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International Macroeconomic Announcements and Intraday Euro Exchange Rate Volatility

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Abstract

The short-run reaction of Euro returns volatility to a wide range of macroeconomic announcements is investigated using five-minute returns for spot Euro-Dollar, Euro-Sterling and Euro-Yen exchange rates. The marginal impact of each individual macroeconomic announcement on volatility is isolated whilst controlling for the distinct intraday volatility pattern, calendar effects, and a latent, longer run volatility factor simultaneously. Macroeconomic news announcements from the US are found to cause the vast majority of the statistically significant responses in volatility, with US monetary policy and real activity announcements causing the largest reactions of volatility across the three rates. ECB interest rate decisions are also important for all three rates, whilst UK Industrial Production and Japanese GDP cause large responses for the Euro-Sterling and Euro-Yen rates, respectively. Additionally, forward looking indicators and regional economic surveys, the release timing of which is such that they are the first indicators of macroeconomic performance that traders observe for a particular month, are also found to play a significant role.

Keywords: Intraday volatility; macroeconomic announcements; exchange rates

JEL: G12, E44, E32

1. Introduction

Investigation of the way in which news about macroeconomic fundamentals is incorporated into asset prices, and the consequent characterisation of the price discovery process, lies at the heart of empirical finance literature concerned with market efficiency and market microstructure. One of the most successful innovations in the empirical study of market microstructure and price discovery in recent years has followed from the availability and application of high frequency data. Much of the advance in empirical work on high frequency asset return volatility stems from a series of seminal papers by Andersen and Bollerslev (1997a, 1997b, 1998) that identify a component structure to high frequency returns volatility and rationalizes the stylised patterns observed in asset price volatility in terms of a theory of public information arrival. In particular, Andersen and Bollerslev (1997a) propose a general methodology for the extraction of the intraday periodic component of return volatility, whilst Andersen and Bollerslev (1998) provide a robust econometric methodology for capturing distinct volatility components and isolating macroeconomic announcement effects simultaneously. Specifically, Andersen and Bollerslev (1998) model the intraday periodicity and long-run dependence found in DEM-USD returns and isolate macroeconomic news as the remaining component of volatility. This method has also been applied by Andersen et al. (2000) and Bollerslev et al. (2000) to different market settings, including the Japanese stock market and the US Treasury bond market.[1] However, very few other studies tackle the full complexity involved in the simultaneous modelling of all components of intraday volatility,

[1] Andersen and Bollerslev (1998) find that US news regarding the real economy are the most significant news releases, including the Employment Report, Trade Balance and Durable Goods orders, while the most important German announcements are monetary, namely Bundesbank meetings and M3 Money Supply figures. Bollerslev et al. (2000) separate volatility components in the US Treasury bond market. Regularly scheduled macroeconomic announcements are an important source of volatility at the intraday level, with the Humphrey-Hawkins testimony, the Employment Report, PPI, Employment Costs, Retail Sales and the National Association of Purchasing Managers (NAPM) Index having the greatest impact. Bollerslev et al. (2000) also uncover striking long memory volatility dependencies in the fixed income market. Andersen et al. (2000) characterise volatility in the Japanese stock market in a similar fashion. Again, they identify strong intraday patterns and interday persistence in five minute Nikkei 225 returns, but find that Japanese macroeconomic news releases are of limited importance with only some announcements having a significant short term impact on volatility.

and many discard valuable information relating to macroeconomic announcements by grouping release events into categories according to the type of announcement, or consider only a limited range of announcements.[2]

This paper therefore seeks to extend and appraise the earlier results of Andersen and Bollerslev (1998) and others for the DEM-USD to five-minute bid-ask quotes of the EUR-USD, which constitutes a new market that has yet to be investigated in this econometric framework, and using a far wider range of individual macroeconomic announcements across countries and economic conditions than has been considered hitherto in the literature.[3] Thus, the dataset includes a broad selection of macroeconomic news announcements emanating from the US, Eurozone, Germany, France, UK and Japan to examine whether announcements regarding relative economic performance impact upon bilateral exchange rate volatility. In addition to seeking to extend previous results for the DEM-USD exchange rate to a new sample period for its EUR-USD successor, we also provide complementary analyses for two of the other major exchange rates, namely the EUR-GBP and EUR-JPY, which have not yet

[2] Payne (1996) analyses the DEM-USD exchange rate and reports large volatility impacts associated with the release of the Employment Report and Trade figures. Markets are found to quieten in anticipation of news releases, but after the release there is a pronounced and persistent impact on volatility. The DEM-USD rate is also the subject of work by Almeida et al. (1998), who identify significant impacts of most macroeconomic news announcements within fifteen minutes of the release. The strong, quick impact of macroeconomic news on the exchange rate reflects the anticipated policy reaction by monetary authorities to the piece of news just released, showing that the foreign exchange market's primary concern is with the future likely reaction of the monetary authorities. News from German announcements is found to be incorporated more slowly due to differences in the timing and scheduling arrangements of announcements between Germany and the US, and DEM-USD volatility is found to be driven more by US than German announcements. Chang and Taylor (2003) investigate the DEM-USD exchange rate and find that US and German macroeconomic news and German Bundesbank monetary policy news all have a significant impact on intraday DEM-USD volatility. Ehrmann and Fratzscher (2005) analyse the link between economic fundamentals and exchange rates by investigating the importance of real-time data. They find that economic news in the US, Germany and Eurozone have been a driving force behind daily USD-DEM developments, with US news having the largest influence, particularly in periods of large market uncertainty and when negative or large shocks occur. DeGennaro and Shrieves (1997) investigate the USD-JPY rate and also conclude that news releases affect volatility levels and are important determinants of exchange rate volatility.

[3] In the only known study of this type for EUR-USD since European Monetary Union, Bauwens et al. (2005) analyse the impact of nine categories of news on high frequency EUR-USD volatility, filtered by the average intraday volatility pattern, in the framework of ARCH models. In related work, Sager and Taylor (2004) implement higher frequency data and concentrate on the impact of European Central Bank (ECB) Governing Council interest rate announcements, finding strong evidence that the policy announcements contain significant news content. Jansen and De Haan (2005) also focus on the ECB, but expand their coverage to include statements as well as policy announcements. The impact of the full range of international macroeconomic announcements on Euro exchange rate volatility therefore remains to be addressed.

been considered using the empirical methodology established in the recent high frequency empirical literature. It is also of interest to consider the EUR-GBP exchange rate given the status of the UK as an EU member but not a full participant in EMU, in order to determine whether different market microstructure effects prevail in that scenario. Further, the methodology adopted follows that pioneered by Andersen and Bollerslev (1998) in permitting the simultaneous modelling of the three principal volatility components associated with long memory, intraday periodicity and macroeconomic announcement effects, as described above, but where the complexities of such news effects are more efficiently identified in terms of volatility response functions rather than the more common use of simple dummy variables associated with categories of grouped news events. Furthermore, the robustness of the results reported is assessed in relation to two different, alternative, means of filtering the intraday periodicity component of volatility, namely the flexible Fourier form method previously applied in the literature and a cubic spline approach which has certain advantages in more closely modelling volatility peaks associated with the opening and closing of regional foreign exchange markets.

The remainder of the paper is structured as follows. Section 2 describes the data and section 3 describes the econometric modelling approach and briefly outlines the intraday periodicity filters applied. Section 4 reports the empirical results for the statistical significance of individual macroeconomic announcement effects for each of the three bilateral Euro exchange rates under consideration. Section 5 summarizes our findings and conclusions.

2. Data

This study utilises inter-bank bid-ask quotes for Euro-Dollar (EUR-USD), Euro-Sterling (EUR-GBP) and Euro-Yen (EUR-JPY) spot exchange rates provided by Olsen Data.[4] The

[4] www.olsen.ch

sample period runs from January 2002 to July 2003 and so includes a period of global economic recovery following the US recession at the end of 2001, and an unofficial economic slowdown in the summer of 2002 and spring of 2003. The nineteen-month sample period also includes episodes of monetary policy easing when the Federal Reserve, European Central Bank and Bank of England all reduced interest rates.[5] The sample therefore includes a period when monetary policy authorities were lowering interest rates and when interest rate announcements were surrounded by great uncertainty, making the timing of decisions to cut interest rates and the magnitude of the cuts difficult to predict, particularly for the FOMC and ECB, and also covers the beginning of conflict in Iraq. The data set also includes information concerning important macroeconomic announcements in the US, Europe, the UK and Japan which has been provided by Money Market Services International, including the actual data released and its exact timing to the nearest minute. More specifically, this information set contains announcements on 132 separate macroeconomic indicators, comprising 37 indicators for the US, 21 for the Eurozone, 18 for Germany, 17 for France, 19 for the UK and 20 for Japan. [6]

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[5] Over the sample, the FOMC reduced interest rates three times: by 50 basis points on 30th January 2002; by 50 basis points on 6th November 2002 and by 25 basis points on June 25th 2003, and this period of aggressive monetary policy relaxation caused dramatic movements in the EUR-USD exchange rate.

[6] In full, these announcements are, by country: US - Business Inventories, Challenger Layoffs, Chicago National Activity Index, Chicago PMI, Construction Spending, Consumer Confidence, Consumer Credit, CPI, Current Account, Durable Goods Orders, Employment Report (including Non-Farm Payrolls, Unemployment Rate, Hourly Earnings and Average Work Week), Existing Home Sales, Factory Orders (and Inventories), FOMC, GDP Advance, GDP Preliminary, GDP Final, Housing Completions (and Housing Starts and Building Permits), Import Price Index (and Export Price Index), Industrial Production (and Capacity Utilisation), Initial Claims for Unemployment Benefit, ISM Manufacturing, ISM Non-manufacturing, Leading Indicators, Michigan Sentiment Preliminary, Michigan Sentiment Final, M2, NAHB Housing Index, New Home Sales, Personal Income (and Consumption Expenditure), Philadelphia Fed Index, PPI, Productivity Preliminary, Productivity Revised, Retail Sales, Trade Balance, Treasury Budget; EU - Business Climate Index, Consumer Confidence Index (and Business Confidence Index and Sentiment Index), CPI, Current Account, GDP Preliminary, GDP Final, GDP Revised, HCPI, Industrial Production, Labour Costs Preliminary, Labour Costs Final, Labour Costs Revised, M3, OECD Leading Indicators, PPI, PMI, Retail Sales, Services Index (and Composite Index), Trade Balance Preliminary (and Final), Unemployment, ECB; Germany – Capital Account, COL Preliminary, COL Final, Current Account, Employment, GDP, IFO Business Expectations (with Business Climate and Current Conditions), IFO Manufacturing Survey, Import Prices, Industrial Production, Manufacturing Orders, PMI, PPI, Retail Sales, Services Index, Trade Balance, Unemployment, ZEW Expectations; France - Business Climate, CPI Final, CPI Preliminary, Current Account, GDP Preliminary, GDP Final, Household Consumption, Household Survey, Industrial Production (and Manufacturing), INSEE Report, Non-Farm Payrolls Preliminary, Non-Farm Payrolls Final, PPI, PMI, Services Index, Trade Balance, Unemployment (with Job Seekers); UK –

In order to construct the returns series, bid and ask quotes were sampled at five-minute intervals from 21:00 GMT on 1st January 2002 to 21:00 GMT on 31st July 2003. These data represent the last quotes during a particular five-minute interval, thus avoiding the problem of linear interpolation, and intervals that do not contain any quotes are assigned the same quote as that for the previous interval. The logarithmic price, $\log(P_{t,n})$, is defined as the mid-point of the logarithmic bid and ask spread. Since trading in the FX market is continuous and trading activity in the world's major financial centres overlaps, the trading day is twenty-four hours long, beginning at 21:00 GMT to capture the opening of trading in Sydney and Asia and continuing until 21:00 GMT the following day to include the close of trading in the US.[7] This produces 288 five-minute intervals during the day.[8] The n-th return within day t, ($R_{t,n}$), is calculated as the change in logarithmic prices during the corresponding period, $R_{t,n} = 100 \times [\log(P_{t,n}) - \log(P_{t,n-1})]$, where $t=1, 2\ldots T$ references the trading day and $n=1, 2\ldots N$ represents the intraday interval, with $T=412$ and $N=288$ so the sample contains $TN=118,656$

CIPS Manufacturing Survey, CIPS Services Survey, Consumer Confidence, Consumer Credit, GDP Preliminary, GDP Provisional, GDP Final (with Current Account), Halifax House Prices, Industrial Production (with Manufacturing Output), M4 Provisional, M4 Final, MPC, Nationwide House Prices, PPI Input (and Output), PSNCR, Retail Sales, RPI (with RPIX and HCPI), Trade Balance, Unemployment (with Average Earnings); Japan – Bank of Japan, Coincident Index, Construction Orders (with Construction Starts and Housing Starts), Consumer Confidence, CPI National (with CPI Tokyo), Department Store Sales, FX Reserves, GDP, GDP Revised, Income, Industrial Production, M2, Retail Sales, Shipments, Supermarket Sales, Tankan Manufacturing with Tankan Non-manufacturing), Tokyo Department Store Sales, Trade Balance (with Current Account), Tertiary Index, Unemployment (with Job Offers/Seekers Ration).

[7] To demonstrate this it is possible to assign subjective trading hours to each trading centre: Wellington, 20:00 to 4:00; Sydney 21:00 to 6:00; Tokyo, 00:00 to 8:00; Europe, 6:00 to 15:00; London, 7:00 to 16:00 and US, 11:30 to 20:30.

[8] To avoid confounding the data by the inclusion of slower trading periods over weekends, quotes form Friday 21:00 GMT to Sunday 21:00 GMT were removed following the weekend definition and adjustment established by Bollerslev and Domowitz (1993). Since weekend quotes between 21:00 GMT on Friday and 21:00 GMT on Sunday are removed, the first return calculated on a Monday morning measures the difference between prices on Friday 21:00 GMT and Sunday 21:05 GMT. This return is likely to reflect information related to geopolitical events gathered on days when the world's major trading centres are closed. However, closer inspection of the data reveals that there are often gaps in the data in early Monday morning trading, which manifest themselves as long series of zero returns. These episodes give rise to a large return at 21:05 GMT on Monday which reflects the difference between the price at the Friday close and the stale price generated by the gap in the data and this tends to be followed by another large return of the opposite sign. Following Andersen and Bollerslev (1998), these episodes of missing data are treated as market closures and assigned an artificially low, positive return so as not to disrupt any underlying periodicities in intraday volatility.

five-minute returns for each exchange rate.[9]

3. Econometric Method

As noted above, the volatility dynamics of high frequency foreign exchange returns are characterised by pronounced intraday periodicity and short-lived intraday announcement effects, as well as long memory at the daily frequency. In the modelling procedure adopted here, which follows Andersen and Bollerslev (1998), the volatility process is driven by the simultaneous interaction of these components associated with predictable calendar effects and intraday patterns, macroeconomic news announcements and a potentially persistent, unobserved latent factor. The procedure allows standard regression techniques to be used to account simultaneously for each separate component of volatility with the objective of isolating the dynamic behaviour of volatility around macroeconomic news announcements. In full generality, the model takes the following form:

$$R_{t,n} - \overline{R}_{t,n} = s_{t,n} \cdot s_{t,n} \cdot Z_{t,n}, \tag{1}$$

where $\overline{R}_{t,n}$ is the expected five-minute return such that $R_{t,n} - \overline{R}_{t,n}$ measures excess returns, $Z_{t,n}$ is an independent and identically distributed zero mean and unit variance error term, $s_{t,n}$ represents the intraday pattern and also controls for calendar features and macroeconomic announcement effects, and $s_{t,n}$ denotes the remaining latent, long memory, volatility component. All volatility components are assumed to be independent and non-negative. Note

[9] Days during which quoting activity is so low as to render returns unreliable are classified as market closures, and five-minute returns during these intervals are also assigned an artificially low, positive return. Specifically, these periods are Easter, Christmas and New Year's Day. In addition, there are some days in the sample during which quoting activity during parts of the trading day is low due to regional public holidays. Such regional holidays affect only a small segment of the trading day and the overlap of trading in different locations ensures that returns are reliable even if activity is low and so they are maintained in the sample. Full details are available from the authors on request. The effect of these regional holidays on volatility is controlled for explicitly in the analysis below.

that the components of equation (1) are not separately identifiable without additional restrictions. However, the process of squaring and taking logs allows $s_{t,n}$ to be isolated as the sole explanatory variable:

$$2\log\left[\left|R_{t,n} - \overline{R}_{t,n}\right|\right] - \log s_{t,n}^{2} = m_0 + 2\log s_{t,n} + u_{t,n}\,, \tag{2}$$

where $m_0 = E\left[\log Z_{t,n}^2\right]$ and $u_{t,n} = \log Z_{t,n}^2 - E\left[\log Z_{t,n}^2\right]$. Two important empirical features of this expression are that the use of mean-adjusted five-minute returns annihilates the problem of returns with a value of zero, while the log transformation eliminates any extreme outliers, rendering the regression analysis more robust.

To obtain an operational regression equation some additional structure is imposed. First, $\overline{R}_{t,n}$ is assumed constant and well approximated by the sample mean, $\overline{R}$. Second, to help control for systematic volatility movements caused by the latent volatility component, an *a priori* estimate of the return standard deviation, $\hat{s}_{t,n}$, is applied.[10] Third, note that since each particular macroeconomic announcement is unique, $\log s_{t,n}$ will be stochastic. That is, the price and volatility reaction will reflect the news content (the innovation relative to consensus forecasts) of the announcement, the dispersion of beliefs among traders and other market conditions at the time of the release. To capture these dynamic features directly, it would be necessary to model a wide information set including expectations and recent return

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[10] More specifically, the potentially highly persistent volatility component, $\hat{s}_{t,n}$, is estimated as follows. Daily volatility, s_t, is estimated from a fractionally integrated MA(1)-FIGARCH(1,d,1) model applied to a longer series of daily returns from 2nd January 1999 to 31st July 2003. This follows the approach of Bollerslev et al. (2000), but as a robustness check which follows the earlier approach of Andersen and Bollerslev (1998), a simple MA(1)-GARCH(1,1) model is also used due to its simplicity and popularity. Estimation results for these various conditional variance models are not shown here in the interests of brevity but are available from the authors on request, and the results of the robustness check are footnoted where appropriate. Assuming that the daily volatility component is constant throughout the trading day, the associated intraday estimates are given by $\hat{s}_{t,n} = \hat{s}_t / N^{1/2}$, where *N=288* represents the number of five-minute intervals during the trading day.

innovations, for example, amongst other factors. To maintain tractability in estimation, the (log-)volatility response conditional on the type and timing of the announcement and other relevant calendar information is assumed to have a well defined expected value, $E[\log s_{t,n}]$. This average impact is governed by purely deterministic regressors such that the innovation resulting from a new release, $\log s_{t,n}$-$E[\log s_{t,n}]$ can be isolated. The final restriction is that $\log s_{t,n}$ is strictly stationary and has a finite unconditional mean, $E[\log s_{t,n}]$. The operational regression then becomes:[11]

$$2\log\frac{|R_{t,n}-\overline{R}|}{\hat{s}_{t,n}} = \hat{m}_0 + E[\log s_{t,n}] + \hat{u}_{t,n}, \quad (3)$$

where $\hat{m}_0 = E[\log Z_{t,n}^2] + E[\log s_{t,n}^2 - \log \hat{s}_{t,n}^2]$, the error process $\hat{u}_{t,n}$ is stationary, and the term $E[\log s_{t,n}]$ represents a choice of parametric function that models the intraday volatility pattern, calendar features and announcement effects in combination.

Two approaches to the parametric representation imposed on the regressor $E[\log s_{t,n}]$ are taken here. A benefit of both these approach is that they use the entire span of data in fitting the intraday pattern, rather than relying on intraday average absolute returns.[12] First, following Andersen and Bollerslev (1998), a variant of the flexible Fourier form (FFF) is

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[11] Note that standardisation of the mean-adjusted absolute returns by $\hat{s}_{t,n}$ allows the daily volatility factor on the left hand side of (3) to vary over time thus improving the efficiency of the estimation, and accommodates the volatility clustering and high persistence that is prevalent in financial data at the daily frequency. It is important to recognise, however, that this procedure may give rise to a generated regressors problem which may impart a bias to the standard errors. As a further robustness check, the time-varying estimates are also compared to a constant daily volatility factor, which is free of any generated regressor problem, calculated as $\hat{s}_{t,n} = \overline{s}/N^{1/2}$, where $\overline{s}$ denotes the sample mean of $\hat{s}_t$. The results of this robustness check are footnoted where appropriate.

[12] That is, it is possible to adjust the intraday volatility pattern in returns by standardizing absolute mean-adjusted returns by the sample mean absolute return for a particular intraday interval (Andersen and Bollerslev, 1997a, b). However, this technique does not allow a sufficiently accurate separation of volatility spikes from the underlying intraday pattern since the mean absolute return for an interval immediately following a macroeconomic announcement will be high and the very effect that is to be investigated is filtered away. There are, of course, further alternative methods available for eliminating the intraday periodicity. For example, Gençay et al. (2001) use a method based on a wavelet multi-scaling approach. We do not pursue such further alternatives here.

chosen for the simultaneous modelling of the regular intraday periodicity in exchange rate volatility and the effects of calendar and scheduled macroeconomic announcement events. The augmented FFF specification is defined as follows:

$$E[\log s_{t,n}] = m_1 + \sum_{q=1}^{Q}\left(d_{\cos,q} \cdot \cos\frac{q2p}{N} n + d_{\sin,q} \cdot \sin\frac{q2p}{N} n\right) + \sum_{k=1}^{K} l_k \cdot I_{k,t,n} \,. \tag{4}$$

This expression is non-linear in the intraday time interval, n, parameterised by a number of sinusoids that occupy precisely one day. During periods of daylight saving time (DST) the sinusoids are translated leftwards by one hour using a time deformation procedure. The tuning parameter Q refers to the order of expansion, and μ_0, $?_k$, $d_{cos,q}$ and $d_{sin,q}$ are the fixed coefficients to be estimated.[13] Second, and in order to appraise the robustness of the results to the choice of the FFF intraday periodicity filter, the analysis is replicated using an alternative cubic spline specification previously utilized by Engle and Russell (1998), Zhang et al. (2001), Taylor (2004a,b) and Giot (2005). This alternative method allows different cubic spline functions to be estimated between selected points (termed 'knots') in the periodic cycle, such as the various market opening and closing times in the twenty-four hour foreign exchange trading cycle, and offers the potential to more closely match the fitted intraday periodic pattern with the known times of opening and closing on those markets. As recently advocated by Taylor (2004a, b), a series of third order polynomials are therefore fitted between clearly defined 'knots' during the day:

[13] Empirically, and consistent with results reported in Andersen and Bollerslev (1998), $Q=4$ is selected based on the significance of estimated coefficients, the Akaike Information Criteria (AIC) and the success of the model in fitting the intraday volatility pattern.

$$E[\log s_{t,n}] = m_1 + \sum_{m=1}^{M}\left[a_{1,m}D_m\left(\frac{n-l_m}{N}\right) + a_{2,m}D_m\left(\frac{n-l_m}{N}\right)^2 + a_{3,m}D_m\left(\frac{n-l_m}{N}\right)^3\right] + \sum_{k=1}^{K} l_k \cdot I_{k,t,n}\,, \tag{5}$$

where l_m denotes the interval of the day in which knot m ($m=1,2,\ldots,M$) is placed, and these are chosen a priori based on the underlying intraday pattern, where D_m are dummy variables taking the value 1 if $n=l_m$ and 0 otherwise and $a_{1,m}$, $a_{2,m}$ and $a_{3,m}$ are coefficients to be estimated.[14]

The $I_{k,t,n}$ regressors in equations (4) and (5) are indicator dummy variables for an event k occurring during interval n on day t associated with weekdays, holidays and other calendar related characteristics. Simple dummy variables are included for each day of the week to account for any potential systematic weekly patterns in exchange rate volatility, and a similar simple dummy is included to allow for systematically higher volatility during DST. Amongst the remaining simple indicators which relate to intraday events, holiday dummies refer to regional holidays that cause volatility slowdowns but still provide reliable returns, in the sense that they only affect the portion of the trading day corresponding to the trading activity of the financial centre affected by the holiday.

Further time related characteristic dummies refer to volatility jumps at the opening of markets in Tokyo and Hong Kong, Singapore and Malaysia, and volatility slowdowns surrounding weekends, especially during periods of DST. To account properly for these more complex intraday effects, whilst maintaining the smooth cyclical periodicity of the intraday

[14] In light of the twenty-four hour intraday volatility pattern, there are five knots imposed in total ($M=5$). The first knot is positioned at interval 0 (21:00 GMT), $l_1=0$, corresponding to the start of the trading day, and $l_2=36$ (00:00 GMT) such that the second knot corresponds to the opening of markets in Tokyo. A cubic spline is therefore fitted to the volatility pattern between the opening of trading in Sydney and Tokyo demonstrating that the knots are not chosen arbitrarily, but are chosen to reflect the geographical nature of the foreign exchange market that drives the distinctive intraday volatility pattern. Thus $l_3=96$ (5:00GMT) in winter to capture the volatility slowdown before the onset of early trading in Europe and this is shifted leftwards by one hour during DST ($l_3=84$ corresponding to 4:00 GMT). Similarly, $l_4=132$ during winter and $l_4=120$ during DST (8:00 and 7:00 GMT, respectively) to position the fourth knot at the volatility peak occurring at the overlap of trading in Japan, Europe and the UK, and finally, $l_5=216$ in winter and 204 in DST (15:00 and 14:00 GMT) at the highest point of the intraday pattern.

volatility pattern, a polynomial structure is imposed on the volatility response for these events. As argued by Andersen et al. (2003), the use of lower ordered polynomials constrains the volatility response in helpful ways: by promoting parsimony, by retaining flexibility of approximation and by facilitating the imposition of sensible constraints on the response pattern. In full generality, if an event affects volatility from time t_0 to time t_0+O, the impact on volatility can be represented over the event window $t=0,1.....O$ by $l_k(t) = l_k \cdot p(t)$ using the polynomial $p(t) = j_0 + j_1 t + ... + j_P t^P$. Specifically, enforcing $p(0)=0$ ensures there is no jump in volatility away from the underlying intraday pattern and $p(O)=0$ enforces the requirement that the impact effect slowly fades to zero. The latter constraint gives the alternative polynomial: $p(t) = j_0[1-(t/\Omega)^P] + ... + j_1 t[1-(t/\Omega)^{P-1}] + j_{P-1} t^{P-1}[1-(t/\Omega)]$.[15] Finally, and given the finding in previous research that foreign exchange markets are highly responsive to US macroeconomic announcements, initial controls are also introduced for the average impact of all US macroeconomic announcements on each of the bilateral exchange rates analyzed.[16] Thereafter, in order to analyse individual US news releases, the

[15] Based on close inspection of the data and the underlying intraday patterns, the Tokyo opening effect is afforded a linear response (*P=1*) beginning at 00:05 GMT and lasting until 00:30 GMT (*O=6*) with the effect fading to zero at 00:35 GMT (*p(O)=0*). Identical structure applies to the Hong Kong, Singapore and Malaysia opening effect but the effect begins an hour later at 01:05 GMT. To account for a Monday morning slowdown, when traders in Sydney and Wellington are the only participants active in the market, a second order polynomial (*P=2*) is imposed from 21:05 GMT to 23:00 GMT (*O=23*) with the restriction that *p(O)=0*. Similarly, a Friday night slowdown, when US traders are the only active group, is also modelled by a second order polynomial. Based on the plots in Figure 1, this effect begins at 17:05 GMT in winter time and lasts until 21:00 GMT (*O=47*) with the start of the effect shifted by one hour to 16:05 GMT (*O=59*) during DST. For this polynomial the restriction that *p(0)=0* ensures that there is no step away from the intraday pattern at the impact of the event. The leftward shift of the intraday pattern by one hour during DST gives rise to a hiatus between the close of trading in the US and the opening of trading in Wellington and this is accommodated for by a second order polynomial for each day during DST beginning at 19:05 GMT and lasting until 21:00 GMT (*O=23*) with the restrictions *p(O)=0* and *p(0)=0* imposed. The final calendar effect is a winter slowdown which occurs for EUR-USD only, whereby volatility tends to be lower in the early part of the trading day and this effect is accounted for by a second order polynomial beginning at 21:05 GMT on days during winter time lasting until 00:00 GMT (*O=35*). The effect of the winter slowdown polynomial is restricted to reach zero at 00:00 GMT *(p(O)=0)*.

[16] More specifically, and following the findings of Andersen and Bollerslev (1998), Andersen et al. (2000) and Bollerslev et al. (2000), the average volatility dynamics in response to macroeconomic news announcements are approximated by a third order polynomial restricted to equal zero at the end of the response horizon, as represented by *P=3* and *O=12*. Each announcement has a fixed response horizon of one hour (*O=12*) except interest rate announcements from the FOMC and the Employment Report, which are afforded a two hour horizon based on visual inspection of plots of their influence. To calculate this elongated two hour response whilst retaining the benchmark pattern, the *t* variable is allowed to progress only by a (12/24) fraction of a unit per five-

announcement in question is removed from the control group and allowed to appear as a separate indicator variable regressor in equations (4) and (5), as is the general case for the investigation of non-US macroeconomic announcements.

4. Empirical Results

The relative empirical success of the intraday volatility models described in the preceding section in modelling the intraday periodicity in exchange rate volatility may be readily judged by comparing the fitted patterns to the corresponding sample average patterns.[17] Figure 1 therefore shows the fitted and average actual intraday log-volatility pattern for each currency pairing, for the FFF method in the left hand panels and the alternative cubic spline method in the right hand panels.[18] The smooth cyclical nature of the FFF pattern is clearly evident in the left hand panel plots, and captures the rise in volatility when Sydney, Wellington and Tokyo traders are active, then a decline through the afternoon in Tokyo before rising again as European traders commence trading. The slowdown in volatility in the morning in the UK and Europe is also apparent, along with a subsequent increase to a peak when UK and US trading activity overlaps and then a steady decline through the US afternoon. The Tokyo market opening effect at 00:00 GMT and the effect of the opening of markets in Hong Kong, Singapore and Malaysia one hour later are also clearly shown, being particularly pronounced for EUR-JPY. Superimposing the sample average log volatility pattern onto the fitted patterns

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minute interval, rather than a full unit. This time deformation technique stretches the event time scale so that it conforms to the desired horizon. The response pattern is then fixed according to these estimates, leaving $?_k$ as the only free parameter to be estimated, which measures the degree to which the event loads onto this pattern.

[17] Coefficient estimates and their associated robust *t* statistics for equation (3) in conjunction with the FFF and cubic spline approaches to modelling the intraday volatility pattern given by equations (4) and (5), respectively, are suppressed here in the interests of brevity but are available from the authors on request. Since there is little economic interpretation to be gained from these parameter estimates, they are not discussed further in the text, and we focus instead on the more easily interpreted plots of the actual and fitted log-volatility series and concentrate our discussion on the primary issue of interest, namely the volatility response to macroeconomic announcements.

[18] The log-volatility patterns illustrated are for winter time GMT only in order to ease diagrammatic comparison, the plots for summer time for EUR-USD and EUR-GBP being shifted rightwards by one hour and exhibiting slightly elevated volatility, but are otherwise identical qualitatively.

in Figure 1 clearly reveals the relative success of the models in capturing the intraday volatility dynamics, and the fit is good for all currency pairs.

The corresponding patterns for the cubic spline intraday models in the right hand panels are in general very similar but, with the flexibility of the positioning of the knots, an advantage of the cubic splines over FFF is that it does not necessarily impose a smooth pattern on intraday volatility but allows sharp peaks and troughs. A clear example is the peak during morning trading in Europe and the UK. Although the sharpness of this peak does not diverge greatly from the FFF pattern, this feature may be of more critical importance at times when the position of the knot at this peak coincides with a macroeconomic news announcement. The fit is particularly good for EUR-USD and EUR-JPY, whilst the EUR-GBP patterns show wider dispersion. Whilst both the FFF and cubic spline functions show accurate fits, the cubic spline patterns appear to fit marginally better at the knot positions. The actual log volatility patterns in Figure 1 also provide some initial evidence of the influence of scheduled macroeconomic news announcements on volatility. The first plot in the first column of Figure 1, for example, shows clear spikes for EUR-USD volatility during intervals ending at 12:35, 13:35, 14:05 and 15:05 GMT, times that correspond exactly with regularly scheduled announcements of US macroeconomic indicators at 8:30 and 10:00 Eastern Standard Time (EST).

In order to assess the relative importance of each individual macroeconomic announcement, and as described in the previous section, the average effect of all US macroeconomic announcements are controlled for throughout while estimating the marginal impact of the release under investigation.[19] In the case of assessing a US macroeconomic

[19] Specifically, the third-order polynomial representation of the volatility pattern following a US macroeconomic announcement is determined by $p(t) = j_0[1-(t/12)^3] + j_1 t[1-(t/12)^2] + j_2 t^2[1-(t/12)]$ for $t = 0,1,2,...,12$. This pattern is calibrated by fitting the three polynomial parameters for the 37 US announcements combined in equations (4; FFF) and (5; CS) under the restriction ?=1, for each of the three bilateral exchange rates relative to the EUR. The resulting estimates for (j_0, j_1, j_2) are: USD-FFF (1.2206,-

announcement, the release in question is removed from the control group in the empirical estimation of the average effect of all US announcements. Tables 1 to 3 report the resulting coefficient estimates, robust t statistics, the percentage instantaneous jump in volatility, and the cumulative effect on volatility over the response horizon as a percentage of the median daily cumulative absolute returns for all statistically significant announcements.[20] These significant announcements are ordered in the tables by their contribution to daily returns variability. The instantaneous jump in volatility is measured by $[\exp(\hat{l}_k \cdot p(0)/2) - 1]$, the volatility response at the t-th lag is calculated as $[\exp(\hat{l}_k \cdot p(t)/2) - 1]$ and the cumulative response over the event horizon is given by $\sum_{t=0,\Omega} [\exp(\hat{l}_k \cdot p(t)/2) - 1]$, where $p(t)$ is the predetermined volatility response pattern.

Table 1 shows clearly the dominance of US announcements in impacting EUR-USD volatility. Of the total 132 individual international macroeconomic announcements analyzed here, under the FFF model 15 of the 25 significant announcements (or 60%) emanate from the US, while for the cubic spline model 19 of the 29 significant announcements (or 66%) are from the US. Interest rate decisions announced by the FOMC are by far the most important announcement, causing the largest instantaneous jump in volatility measuring 815% and 835% for the FFF and cubic spline patterns, respectively, with the associated cumulative

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0.4166, 0.0555), USD-CS(1.2498, -0.4093, 0.0543); GBP-FFF(0.6387, -0.1043, 0.0048), GBP-CS(0.6625, -0.1100, 0.0065); JPY-FFF(0.6994, -0.2199, 0.0304), JPY-CS(0.7224, -0.2258, 0.0319).

[20] Significant announcements are selected as those reporting a loading parameter statistically greater than zero at the 5% level under the alternative to the null hypothesis of a zero loading coefficient of a non-zero coefficient at asymptotic significance levels using t-statistics generated using robust standard errors; see Tables 1-3. Whilst not presented here in full, the results of an alternative version of the model in which absolute mean-adjusted returns are standardised using the sample mean of $\hat{s}_{t,n}$, and which thus ignores any temporal variation in this volatility factor, have also been considered. Whilst this version of the model does nothing to alleviate heteroscedasticity at the daily frequency, it ensures that there is no practical generated regressors problem, which may exist when using $\hat{s}_{t,n}$. The parameter estimates are largely unchanged and the qualitative features of the inference unaffected, so the use of $\hat{s}_{t,n}$ does not, therefore, seem to give rise to a generated regressors problem. As a further robustness check, estimation results for both these versions of the model that uses $\hat{s}_{t,n}$ as the daily volatility factor generated from an orthodox MA(1)-GARCH(1,1) model, rather than its fractionally integrated counterpart, have also been considered. Again, parameter estimates and inferences are similar to those reported in the tables, and confirm that the intraday features described in the text are not influenced by the choice of the daily volatility measure.

responses calculated as 12.79% and 13.75% of daily volatility. The sample includes a period when monetary policy authorities were lowering interest rates and when interest rate announcements were surrounded by great uncertainty, making the timing of decisions to cut interest rates and the magnitude of the cuts very difficult to predict. In confirmation of the previous findings of Ederington and Lee (1993), Payne (1996), Andersen and Bollerslev (1998), Bollerslev et al. (2000) and Andersen et al. (2003), the Employment Report is also an important indicator, causing immediate jumps in volatility of 373% and 393% for FFF and cubic spline versions, respectively, with the associated cumulative response measures of 9.33% and 10.28% of the median daily cumulative absolute return, respectively. GDP figures are also crucial with the earlier Advance figures causing a more violent response than the Preliminary figures suggesting that traders learn from the Advance figures and are able to produce more accurate forecasts for the later Preliminary data.

Among the remaining significant announcements, the US Trade Balance features very prominently, confirming the previous findings of Ederington and Lee (1993), Payne (1996), Andersen and Bollerslev (1998) and Andersen et al. (2003), but the remaining important US announcements are dominated by forward looking indices such as the Philadelphia Federal Reserve Index, the University of Michigan Sentiment Index (Preliminary and Final) and Chicago PMI. Aside from their economic content and forward looking nature, these indices are released very early and are typically the first indicators for a particular month that traders will see, so it is perhaps not surprising that they are such important drivers of volatility. However, and contrary to previous findings that document the greater importance of more traditional economic announcements (such as PPI, Durable Goods Orders, Retail Sales, CPI and Initial Claims for State Unemployment Benefits), it would seem that the informational content and timing of these forward looking indicators make them a more important source of EUR-USD volatility.

Macroeconomic announcements from Europe combined (EU, UK, Germany, France) account for half as many significant instances as for the US, numbering 7 (28%) and 9 (31%) for the FFF models and cubic spline models respectively. The most important announcements for EUR-USD volatility emanating from European countries are the ECB monetary policy decision for the Eurozone, German IFO Business Expectations Survey, provisional GDP for the UK and French Non-Farm Payrolls. The more general lack of significant European announcements (particularly relating to GDP, trade and inflation data) confirms that US announcements generate a more vigorous EUR-USD exchange rate volatility response.

Considering Table 2, there is an increased presence and importance of UK and European announcements in driving EUR-GBP volatility compared to EUR-USD. Of the statistically significant macroeconomic data releases identified for EUR-GBP volatility, for the FFF model 7 (32%) of the 21 significant cases relate to the US while 14 (64%) relate to Europe combined, 6 of these pertaining to the EU, 3 to the UK, and 4 to Germany. Additionally, BOJ Monetary Policy provides the only significant Japanese release. These results are very similar for the cubic spline model, where 8 (36%) of the 22 significant instances relate to the US and 13 (59%) to Europe combined, the latter comprising of 5 releases from the EU, 4 from the UK, 3 from Germany and 1 from France (and 1 from Japan). Nevertheless, US interest rate announcements by the FOMC are again predominant with an instantaneous jump in volatility of 350% and 362% for the FFF and cubic spline versions, respectively, and cumulative response impacts of 6.89% and 7.38% of the daily level, which are approximately half of the corresponding measures for EUR-USD. The Employment Report is again the second quantitatively most important releases and generates incremental instantaneous volatility increases of 200% and 213% and cumulative responses of 6.42% and 7.11% of daily volatility for the FFF and cubic spline models, respectively, again more muted reactions than for EUR-USD. ECB interest rate announcements, however, generate a larger proportionate volatility reaction for EUR-GBP than EUR-USD, contributing 3.12% and 3.14% of daily EUR-GBP volatility for FFF and cubic splines, respectively, compared to 2.79% to 2.91% for EUR-USD. UK Industrial Production and the US GDP Advance are the next most important announcements for EUR-GBP. UK Final GDP and Retail Sales (but, perhaps surprisingly, not UK MPC interest rate decisions)[21] are the other prominent significant UK releases. Eurozone and German GDP and PPI announcements, and EU Labour Costs Revised, are also significant and fairly highly ranked, showing that these more orthodox economic fundamentals are also important sources of EUR-GBP volatility. Perhaps the only surprising omissions from these lists are Balance of Payments and/or Current Account data releases.

Table 3 lists the significant announcements for EUR-JPY. Again, US news has a strong influence on EUR-JPY, with 9 of the 21 significant announcements for the FFF model and 20 for the cubic spline model (43% and 45% respectively) emanating from the US, whilst only 3 significant releases are from Japan, with the remaining significant announcements coming from Europe combined. Although FOMC interest rate announcements cause the largest instantaneous jumps in EUR-JPY volatility (309% and 324% for the FFF and cubic spline models, respectively), the Employment Report contributes the largest percentage cumulative responses (4.89% and 5.39% of daily volatility, respectively). Japanese GDP is the only highly ranked Japanese announcement, but as the third largest cumulative response it causes vigorous movements in EUR-JPY, the incremental instantaneous volatility reactions measuring 255% and 219% and the cumulative response calculated as 2.21% and 2.02% for FFF and cubic splines, respectively. ECB interest rate announcements also feature very

[21] Whilst UK Monetary Policy Committee interest rate decision announcements are not statistically significant at the conventional asymptotic 5% level on a two-tailed test and are therefore excluded from Table 2, they are quantitatively important, yielding incremental instantaneous volatility increases of 80% and 70% and cumulative responses of 1.54% and 1.42% of daily volatility for the FFF and cubic spline models, respectively. The only other similar exclusion from Table 2 is US GDP Preliminary, which whilst again statistically insignificant is associated with incremental instantaneous volatility increases of 86% and 87% and cumulative responses of 1.63% and 1.73% of daily volatility for the FFF and cubic spline models, respectively. There are no such similar exclusions from Table 1.

prominently, and far more so than BOJ Monetary Policy announcements. Amongst the remaining significant announcements, once again, releases of forward looking economic surveys cause larger volatility reactions than news about more traditional economic fundamentals, but the latter notably include a range of European indicators, including Eurozone Trade Balance.[22]

Finally, comparison of the alternative econometric techniques for capturing the inherent intraday volatility pattern yields further information concerning the robustness of the results described above, and for the econometric modelling of the reaction of volatility to macroeconomic news announcements more generally. Most obviously, there is much agreement between the results obtained using the FFF and cubic spline models concerning the macroeconomic announcements which cause statistically significant responses in exchange rate volatility. That is, the two methods are in agreement concerning 22 of the maximum possible 29 significant announcements for EUR-USD, 20 of the possible 22 cases for EUR-GBP, and 19 of the maximum possible 21 cases for EUR-JPY. The results reported are therefore highly robust to the choice of intraday volatility periodicity modelling, in the sense of identifying statistically significant announcement effects. However, these different specifications for the intraday pattern produce different volatility response patterns that give rise to striking differences in the instantaneous and cumulative response measures. The discrepancy is sufficiently large in many cases that ordering the announcement effects by their cumulative responses ranks the releases in different sequences of importance. Moreover, whilst allowing response patterns to vary between the intraday models, measures obtained form the FFF approach tend to understate those generated by the cubic spline specification.

[22] It is also of note that, whilst marginally statistically insignificant and therefore excluded from Table 3, US Trade Balance and US Current Account announcements cause sizeable instantaneous volatility responses. For the trade Balance, the incremental instantaneous volatility increase is of the order of 66% and 58%, and the cumulative response is 1.07% and 0.932% of daily volatility, for the FFF and cubic spline models, respectively. The US Current Account is associated with incremental instantaneous volatility increases of 64% and 60% and cumulative responses of 1.04% and 0.95% of daily volatility for the FFF and cubic spline models, respectively.

This is exemplified by the entries in Table 1 for the effect of the forward-looking German IFO Business Expectations survey announcement for EUR-USD volatility, which differs between the two models. Under the FFF paradigm, this announcement causes the seventh largest cumulative volatility response calculated as 2.62% with an instantaneous volatility jump of 223%. For the cubic spline approach, however, this same announcement generates the fifth largest cumulative volatility response measuring 3.14% at the daily level and corresponding to an incremental instantaneous volatility response of 267%. This discrepancy between the volatility response measures also holds more generally, with the FFF model results understating the percentage cumulative volatility response compared to the cubic spline model almost all cases in Tables 1-3. Thus, whilst the identification of significant macroeconomic announcements for exchange rate volatility is not sensitive to the choice of intraday volatility specification, the quantification of that volatility response is sensitive to that choice.

5. Conclusions

This paper has sought to provide a comprehensive characterisation of Euro exchange rate volatility, focusing on the volatility response to a range of international macroeconomic announcements. The paper contributes to the literature in several ways. First, it uses five-minute bid-ask quotes of the Euro against the US Dollar, UK Pound sterling and Japanese Yen, which constitutes a new market that has yet to be investigated. Second, it considers a far wider range of announcements across countries and economic conditions than has been considered hitherto in the literature, and against a turbulent economic and geopolitical background. Third, the complexity of the volatility response to individual macroeconomic announcements is assessed through volatility response functions rather than the significance of simple dummy variables for categories of announcement type as typically applied in the previous literature. Fourth, the empirical methodology which permits simultaneous modelling of these announcement effects together with long-memory features and intra-day periodicity utilizes two approaches to the modelling of the latter, namely the conventional FFF approach and an alternative method using cubic splines.

The largest reactions of volatility across the three exchange rates are found to occur in response to US announcements. In a sample period of poor global economic performance, the decisions of the FOMC regarding US interest rates generate the largest instantaneous jumps in volatility and often the largest cumulative response over the period immediately following the announcement. Interest rate decisions by the ECB also feature prominently showing that monetary policy decisions are an important source of exchange rate volatility over the sample, which may have been confounded during the sample period by the ECB's monetary policy reactions being difficult to predict accurately. In confirmation of previous studies, indicators of real activity such as the US Employment Report and GDP also cause dramatic price reactions, whilst similar measures for the UK (including UK Industrial Production), Eurozone, Germany and Japan are among the highest ranking non-US announcements. The US Trade Balance is also found to be important, causing a larger EUR-USD reaction than US inflation data. Aside from such traditional macroeconomic information, forward looking indicators and regional economic surveys are found to play a crucial and interesting role. These releases include the Philadelphia Federal Reserve Index, University of Michigan Consumer Sentiment Index, Chicago Purchasing Managers Index, Consumer Confidence Index and Institute of Supply Management Index for the US, and the IFO Business Expectations Index for Germany. The timing of these announcements is such that they are the first indicators of macroeconomic performance for a particular month that traders observe, and such releases are therefore likely to generate larger price reactions. By learning from this early information, subsequent announcements pertaining to the same month can be forecast with greater accuracy, such that subsequent announcements cause smaller deviations from expectations and hence do not cause such dramatic volatility movements.

There are several possible avenues for further research. The data sample used in this study are of particular interest covering a period of economic turbulence, geopolitical tension and episodes of monetary policy easing. However, it would be appealing to extend the sample to cover different phases of the business cycle in order to analyse whether markets react symmetrically to good and bad news and whether this reaction is symmetric during economic expansions and contractions. Given the importance of those identified monetary policy reactions, it would also be interesting to relate any asymmetric news effects to the reaction functions of monetary policy authorities. Finally, in the context of realised volatility models, the econometrics of quantifying and explaining volatility 'jumps' represent an innovative area of empirical finance research and, given the findings reported here, the contribution of such 'jumps' to total volatility is arguably linked to macroeconomic announcements and news.

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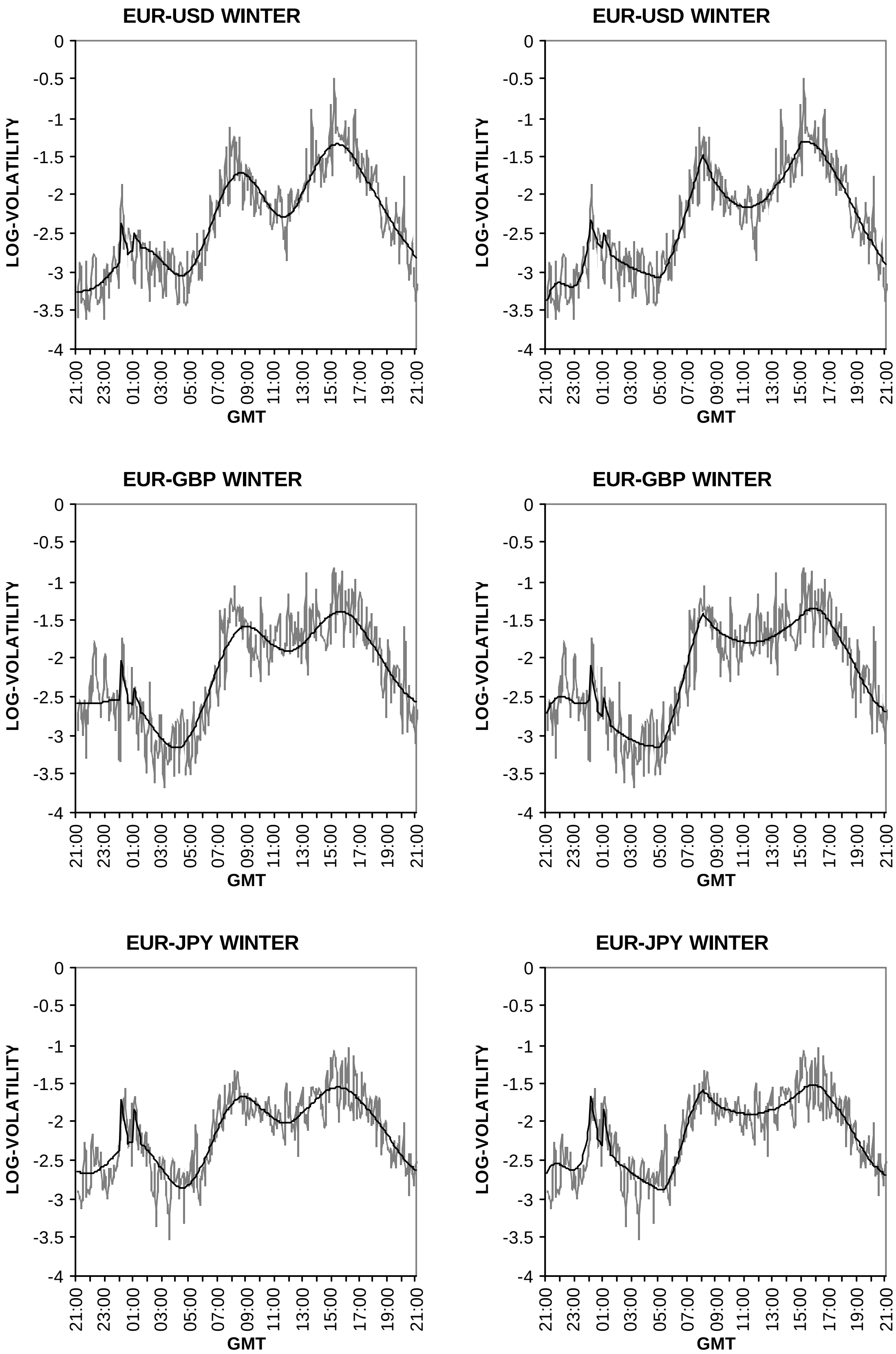
Figure 1. Actual and Fitted Intraday Log-Volatility Patterns.



Notes: The left-hand panels depict the actual and fitted intraday log-volatility patterns modelled using the FFF method, while the right hand panels show the corresponding results for the cubic spline method.

Table 1. Significant Macroeconomic Announcement Effects for EUR-USD Volatility

FFF Model

ANNOUNCEMENT	C'TRY	COEFF	ROB.T	%JUMP	% DAY
FOMC Fed. Funds	US	3.63	5.78	815.43	12.79
Employment Report	US	2.55	7.68	373.14	9.33
GDP Advance	US	2.31	3.11	308.61	4.49
GDP Preliminary	US	1.68	3.18	178.77	2.85
ECB Interest Rate	EU	1.82	4.40	204.30	2.79
Trade Balance	US	1.59	4.97	163.75	2.65
IFO Business Expectations	GER	1.95	5.89	227.90	2.62
Philadelphia Fed. Index	US	1.90	5.59	219.39	2.54
Michigan Sentiment Prelim.	US	1.54	5.45	155.57	2.54
Industrial Production	US	1.52	4.72	153.54	2.51
Chicago PMI	US	1.26	3.06	115.65	1.96
Non Farm Payrolls Final	FRA	1.51	3.58	151.53	1.86
Consumer Confidence	US	1.16	3.56	102.83	1.77
GDP Provisional	UK	1.38	3.75	132.34	1.66
PPI	US	1.02	3.59	86.60	1.52
Michigan Sentiment Final	US	0.96	2.14	79.71	1.41
New Home Sales	US	0.89	3.14	71.76	1.29
Durable Goods Orders	US	0.81	1.97	63.78	1.16
Halifax House Prices	UK	1.06	3.00	90.68	1.07
Current Account	FRA	0.88	3.25	71.36	0.96
GDP	JAP	1.11	1.99	97.45	0.85
Industrial Production	EU	0.89	2.51	72.19	0.81
Initial Claims	US	0.55	2.73	39.48	0.74
Retail Sales	JAP	0.99	2.00	82.87	0.73
M2	JAP	0.94	2.27	77.87	0.69

Cubic Spline Model

ANNOUNCEMENT	C'TRY	COEFF.	ROB.T	%JUMP	%DAY
FOMC Fed. Funds	US	3.58	5.99	834.98	13.75
Employment Report	US	2.55	8.02	392.72	10.28
GDP Advance	US	2.31	3.12	324.02	4.92
GDP Preliminary	US	1.71	3.33	191.32	3.18
IFO Business Expectations	GER	2.08	6.56	266.69	3.14
Trade Balance	US	1.61	5.08	173.67	2.93
ECB Interest Rate	EU	1.77	4.45	201.79	2.91
Industrial Production	US	1.57	4.96	166.70	2.83
Michigan Sentiment Prelim.	US	1.47	5.33	151.36	2.61
Philadelphia Fed. Index	US	1.76	5.29	200.13	2.48
GDP Provisional	UK	1.51	4.15	157.64	2.03
Chicago PMI	US	1.17	2.93	107.96	1.95
Current Account	US	1.06	1.98	94.51	1.73
PPI	US	1.05	3.77	93.17	1.71
Consumer Confidence	US	1.05	3.29	92.49	1.70
Non Farm Payrolls Final	FRA	1.18	2.95	109.56	1.48
Durable Goods Orders	US	0.91	2.30	76.30	1.43
Michigan Sentiment Final	US	0.89	2.04	73.96	1.39
Retail Sales	US	0.87	1.98	71.93	1.36
ISM Non Manufacturing	US	0.84	2.34	68.64	1.30
New Home Sales	US	0.79	2.83	63.39	1.21
M3	EU	0.85	2.30	70.13	1.00
Initial Claims	US	0.65	3.35	50.20	0.98
Halifax House Prices	UK	0.89	2.58	73.86	0.94
Consumer Confidence	JAP	0.77	2.15	61.59	0.89
CPI	US	0.54	2.09	40.04	0.79
Retail Sales	UK	0.69	2.14	54.28	0.79
Industrial Production	EU	0.73	2.19	58.28	0.70
Current Account	FRA	0.59	2.18	44.61	0.66

Table 2. Significant Macroeconomic Announcement Effects for EUR-GBP Volatility

FFF Model						Cubic Spline Model					
ANNOUNCEMENT	**C'TRY**	**COEFF**	**ROB.T**	**%JUMP**	**%DAY**	**ANNOUNCEMENT**	**C'TRY**	**COEFF.**	**ROB.T**	**%JUMP**	**%DAY**
FOMC Fed. Funds	US	4.71	5.15	350.30	6.89	FOMC Fed. Funds	US	4.62	5.28	361.53	7.38
Employment Report	US	3.44	5.30	199.51	6.42	Employment Report	US	3.45	5.63	213.08	7.11
ECB Interest Rate	EU	2.86	3.64	149.01	3.12	ECB Interest Rate	EU	2.68	3.58	143.17	3.14
GDP Advance	US	2.89	3.14	151.46	2.71	Industrial Production	UK	2.93	5.59	163.93	3.04
Industrial Production	UK	2.79	5.15	143.84	2.59	GDP Advance	US	2.83	3.11	155.46	2.90
Michigan Sentiment Prelim.	US	2.51	4.30	123.02	2.25	Michigan Sentiment Prelim.	US	2.41	4.27	122.42	2.35
Michigan Sentiment Final	US	2.19	2.68	101.39	1.89	GDP Final	UK	2.39	3.86	120.90	2.32
GDP Final	UK	2.19	3.50	101.32	1.89	IFO Business Expectations	GER	2.31	3.38	115.06	2.22
IFO Business Expectations	GER	2.13	3.00	97.19	1.82	Michigan Sentiment Final	US	2.15	2.70	103.58	2.02
GDP Preliminary	EU	2.25	3.39	105.32	1.76	Retail Sales	UK	2.10	2.92	100.18	1.96
Labour Costs Revised	EU	2.23	2.09	103.99	1.74	Labour Costs Revised	EU	2.11	2.07	101.47	1.78
Retail Sales	UK	1.92	2.57	84.86	1.61	GDP Preliminary	EU	2.04	3.08	96.37	1.70
PPI	GER	2.11	3.94	96.17	1.50	Industrial Production	US	1.75	2.43	78.51	1.57
GDP	GER	2.03	1.99	91.35	1.44	Non Farm Payrolls Prelim.	FRA	1.88	2.20	86.44	1.43
Industrial Production	US	1.57	2.08	64.95	1.26	PPI	GER	1.77	3.34	79.90	1.33
ISM Non Manufacturing	US	1.50	2.07	61.62	1.20	M3	EU	1.52	2.59	65.19	1.32
COL Final	GER	1.64	2.78	68.98	1.11	BOJ Monetary Policy	JAP	2.05	2.30	97.01	1.27
M3	EU	1.29	2.15	51.08	1.01	ISM Non Manufacturing	US	1.46	2.08	62.02	1.26
HCPI	EU	1.39	2.37	56.08	0.99	CIPS Services	UK	1.34	2.06	55.88	1.15
PPI	EU	1.30	1.99	51.32	0.91	HCPI	EU	1.26	2.35	52.00	0.97
BOJ Monetary Policy	JAP	1.16	1.97	45.00	0.60	COL Final	GER	1.34	2.34	56.12	0.96
						Initial Claims	US	0.70	2.01	25.90	0.55

Table 3. Significant Macroeconomic Announcement Effects for EUR-JPY Volatility

FFF Model						Cubic Spline Model					
ANNOUNCEMENT	**C'TRY**	**COEFF**	**ROB.T**	**%JUMP**	**%DAY**	**ANNOUNCEMENT**	**C'TRY**	**COEFF.**	**ROB.T**	**%JUMP**	**%DAY**
Employment Report	US	3.10	5.50	195.19	4.89	Employment Report	US	3.14	5.84	210.41	5.39
FOMC Fed. Funds	US	4.03	4.45	309.02	4.71	FOMC Fed. Funds	US	4.00	4.65	324.11	5.06
GDP	JAP	3.63	5.30	255.38	2.21	GDP	JAP	3.21	5.04	219.31	2.02
Philadelphia Fed. Index	US	2.56	5.30	144.84	2.07	Philadelphia Fed. Index	US	2.35	5.04	133.83	2.00
ECB Interest Rate	EU	2.04	2.96	104.13	1.81	ECB Interest Rate	EU	1.96	2.98	103.03	1.86
COL Final	GER	2.46	3.95	136.52	1.64	Durable Goods Orders	US	1.99	3.54	105.24	1.62
Michigan Sentiment Final	US	1.96	2.54	98.12	1.48	GDP Preliminary	US	1.90	3.05	98.90	1.54
Durable Goods Orders	US	1.91	3.25	95.05	1.44	Industrial Production	UK	1.90	3.44	98.72	1.53
GDP Preliminary	US	1.86	2.90	91.67	1.39	Michigan Sentiment Final	US	1.88	2.52	97.08	1.51
Michigan Sentiment Prelim.	US	1.81	3.15	88.39	1.35	COL Final	GER	2.13	3.50	115.49	1.47
Non Farm Payrolls Final	FRA	2.08	2.67	106.86	1.33	Michigan Sentiment Prelim.	US	1.79	3.21	90.96	1.43
Industrial Production	UK	1.72	2.97	82.58	1.27	IFO Business Expectations	GER	1.57	2.00	76.00	1.22
Existing Home Sales	US	1.49	2.13	68.18	1.07	Non Farm Payrolls Final	FRA	1.75	2.29	87.89	1.15
Trade Balance	EU	1.49	3.73	68.23	1.00	Existing Home Sales	US	1.44	2.15	68.08	1.10
BOJ Monetary Policy	JAP	1.71	2.18	81.99	0.84	Trade Balance	EU	1.23	3.23	56.09	0.86
Industrial Production	EU	1.27	2.38	55.94	0.83	BOJ Monetary Policy	JAP	1.65	2.18	81.31	0.86
Consumer Confidence	US	1.15	2.18	49.47	0.80	Consumer Confidence	US	1.03	2.03	45.22	0.76
PPI	GER	1.30	2.93	57.45	0.76	Industrial Production	EU	1.06	2.07	46.43	0.73
M2	JAP	1.37	2.44	61.42	0.65	PPI	GER	0.94	2.11	40.42	0.57
Household Consumption	FRA	1.12	2.24	48.12	0.65	M2	JAP	1.11	2.02	49.12	0.55
Trade Balance	JAP	1.33	2.12	59.29	0.63						