.046	0.046*	0.053	**0.054**
14.55	0.035*	0.043	0.040	**0.066**	0.048
15.00	0.030	0.037	0.034	**0.061**	0.044
15.05	0.032	0.035	0.035	0.032	**0.037**
15.10	0.025	0.030	0.028	**0.047**	0.040
15.15	0.027	0.036	0.035	0.041	**0.047**
15.20	0.031	0.031	0.030	0.039	**0.040**
15.25	0.026	**0.030**	**0.030**	0.028	0.029
15.30	0.028	0.036	0.036	0.039	**0.042**

Notes: CD: control days, AD: announcement days, NS: no surprise days, SD: surprise days, CD: comments on exchange rate days.

4 The FIGARCH Model

The decay behavior of the autocorrelation function of the absolute filtered return series investigated in Section 3.2 suggests that the conditional variance of the filtered return series should be modeled as a fractionally integrated process. Among the GARCH-type models which allow for such a behavior in the conditional variance, the Fractionally Integrated GARCH (FIGARCH) model proposed by Baillie et al. (1996) is definitely the most prominent one. The FIGARCH has been successfully applied e.g. by Baillie et al. (2000) to model the high-frequency Deutschmark-$ exchange rate and by Beine et al. (2002) to investigate the effects of central bank interventions on the volatility of the Deutschmark-$ and Japanese Yen-$ exchange rate. For this reason we utilize the Fractionally Integrated GARCH (FIGARCH) model proposed by Baillie et al. (1996) to model the conditional variance of the filtered return series. The impulse response function of the FIGARCH process is characterized by a hyperbolic rate of decay and hence captures the stylized fact observed for the five-minute return data.

We now denote by $Y_t,\ t = 1, \ldots, T$, the stacked version of the matrix $R = (\widetilde{R}_1 \widetilde{R}_2 \cdots \widetilde{R}_K)$ with $\widetilde{R}_k = (\widetilde{R}_{k,1} \cdots \widetilde{R}_{k,N})^T$. For the mean equation we assume the following autoregressive structure including I exogenous regressors $X_{t,i}$.

$$Y_t = \mu + \sum_{j=1}^{P} \varphi_j Y_{t-j} + \sum_{i=1}^{I} \delta(L) X_{t,i} + \varepsilon_t \tag{5}$$

The innovations $\{\varepsilon_t\}$ follow a FIGARCH(p, d, q) process as introduced by Baillie et al. (1996) defined via the equations

$$\varepsilon_t = Z_t \sqrt{h_t}, \tag{6}$$

where $\{Z_t, t \in \mathbb{Z}\}$ is a sequence of independent and identically distributed random variables with $\mathbf{E}(Z_t) = \mathbf{E}(Z_t^2 - 1) = 0$, and

$$(1 - L)^d \Phi(L) \varepsilon_t^2 = \omega + B(L) v_t, \tag{7}$$

for some $\omega \in \mathbb{R}^+$, lag polynomials $\Phi(L) = 1 - \sum_{i=1}^{q} \phi_i L^i$ and $B(L) = 1 - \sum_{i=1}^{p} \beta_i L^i$ and $0 \leq d \leq 1$ being the fractional differencing parameter and with $v_t = \varepsilon_t^2 - h_t$. The FIGARCH model reduces to the GARCH model for $d = 0$ and to the IGARCH model for $d = 1$. For any $0 < d < 1$ the FIGARCH process is not covariance stationary, since its unconditional variance does not exist, it is however strictly stationary and ergodic (see Baillie et. al, 1996). For an in depth discussion of the properties of the FIGARCH model see Conrad and Haag (2006). An important issue in specifying a valid FIGARCH model is to restrict the parameters of the process such that the conditional variance h_t is non-negative almost surely for all t. Necessary and sufficient conditions have been derived in Conrad and Haag (2006). These conditions ensure that all the ψ_i coefficients in the so-called ARCH(∞) representation of the FIGARCH process are non-negative. The FIGARCH implies the ARCH(∞) representation

$$h_t = \frac{\omega}{B(1)} + \left(1 - \frac{(1 - L)^d \Phi(L)}{B(L)}\right) \varepsilon_t^2 = \frac{\omega}{B(1)} + \sum_{j=1}^{\infty} \psi_j \varepsilon_{t-j}^2 \tag{8}$$

Since later on the FIGARCH$(1, d, 1)$ will be used, we restate the necessary and sufficient condition for this model explicitly.

Theorem 1 (Conrad and Haag, 2006, Corollary 1)**.** *The conditional variance of the FIGARCH(1,d,1) is non-negative a.s. iff*

Case 1: $0 < \beta_1 < 1$

either $\psi_1 \geq 0$ *and* $\phi_1 \leq f_2$ *or for* $k > 2$ *with* $f_{k-1} < \phi_1 \leq f_k$ *it holds that* $\psi_{k-1} \geq 0$.

Case 2: $-1 < \beta_1 < 0$

either $\psi_1 \geq 0$, $\psi_2 \geq 0$ *and* $\phi_1 \leq f_2(\beta_1+f_3)/(\beta_1+f_2)$ *or for* $k > 3$ *with* $f_{k-2}(\beta_1+f_{k-1})/(\beta_1+f_{k-2}) < \phi_1 \leq f_{k-1}(\beta_1+f_k)/(\beta_1+f_{k-1})$ *it holds that* $\psi_{k-1} \geq 0$ *and* $\psi_{k-2} \geq 0$.

where $f_i = (i-1-d)/i$, $i = 1, 2, \ldots$.

Bollerslev and Mikkelsen (1996) provided a sufficient condition for the non-negativity of the conditional variance, which is overly restrictive in comparison to the set of parameter combinations allowed for by Theorem 1. In particular, their condition implies the upper bound $\phi_1 < f_3$, which is often violated for high frequency data (see Baillie et al., 2004).

Alternatively, we allow for exogenous regressors in the conditional variance equation.

$$B(L)h_t = \omega + \sum_{i=1}^{I} \omega_i(L)X_{t,i} + \left(B(L) - (1-L)^d\Phi(L)\right)\varepsilon_t^2 \tag{9}$$

with $\omega_i(L) = \omega_{1,i}L + \ldots + \omega_{l,i}L^i$. Note, that in equation (9) the exogenous variables $X_{t,i}$ enter with at least one lag. In this way, we ensure that $\mathbf{E}(\varepsilon_t^2|\mathcal{F}_{t-1}) = h_t$ is a constant and can be interpreted as a conditional variance.

5 Empirical Results

5.1 Pure AR-FIGARCH Models

Before we analyze the effects of the monetary policy decision announcements on the level and volatility of the EUR-$ exchange rate in detail we present estimation results from pure AR-FIGARCH models for the control sample and the announcement days without including any exogenous regressors. Table 2 presents the estimation results. The serial correlation in the filtered five-minute return series is well captured by the inclusion of three autoregressive lags in the mean equation, while in the conditional variance a FIGARCH$(1, d, 1)$ was the preferred specification based on the AIC and SIC information criteria compared to models of higher order. To capture the apparent leptokurtosis in the filtered return series, the innovation term is assumed to be t-distributed with ν degrees of freedom. As can be seen from Table 2, the constant and the estimated AR parameters in the mean equation are highly significant. The estimated persistence parameter, d, in the conditional variance equation is around 0.3 and significantly different from zero or one. The ϕ_1 and β_1 parameters are again highly significant and lie outside the sufficient parameter set given by the Bollerslev and Mikkelsen (1996) sufficient condition. Note, that in particular $\widehat{\phi}_1 > \widehat{f}_3$. However, they do lie insider the necessary and sufficient parameter set provided by Conrad and Haag (2006). Moreover, the Ljung-Box Q-statistics for the squared standardized residuals (not reported) indicate that the FIGARCH specification does very well in capturing the hyperbolic memory in the squared filtered returns. Most importantly, the parameters estimated for the control days and the announcement days are very similar and in most cases not statistically different from each other.

Table 2: AR(3)-FIGARCH$(1, d, 1)$ models for filtered five-minute EUR-$ returns.

	μ	φ_1	φ_2	φ_3	$\omega \cdot 10^{-4}$	ϕ_1	β_1	d	ν
CD	0.0009	0.1234	-0.0653	-0.0239	1.3899	0.7271	0.8241	0.2976	5.5060
	(0.0004)	(0.0072)	(0.0065)	(0.0063)	(0.2019)	(0.0300)	(0.0221)	(0.0176)	(0.1865)
AD	0.0008	0.0941	-0.0557	-0.0288	1.3413	0.7083	0.8032	0.3103	5.4455
	(0.0003)	(0.0070)	(0.0062)	(0.0059)	(0.1986)	(0.0315)	(0.0236)	(0.0201)	(0.1824)

Notes: Robust standard errors are given in parenthesis. Numbers in brackets are p-values. CD: control days (89). AD: announcement days (89).

5.2 AR-FIGARCH Dummy Models

Next, in Table 3 we reestimate the AR(3)-FIGARCH$(1, d, 1)$ models with dummies in the conditional mean and variance equation. The advantage of this approach is that it allows for the simultaneous estimation of mean and variance effects which is more efficient than previous attempts as e.g. Ehrmann and Fratzscher (2005b) who apply an iterative, weighted least squares approach.

We employ dummies at 13.50 in the mean and in the conditional variance, denoted by $D^m_{13.50}$ and $D^v_{13.50}$ to capture the immediate effect after the press release.[12] Analogously, we construct dummies at 14.45, denoted by $D^m_{14.45}$ and $D^v_{14.45}$, to capture the effect of the press conference. As expected, on the control days none of the dummies is significant indicating, that the filtered control day returns are free of any effects due to macroeconomic announcements. The picture for the announcement days is very different. We observe a significant 13:50 dummy in the mean with a negative sign, i.e. monetary policy decisions as made public by the press release tend on average to have a negative effect on the level of the exchange rate immediately after the press release. No effect on the level is evident after the press conference. In the volatility we find significant increases at 13:50 as well as 14:45. When an additional dummy at 13:55 is included the jump in volatility at 13:50 becomes much more pronounced with an immediate decrease at 13:55. These results deliver overwhelming evidence for the hypothesis that the press release launched at 13:45 has a significant impact on the level as well as the volatility of the EUR-$ exchange rate. The effect on the volatility observed at 14:45 CET is significant across all three specifications showing that the ECB press conference impacts the EUR-$ exchange rate in addition to the usually announced macroeconomic news in the US.

Next, we analyze the announcement days more closely by grouping them in surprise days and no surprise days. The regressions run include all announcement days but the time dummies take the value of one only for the surprise days or no surprise days, respectively. The results for the no surprise days

[12] Ehrmann and Fratzscher (2005b) argue that news may leak into the markets before the official release date. However, this argument against high frequency data has low applicability for central banks. For instance central bank officials are not allowed to speak one week ahead of the official press release about the upcoming decision meeting. Hence, there is low probability that this information comes into the market short before the official meeting.

Table 3: AR-FIGARCH-Dummy models.

$D^m_{13.50}$	$D^m_{14.45}$	$D^v_{13.50}$	$D^v_{13.55}$	$D^v_{14.45}$
Panel A: Control Days				
-	-	-	-	-
Panel B: Announcement Days				
-0.0088**	-0.0043	0.514***	-	0.273**
(0.0037)	(0.0030)	(0.180)		(0.132)
-0.0088**	-	0.514***	-	0.277**
(0.0037)		(0.180)		(0.132)
-0.0087**	-	2.013**	-1.466*	0.289**
(0.0041)		(1.042)	(0.843)	(0.124)
Panel C: Announcement Days with no **mean** surprise				
-0.0078**	-	-	-	0.299**
(0.0037)				(0.121)
Panel D: Announcement Days with **mean** surprise				
-	-	1.602***	-	0.311**
		(0.574)		0.143
-	-	7.661*	-5.754*	0.297**
		(4.019)	(3.257)	(0.125)

Notes: *, ** and *** denote significance at the 10%, 5% and 1% level. Robust standard errors are given in parenthesis. All models are estimated for the entire period 01/1999 – 10/2006. The estimated parameters in the variance equation and their respective standard errors are multiplied by 10^3.

are very similar to the ones for all announcement days. As one would expect, the effect at 13:50 CET on the volatility is now no longer significant, indicating that this effect is merely driven by surprise news. The increase in volatility is still significant after the beginning of the press conference at 14.45 CET.

Important: Usually, it is argued that exchange rates should react only to *news*, i.e. the unexpected component of an announcement. Our results show that on no surprise days, there is a significant effect in the mean at 13.50 although no new information is revealed by the press release. Similarly, Andersen et al. (2003) report *pure announcement effects* in their volatility equation.

Turning to the surprise days, it is the 13:50 CET dummy in the volatility which is dominating. The volatility increase at 13:50 CET is dramatic compared to all announcement days and again best captured by two dummies at 13:50 and 13:55 CET. This also highlights the fact that this effect is very strong, but rather short lived. The dummy at 14.45 is still significant with about the same order of magnitude as before. Surprisingly, we do not find an effect on the mean of the exchange rate. However, this may be explained by the fact that the dummy approach does not control for positive or negative surprises and not for the size of the surprise.

Next, we use the Reuters surprise data and the BHS communication indicator to investigate whether the movements in the mean and variance can be explained by the size and sign of those variables. Table 4 presents the estimation results. The sample now includes all communication days in the entire sample.[13] Additionally, we included separate regressors for positive and negative mean surprises in order to control for asymmetries.

Table 4: AR-X-FIGARCH-X models.

	Mean Equation				
	$MeaS_{13.50,pos}$	$MeaS_{13.50,neg}$	$CE_{14.45}$	$BHS_{14.45}$	
(1)	-	-	-0.0077**	-	
			(0.0044)		
(2)	-	-	-0.0354**	-0.0238 ***	
			(0.0166)	(0.0081)	
	Variance Equation				
	$MeaS_{13.50,pos}$	$\|MeaS_{13.50,neg}\|$	$CE_{14.45}$	$BHS_{14.45,pos}$	$\|BHS_{14.45,neg}\|$
(1')	0.0461***	0.0543**	-	-	
	(0.0173)	(0.0246)			
(2')	0.9430**	0.4838	-	0.0151***	0.0305**
	(0.388)	(0.3641)		(0.0052)	(0.0135)

Notes: *, ** and *** denote significance at the 10%, 5% and 1% level. Robust standard errors are given in parenthesis. Modell (1) is estimated for all 89 announcement days. Modell (2) for the first 68 announcement days only. The estimated parameters in the variance equation and their respective standard errors are multiplied by 10^3.

Positive and negative mean surprises both increase volatility sharply at 13.50. However, the surprise variables do not explain the movements in the level of the exchange rate. The BHS communication index successfully explains the movements in the mean and volatility at 13.45. The more risky the economic environment respectively the economic outlook, the more the EUR-$ depreciates. Both positive and negative values of tend to increase volatility, but with a considerably stronger impact of negative values. Finally, the index, CE, which directly measures the risk associated with the exchange rates has a significant impact on both the mean and volatility at 14.45. A higher value of CE leads to a stronger

[13]Unfortunately, the BHS index is only available for the first 68 meeting days in our sample. Equation (1) is estimated for all days, equation (2) for those 68 meeting days.

depreciation. Andersen et al. (2003) argue that exchange rates tend to react more strongly to large news surprises than to small ones and to negative news rather than to positive ones. This might explain why find no effect on the mean at 13.50. A closer investigation of the data revealed that small surprises indeed do not effect the mean, while larger ones do. In the following we use a redefined mean surprise variable which is equal to the surprise, if the surprise interest change is at least 5 basis points, while zero otherwise.

Andersen et al. (2003) point to the possibility that a full reaction of the exchange rate's mean and volatility to news may not necessarily occur immediately, but that the news is incorporated only gradually over the subsequent time period. Moreover, as noted by Ehrmann and Fratzscher (2005a) the permanent effect of news may be quite different from the initial immediate reaction. In this spirit we reestimate the models from Table 4 for a "shrunk" sample, which is constructed as follows. We sum up the returns between 13.50 and 14.15, i.e. half an hour after the press release, and between 13.35 and 15.30, i.e. one full hour after the start of the press conference, and substitute the corresponding periods with those average returns. This means that we end up with a "shrunk" sample consisting of 272 daily observations. The estimated coefficients from Table 5 contain information about the effect of a surprise interest rate change at 13.45 on the average return in the following half hour. To be able to detect asymmetries in the reaction to positive and negative surprises, the announcement days with surprise are divided into days with positive and negative surprise. The estimation results reveal that an unexpected tightening of the target interest rate by 50 basis points causes an appreciation of approximately 0.5% of the EUR against the US$. In the contrary, an unexpected easing of the target interest rate has no significant effect on the EUR-$ exchange rate. Hence, there is evidence for an asymmetry in the sense that a tightening monetary policy has a strong impact while a easing has no such impact.

5.3 Subsample Analysis

Finally, we investigate whether the effect of the ECB's monetary policy decision on the EUR-$ exchange rate depends on the time period considered. Following the results of the breakpoint tests for a change in the monetary strategy of Berger et al. (2006) we split the whole sample in April 2001. Second, we split the sample at May 2003. The latter point in time is motivated by a change in the structure of the ECB introductory statement by highlighting non-monetary issues. The results presented in Table 6 are again based on dummy variables as exogenous regressors. In the subsample 01/1999 – 03/2001 we find that the dominating effect is driven by the press release at 13.50. The 13.50 dummy in the variance is the only regressor which is significant uniformly over announcement days, surprise days and no surprise days. In the second subsample, 04/2001 – 10/2006, the picture is very different. Now, the dummies at 13.50 and 14.35 are both highly significant, but the effect at 13.45 is dominating. Obviously, the importance of the press conference in relation to the press release has increased from the first to the second subsample.

The results for the subsamples 01/1999 – 03/2003 and 04/2003 – 10/2006 are very similar. In the

Table 5: AR-X-FIGARCH-X models shrunk sample with bound on surprise.

	$MeaS_{13.50,pos}$	$\|MeaS_{13.50,neg}\|$	$CE_{14.45}$	$BHS_{14.45,pos}$	$\|BHS_{14.45,neg}\|$
	Mean Equation				
(1)	0.9617**	0.0441	-0.0548***	0.0101	0.0448***
	(0.4887)	(0.1065)	(0.0182)	(0.0124)	(0.0133)
Full sample (2)	1.0668**	0.0539	-	-0.0183*	0.0513***
	(0.4957)	(0.1105)		(0.0110)	(0.0184)
01/99 – 05/03 (3)	1.0627**	0.0710	-	-0.0283**	0.0284*
	(0.4886)	(0.1673)		(0.0130)	(0.0167)
	Variance Equation				
(1')	0.3106***	0.2962	-	0.0143***	0.0311**
	(0.0942)	(0.2624)		(0.0043)	(0.0143)
Full sample (2')	0.2983***	0.2919	-	0.0153***	0.0342**
	(0.1098)	(0.2568)		(0.0052)	(0.0145)
01/99 – 05/03 (3')	0.3057***	0.1077*	-	0.0156*	0.0151
	(0.1052)	(0.0653)		(0.0084)	(0.0125)

Notes: *, ** and *** denote significance at the 10%, 5% and 1% level. Robust standard errors are given in parenthesis. Modell (1) is estimated for all 89 announcement days. Modell (2) for the first 68 announcement days only. The estimated parameters in the variance equation and their respective standard errors are multiplied by 10^3.

subsample 04/2003 – 10/2006 the dummy at 13.50 is no more significant. However, after 04/2003 there is only one surprise event. These findings are reinforced by Figures 8 and 9. Figure 8 is concerned with all announcement days, and shows a striking difference in the intraday volatility of the EUR-$ exchange rate between the subperiods 01/1999 – 03/2003 and 04/2003 – 10/2006. While in 01/1999 – 03/2003 the press release dominates the whole day, it looses much of its importance in 04/2003 – 10/2006. In sharp contrast now the press conference is most important. This is even true, when we focus on the no surprise days only, as can be see from Figure 9. For those days, the press conference and press release are equally important in the first subsample, while the press conference is clearly more important in the second subsample.

6 Conclusions

We analyze the effect of ECB monetary policy announcements in conjunction with its communication on the level and variance of the EUR-$ exchange rate. We disentangle the effects of an announcement day by focussing on the impact of the interest rate decision at 13.45, the press conference starting at 14.30 and the Q&A session following thereafter. The key result is that ECB announcements significantly drive

Table 6: AR-FIGARCH-Dummy models for subsamples.

	$D^m_{13.50}$	$D^v_{13.50}$	$D^v_{14.35}$	$D^m_{13.50}$	$D^v_{13.50}$	$D^v_{14.35}$
	01/1999 – 03/2001			01/1999 – 04/2003		
AD	-0.0074	0.0126**	0.0031	-0.0308*	0.0118***	0.0042*
	(0.0260)	(0.0052)	(0.0030)	(0.0167)	(0.0045)	(0.0023)
NS	-0.0171	0.0074***	0.0032	-0.0249	0.0051***	0.0032**
	(0.0258)	(0.0028)	(0.0025)	(0.0153)	(0.0016)	(0.0016)
SD	0.1993	0.0611*	-0.0032	-0.0189	0.0686**	-0.0048
	(0.1930)	(0.0319)	(0.0060)	(0.1196)	(0.0297)	(0.0048)
	04/2001 – 10/2006			05/2003 – 10/2006		
AD	-0.023***	0.0024**	0.0042***	-0.015*	0.0012	0.0051**
	(0.0087)	(0.0010)	(0.0015)	(0.0086)	(0.0009)	(0.0021)
NS	-0.0210**	0.0018**	0.0041***	-0.0167*	0.0012	0.0043***
	(0.0087)	(0.0008)	(0.0014)	(0.0095)	(0.0008)	(0.0017)
SD	-0.1173	0.0198	0.0038	-	-	-
	(0.0768)	(0.0211)	(0.0055)			

Notes: Robust standard errors are given in parenthesis. AD: announcement days, NS: announcement days with no surprise, SD: announcement days with surprise.

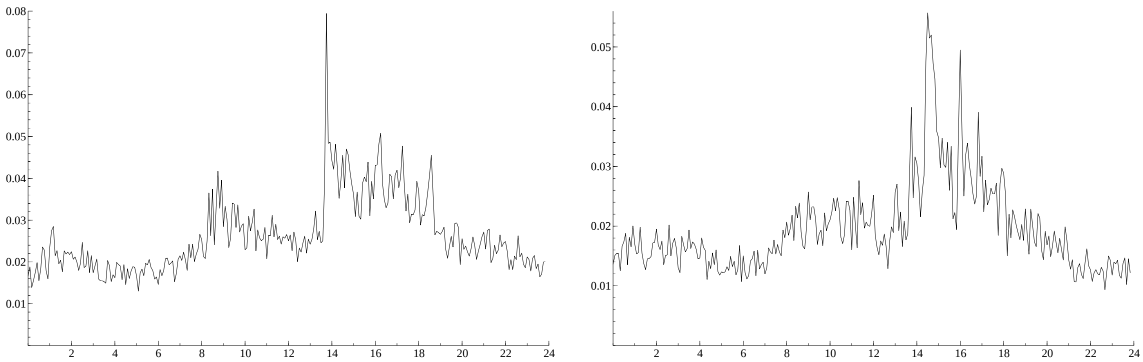

Figure 8: Average absolute five-minute EUR-$ returns for each five minute interval. The upper panel shows announcement days before May 2003. The lower panel shows announcement days from May 2003 onwards.

exchange rate movements at that points in time. In addition, we find evidence for asymmetries in the response to positive and negative shocks.

The impact of the interest announcement is significant if the decision was not anticipated by market participants. The surprise element in the interest rate movement is captured by employing the Reuters

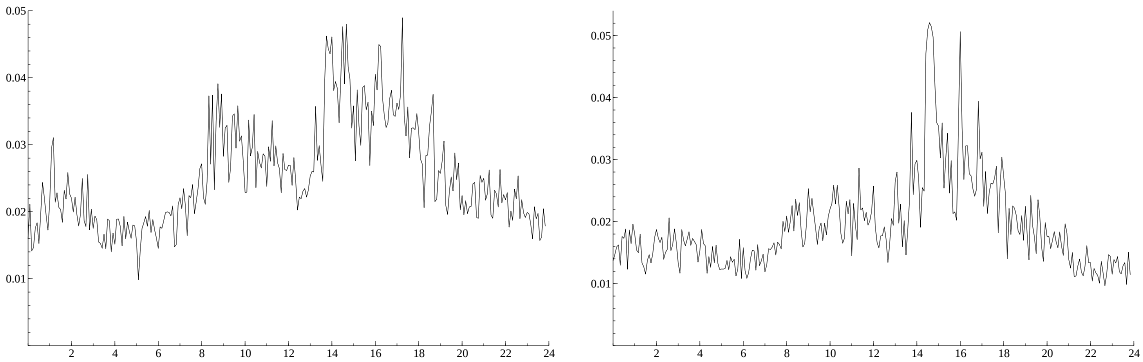

Figure 9: Average absolute five-minute EUR-$ returns for each five minute interval. The upper panel shows announcement days with no surprise before May 2003. The lower panel shows announcement days with no surprise from May 2003 onwards.

survey. Being more specific, unexpected tightening of the monetary policy exhibit positive impact in comparison to an unexpected easing which does not reveal any significant effect. Moreover, while the impact on the return is not significant in all specifications, there is overwhelming evidence concerning its effect on the variance.

Second, the introductory statements play an important role for market participants. Especially, aggregated over the relevant period there is compelling evidence that a higher risk expressed in the introductory statement by the ECB reduces the value of the Euro. Notably, if the ECB states that risk to price stability has risen this in turn amplifies volatility. On the other hand lower risks to price stability tend to calm the markets and reduce the movement of the exchange rate. In a finer grained analysis we provide evidence that information on price developments reveal more news to market participants compared to the ECB's assessment of developments in the monetary or the real sector.

Third, we find no substantial movement during the Q&A session. It seems that either the Q&A session does not contain any news for market participants or it is used to affirm earlier statements in more detail.

Finally, we explore the stability of the relationship by splitting the sample period. We chose two breakpoints suggested by Berger et al. (2006). The results indicate that there is growing relevance of the introductory statements. The communication indicator rises in significance and magnitude. We conclude that some learning process took place. The interrelationship between ECB decisions and the expectations of the public evolved and seems to stabilize over the recent two years.

References

Andersen, T. G. and Bollerslev, T. (1997). Intraday periodicity and volatility persistence in financial markets. *Journal of Empirical Finance*, 4(2-3):115–158.

Andersen, T. G. and Bollerslev, T. (1998). Deutsche mark-dollar volatility: Intraday activity patterns, macroeconomic announcements, and longer run dependencies. *Journal of Finance*, 53(1):219–265.

Andersen, T. G., Bollerslev, T., Diebold, F. X., and Vega, C. (2003). Micro effects of macro announcements: Real-time price discovery in foreign exchange. *American Economic Review*, 93(1):38–62.

Baillie, R. T., Cecen, A. A., Erkal, C., and Han., Y.-W. (2004). Measuring non-linearity, long memory and self-similarity in high-frequency European exchange rates. *Journal of International Financial Markets, Institutions and Money*, 14:401–418.

Baillie, R. T., Cecen, A. A., and Han, Y.-W. (2000). High frequency Deutsche Mark-US Dollar returns: FIGARCH representations and non- linearities. *Multinational Finance Journal*, 4:247–267.

Beine, M. A., Lecourt, C., and Janssen, G. (2004). Should central bankers talk to the foreign exchange market? Mimeo.

Berger, H., de Haan, J., and Sturm, J.-E. (2006). Does money matter in the ECB strategy? New evidence based on ECB communication. CESifo Working Paper Series 1652, CESifo.

Ehrmann, M. and Fratzscher, M. (2005a). Communication and decision-making by central bank committees - different strategies, same effectiveness? *Journal of Money, Credit and Banking*, forthcoming.

Ehrmann, M. and Fratzscher, M. (2005b). Exchange rates and fundamentals: New evidence from real-time data. *Journal of International Money and Finance*, 24(2):317–341.

Ehrmann, M. and Fratzscher, M. (2005c). How should central banks communicate? ECB Working Paper 557, European Central Bank.

Faust, J., Rogers, J. H., Wang, S.-Y. B., and Wright, J. H. (2006). The high-frequency response of exchange rates and interest rates to macroeconomic announcements. *Journal of Monetary Economics*. forthcoming.

Fratzscher, M. (2004). Communication and exchange rate policy. ECB Working Paper 363, European Central Bank.

Fratzscher, M. (2005). How successful are exchange rate communication and interventions? Evidence from time-series and event-study approaches. ECB Working Paper 528, European Central Bank.

Han, Y. W. (2004). Quantitative analysis of macroeconomic shocks and the Euro currency in high frequency perspective. Mimeo.

Heinemann, F. and Ullrich, K. (2005). Does it pay to watch central bankers' lips? The information content of ECB wording. Working Paper Series 05-70, ZEW.

Jansen, D.-J. and de Haan, J. (2005a). Talking heads: The effects of ECB statements on the euro-dollar exchange rate. *Journal of International Money and Finance*, 24(2):343–361.

Jansen, D.-J. and de Haan, J. (2005b). Were verbal efforts to support the euro effective? A high-frequency analysis of ECB statements. DNB Working Papers 033, Netherlands Central Bank, Research Department.

Kearns, J. and Manners, P. (2006). The impact of monetary policy on the exchange rate: A study using intraday data. *Journal of International Central Banking*, 2(4):157–183.

Lamla, M. J. and Rupprecht, S. M. (2006). The impact of ECB communication on financial market expectations. Working Paper 135, KOF.

Rosa, C. and Verga, G. (2005). Is ECB communication effective? Working Paper Series 682, Centre of Economic Performance.

Zettelmeyer, J. (2004). The impact of monetary policy on the exchange rate: Evidence from three small open economies. *Journal of Monetary Economics*, 51(3):635–652.