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Dynamic News Effects in High Frequency Euro Exchange Rate Returns and Volatility

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Abstract

Investigation of the dynamic, short-run response of exchange rate returns to the information surprise of macroeconomic announcements reveals that US macroeconomic news generates far more dramatic responses in exchange rate returns and returns volatility than news on the macroeconomic performance of other countries. Eurozone, German, French and Japanese news have very little impact. However, some UK announcements are important for the EUR-GBP rate. The reaction of exchange rate returns to news is very quick and occurs within the first five minutes of the release with very little reaction in the following fifteen minutes, thus enabling us to characterise such reactions as conditional mean return jumps. These jumps show that exchange rates are strongly linked to fundamentals in the five-minute intervals immediately following the data release. Interestingly, despite causing large responses in returns volatility, the large jumps in returns following interest rate decisions do not appear to be correlated with the informational innovation surrounding their announcement.

Keywords: Intraday volatility; macroeconomic announcements; exchange rates
JEL: G12, E44, E32

1. Introduction

The theory of efficient markets contends that financial asset prices should completely and instantaneously reflect public information, implying that price changes should respond quickly to news regarding movements in the underlying economic fundamentals. However, the apparent difficulty in empirically mapping economic fundamentals to asset prices is remarkable. Indeed, some empirical studies have gone so far as to suggest that exchange rates and fundamentals are largely disconnected (Meese and Rogoff, 1983). This conclusion has spurred a substantial literature that has re-examined this issue, but more than twenty years later, evidence that fundamentals have predictive content for exchange rate movements remains elusive. [1]

Despite the apparent lack of predictive power of fundamentals for asset prices, the largest absolute intraday asset returns are closely linked to the release of macroeconomic news. Such spectacular surges in volatility are short-lived and comprise only one component of intraday returns volatility, aside from the distinctive intraday volatility pattern at high frequencies and the volatility persistence at the daily level. From an econometric perspective, the robust analysis of macroeconomic announcement effects therefore requires the simultaneous modelling of, and control for, all three of these volatility factors. High frequency data, therefore, are crucial for the analysis of the behaviour of financial markets at the time of public information arrivals associated with major macroeconomic announcements, and these have been shown to dominate volatility in the intervals immediately following news releases.[2] Indeed, in innovative recent work on the foreign exchange market, Andersen et al. (2003) characterise the conditional means of five US dollar

[1] See Mark (1995), Mark and Sul (2001), Berkowitz and Giorgianni (2001), Evans and Lyons (2002) and Faust et al. (2003) for evidence focusing on the foreign exchange market.

[2] See Ederington and Lee (1993, 1995), DeGennaro and Shrieves (1997), Almeida et al. (1998), Goodhart et al. (1993), Andersen and Bollerslev (1998), Chang and Taylor (2003) and Galati and Ho (2003) for evidence on foreign exchange markets; Fleming and Remolona (1999) and Bollerslev et al. (2000), Balduzzi et al. (2001) and Green (2004) for evidence on bond markets; and Boyd et al. (2001) and Flannery and Protopapadakis (2002) for evidence on stock markets.

spot exchange rates for the period January 1992 through December 1998, including the Euro, and find that US (and to a lesser extent German) announcement surprises produce conditional mean jumps and, hence, high-frequency exchange rate dynamics are linked to fundamentals. The details of the linkages, they suggest, are intriguing and include announcement timing and asymmetric sign effects.[3]

In one of the very few other known studies of the Euro since EMU, Galati and Ho (2003) present a preliminary investigation of the extent to which daily movements in the Euro-Dollar (EUR-USD) rate were driven by the macroeconomic situation in the US and Eurozone area over the period January 1999 to December 2000. A number of findings emerge: first, macroeconomic news is found to have a statistically significant correlation with daily movements of EUR against USD; second, there is asymmetry in the response to news, both geographic and in terms of the type of news; third, the impact of macroeconomic news is stronger when the sign of the news is switched; and fourth, there is considerable time variation in the response of the EUR-USD exchange rate. The asymmetric response of the daily EUR-USD exchange rate to macroeconomic and political news, depending on whether it emanates from the US or Eurozone and whether it is good or bad news, is confirmed by Prast and de Vor (2005) for the period April to September, 2000. Sager and Taylor (2004) implement higher frequency data and concentrate on the impact of European Central Bank Governing Council interest rate announcements during 2002-2003, 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 and not just policy announcements during the period January 1999 to May 2002. ECB statements are found

[3] In an extension of this work, Andersen et al. (2004) show that US news surprises cause conditional mean jumps in high frequency US, German and British stock, bond and foreign exchange markets. Furthermore, they show that equity markets react differently to the same news depending on the state of the economy over the business cycle, with bad news having a positive impact during expansions and the traditionally expected negative impact during recessions.

mainly to influence the daily conditional volatility of the EUR-USD exchange rate with some evidence of an asymmetric reaction to news. Finally, Bauwens et al. (2005) study the impact of nine categories of scheduled and unscheduled news announcements on high frequency EUR-USD volatility for the period May to November, 2001. Volatility is found to increase in the pre-announcement periods, particularly before scheduled events, but, surprisingly there is very little evidence reported of a reaction during the post-announcement periods.[4]

However, analysis of the effect of the wide range of international macroeconomic announcements on intraday Euro exchange rates has, to the best of our knowledge, not yet received full empirical attention in the literature. In particular, empirical studies to date have focussed almost exclusively on US announcements and ECB announcements, and only for the EUR-USD rate. There is therefore a need to establish whether these results carry over to high frequency Euro-Yen (EUR-JPY) exchange rate data. It is also of interest to consider the Euro-Sterling (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 context. This study therefore considers high frequency, five-minute, data for these three exchange rates in order to identify the nature and details of linkages between news about macroeconomic fundamentals and exchange rate movements. The sample period runs from January 2002 to the end of July 2003, and 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, and also covers the beginning of

[4] In related research, 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. Evans and Lyons (2005) investigate whether macroeconomic news arrivals affect trading in currency markets over time, finding that news arrivals induce changes in trading behaviour that remain significant for days and have persistent effects on prices, thus currency markets do not respond to news instantaneously.

conflict in Iraq. The dataset also includes a wide selection of macroeconomic news announcements for the US, Eurozone, Germany, France, UK and Japan to examine whether individual announcements regarding relative economic performance impacts upon bilateral exchange rate volatility. Furthermore, this investigation is conducted in the context of two alternative techniques for capturing the intraday volatility pattern. Firstly, the flexible Fourier form (FFF) implemented by Andersen and Bollerslev (1998), Andersen et al. (2000) and Bollerslev et al. (2000). Secondly, an alternative cubic spline specification previously utilized by Engle an Russell (1998), Zhang et al. (2001), Taylor (2004a,b) and Giot (2005) in the context of autoregressive conditional duration models applied to irregularly spaced transaction data, but which has yet to be applied to foreign exchange data.

The remainder of the paper is structured as follows. Section 2 describes the econometric method. Section 3 describes the data and the modelling of daily volatility and intraday periodicity. Section 4 reports the empirical results. Section 5 summarizes the findings and conclusions.

2. Econometric Method

To assess the short-run dynamic response of exchange rates to news announcements, and following Andersen et al. (2003), exchange rate returns are modelled as a linear function of I lagged values of themselves and J lagged values of news on each of K^c fundamentals, where c references the country of origin of the news announcement such that the dynamic effect of news is assessed separately for announcements from different countries:[5]

$$R_{t,n} = \beta_{0^c} + \sum_{i=1}^{I} \beta_{i^c} R_{t,n-i} + \sum_{k^c=1}^{K^c} \sum_{j=0}^{J} \beta_{k^c,j} S_{k^c,t,n-j} + \varepsilon_{c,t,n} \ . \qquad (1)$$

[5] The total number of macroeconomic indicators per country, K^{US}, K^{EU} , K^{GER} , K^{FRA} , K^{UK} , and K^{JAP}, are 35, 21, 17, 18, 18, and 13 respectively.

where TN = 118,656 such that all observations in the sample are used, and I=J=3.[6] In order to focus on the information content of macroeconomic news releases in the intervals surrounding the data releases, and since the units of measurement differ across announcements, the approach adopted here follows Andersen et al. (2003) and Balduzzi et al. (2001) in using standardised news to allow meaningful comparisons across exchange rates and announcement types. Specifically, the standardised news associated with indicator k on day t in interval n is defined as:

$$S_{k,t,n} = \frac{A_{k,t,n} - E_{k,t,n}}{\hat{\sigma}_k}, \qquad (2)$$

where $S_{k,t,n}$ refers to the standardised news for announcement k (k=1,….,122) at time t,n, $A_{k,t,n}$ denotes the announced value of indicator k, $E_{k,t,n}$ represents market expectations of indicator k as measured by the MMS median forecast, and $\hat{\sigma}_k$ is the sample standard deviation of the surprise component, $A_{k,t,n} - E_{k,t,n}$.[7] Since $\hat{\sigma}_k$ is constant for any indicator k, this standardisation affects neither estimated response coefficients nor the fit of regressions in the analysis which follows, compared to the results based on raw surprises.

Following Andersen et al. (2003), the disturbance term in equation (1) is allowed to be heteroscedastic. This is important given the strong evidence reported elsewhere which shows exchange rate volatility to occupy a strict intraday pattern. The full model is therefore estimated in two steps. First, equation (1) is estimated by ordinary least squares (OLS), so

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[6] This choice is not entirely arbitrary, being based on application of the Schwarz and Akaike information criteria. Allowance for negative J in order to capture any information leakage before the official release time was made, but proved unnecessary.

[7] The use of standardised news limits our sample to only those indicators that have an MMS expected value. Although there are no survey expectations of interest rate announcements in this sample, these expectations have been inferred from interest rate futures prices for the US, Eurozone and UK. Japanese nominal interest rates remained at zero for the duration of the sample, but the Bank of Japan did announce changes to liquidity conditions and adaptive expectations are used for these announcements.

modelling the impact on returns of news on each announcement K^c from country c. Second, the time-varying volatility of the regression residuals, $\varepsilon_{c,t,n}$, is estimated as follows:

$$\left|\varepsilon_{c,t,n}\right| = \mu_c + \Pi_c \frac{\hat{\sigma}_t}{\sqrt{288}} + \sum_{k^c=1}^{K^c} \sum_{j'=0}^{J'} \beta_{k^c,j'} D_{k^c,t,n-j'} + s_{c,t,n} + u_{c,t,n}\,, \tag{3}$$

where $\left|\varepsilon_{c,t,n}\right|$ is the absolute value of the residual of equation (1) and proxies for the volatility during interval n on day t. This is modelled in equation (3) by a combination of three factors: a highly persistent daily volatility factor, $\hat{\sigma}_t$; news announcement dummies, $D_{k^c,t,n-j'}$; and intraday volatility patterns and calendar effects, $s_{c,t,n}$. Fitted values of (3) are then used to perform a weighted least squares (WLS) estimation of equation (1).

More specifically, $\hat{\sigma}_t$ measures the volatility for day t, which is estimated using fractionally integrated MA(1)-FIGARCH(1,d,1) models 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), and involves specifying a first order moving average process for the mean daily return, and conditional variance equation, respectively:

$$R_t = \phi_0 + \phi_1 \varepsilon_{t-1} + \varepsilon_t\,, \tag{4}$$

$$\sigma_t^2 = \omega + \theta_1 \sigma_{t-1}^2 + \left[1 - \theta_2 L - \left(1 - \psi L\right)\left(1 - L\right)^d\right]\varepsilon_t^2\,, \tag{5}$$

where L represents the lag operator and d is the fractional integration parameter.[8]

News effects on volatility are modelled by pre-estimating a third order polynomial

[8] As a robustness check, a simple MA(1)-GARCH(1,1) model is also used for its simplicity and popularity, which follows the approach of Andersen and Bollerslev (1998) and produces qualitatively identical results. These results along with the estimation results for the conditional variance models are not shown for brevity but are available from the authors on request.

response pattern over the J' interval event horizon and measuring the extent to which a particular announcement dummy loads onto this pattern.[9] Given the importance of US news on volatility identified in Andersen et al. (2003), the volatility response pattern in equation (3) is calibrated from all US news combined. In terms of the notation in equation (3), the volatility response coefficient is measured as $\beta_{k^c j'} = \gamma_{k^c} p_{US}(j')$ where $p_{US}(j')$ is the volatility response pattern pre-estimated on all US news combined, and γ_{k^c} is the loading coefficient estimated in equation (3) that measures the extent to which indicator k from country c loads onto this average volatility response pattern.[10] More specifically, the average response pattern across all US news is estimated as $p_{US}(j') = c_0[1-(j'/J')^3] + c_1 j'[1-(j'/J')^2] + c_2 j'^2[1-(j'/J')]$, where the coefficients c_0, c_1, and c_2 are allowed to vary across currencies and intraday periodicity filters (see below). Finally, $s_{c,t,n}$ represents a model for the distinctive twenty-four hour intraday volatility pattern that is ubiquitous in foreign exchange markets, together with calendar effects, the explicit treatment of which is described in section 3. In order to examine whether volatility responses to macroeconomic news announcements are sensitive to the modelling technique used to capture this intraday volatility pattern, FFF and cubic spline methods are adopted as alternatives, and are also described in more detail in Section 3.[11]

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[9] On comparison with the use of $|S_{k^c}|$ as the news indicator, simple dummy variables provided a superior fit to the data, indicating that, quite apart from the data surprise conveyed by the news announcement, the very event of macroeconomic news announcements cause volatility reactions. In equation (3), announcements made within the same five-minute interval are treated as a single news release leaving a total of 31, 18, 15, 16, 12 and 10 announcement dummies for the US, Eurozone, Germany, France, UK and Japan, respectively. A one-hour response is stipulated for each announcement except the US Employment Report and the Federal Reserve FOMC interest rate announcements, which are allowed a two-hour response.

[10] For versions of (3) that analyse the impact of non-US news, US announcements are controlled for in the volatility equation by combining all US releases into one dummy variable.

[11] As a robustness check, equation (1) is also estimated using heteroscedasticity and autocorrelation consistent (HAC) standard errors rather than a parametric representation of volatility dynamics. Given that the heteroscedasticity is of known form, as governed by the interaction of intraday and inter-day volatility patterns, preference is given to the WLS approach for the efficient estimation of coefficients in equation (1). There are no qualitative differences between the coefficients estimated under both the WLS and HAC frameworks, but there are fewer statistically significant coefficients under the WLS approach.

3. Data and Intraday Periodicity Filters

This study utilises inter-bank bid-ask quotes for EUR-USD, EUR-GBP and EUR-JPY spot exchange rates provided by Olsen Data.[12] Bid and ask quotes were obtained at five-minute intervals from 21:00 GMT on 1st January 2002 to 21:00 GMT on 31st July 2003. The 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 the previous interval. 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.

The logarithmic price, $\log(P_{t,n})$, is defined as the mid-point of the logarithmic bid and ask. 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.[13] This produces 288 five-minute intervals during the day. 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.[14] The nth 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 $t=1, 2\ldots T$

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[12] www.olsen.ch

[13] 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.

[14] See Bollerslev and Domowitz (1993) for a justification of this weekend definition. 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 of intraday volatility.

references the trading day and *n=1, 2… N* represents the intraday interval, with *T=412* and *N=288* so the sample contains *TN=118,656* five-minute returns for each exchange rate.

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 assigned an artificially low, positive return. Specifically, these periods occur at Easter, Christmas and New Year's Day, which are public holidays in all major financial centres. 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.[15] The effect of these regional holidays on volatility is controlled for explicitly in the analysis below.

The sample means of the five-minute returns for EUR-USD, EUR-GBP and EUR-JPY of 0.000218%, 0.000124% and 0.000124% respectively are indistinguishable from zero at standard significance levels given sample standard deviations of 0.038%, 0.034% and 0.038%, respectively. Returns are clearly not normally distributed, with sample skewness calculated as -0.008, 0.304 and 0.125, and sample kurtosis measured as 9.831, 22.509 and 15.191, which are all highly significant.[16] The first order autocorrelations of -0.08, -0.19 and -0.11 for each currency pair are highly significant because of the large sample size, but they are small in economic terms.[17]

As noted above, two alternative modelling techniques designed to capture intraday

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[15] Full details of the treatment of public and regional holidays are available on request.

[16] The standard errors of these statistics in their corresponding asymptotic normal distributions are $(6/T)^{1/2}$ and $(24/T)^{1/2}$ (see Andersen and Bollerslev, 1997).

[17] These small negative statistics provide some support for the hypothesis that foreign exchange dealers position their quotes asymmetrically relative to the perceived true market price as a way to manage their inventory positions, thus causing the mid-point of the quoted prices to move in a similar fashion to the 'bid-ask bounce' commonly observed on organised exchanges.

pattern in volatility are compared.[18] Firstly, following Andersen and Bollerslev (1998), an adaptation of the FFF specification is defined as follows:

$$s_{t,n} \equiv \mu_1 + \sum_{k=1}^{K} \lambda_k \cdot I_k(t,n) + \sum_{q=1}^{Q} \left(\delta_{\cos,q} \cdot \cos \frac{q2\pi}{N} n + \delta_{\sin,q} \cdot \sin \frac{q2\pi}{N} n \right). \qquad (6)$$

This expression is non-linear in the intraday time interval, n, parameterised by a number of sinusoids that occupy precisely one day and a set of event dummies, I_k, where $I_k(t, n)$ is an indicator for an event k occurring during interval n on day t, Q is a tuning parameter and refers to the order of expansion, while λ_k, $\delta_{cos,q}$ and $\delta_{sin,q}$ are the fixed coefficients to be estimated. During periods of daylight saving time the sinusoids are translated leftwards by one hour using a time deformation procedure. 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.

The second characterisation of the intraday volatility pattern uses a cubic spline specification, whereby, as recently advocated by Taylor (2004a, b), a series of third order polynomials are fitted between clearly defined ‘knots’ during the day:

$$s_{t,n} \equiv \mu_1 + \sum_{k=1}^{K} \lambda_k \cdot I_k(t,n) + \sum_{m=1}^{M} \left[\alpha_{1,m} D_m \left(\frac{n-l_m}{N} \right) + \alpha_{2,m} D_m \left(\frac{n-l_m}{N} \right)^2 + \alpha_{3,m} D_m \left(\frac{n-l_m}{N} \right)^3 \right], \qquad (7)$$

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, D_m are dummy variables taking

[18] There are, of course, further alternative methods available for estimating the intraday periodicity. Andersen and Bollerslev (1997) use the mean volatility for a particular interval averaged across days, Gençay et al. (2001) use a method based on a wavelet multi-scaling approach. We do not pursue these further alternatives here.

the value *1* if $n \geq l_m$ and *0* otherwise and $\alpha_{1,m}$, $\alpha_{2,m}$ and $\alpha_{3,m}$ are coefficients to be estimated.[19]

The $I_k(t, n)$ regressors in equations (6) and (7) indicate dummy variables associated with holidays, weekdays, and calendar related characteristics. Holiday dummies refer to regional holidays that cause volatility slowdowns but still provide reliable returns, and they only affect the portion of the trading day corresponding to the trading activity of the financial centre affected by the holiday. Similar simple dummy variables are also included for each day of the week to account for any systematic weekly patterns in exchange rate volatility. A DST dummy is also included to allow for systematically higher volatility during DST.

The remaining calendar related characteristics 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 calendar effects whilst maintaining the smooth cyclical periodicity of the intraday volatility pattern, a polynomial structure is imposed on the volatility response for these events. In full generality, if an event affects volatility from time t_0 to time $t_0+\Omega$, the impact on volatility can be represented over the event window $\tau=0,1.....\Omega$ by a polynomial specification: $p(\tau) = c_0 + c_1\tau + ... + c_P\tau^P$. 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. Specifically, enforcing $p(0)=0$ ensures there is no jump in volatility away from the underlying intraday pattern and $p(\Omega)=0$ enforces the requirement that the

[19] 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 daylight saving time (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.

impact effect slowly fades to zero. The latter constraint gives rise to a polynomial with one less parameter: $p(\tau) = c_0[1-(\tau/\Omega)^P] + ... + c_1\tau[1-(\tau/\Omega)^{P-1}] + c_{P-1}\tau^{P-1}[1-(\tau/\Omega)]$.[20]

4. Empirical Results

Since there are numerous variables in each regression, rather than display the full regression outputs for each estimation, the following empirical results select the most important features of the models. Figures 1 and 2 plot the average intraday actual absolute residual return obtained from the OLS estimation of equation (1), along with the fitted values of the volatility described by equation (3), using the FFF and cubic spline intraday specifications in equations (6) and (7), respectively.[21] The plots are also separated into winter time and DST to show that the intraday patterns are shifted to the right by one hour during DST to accommodate these timing conventions. The figures show that both specifications generate excellent fits to the average absolute residual return, which demonstrates the success of these models in capturing the volatility dynamics, but the cubic spline model tends to offer a more accurate fit to the intraday volatility pattern in relation to the volatility peaks.

Table 1 reports the instantaneous response of exchange rate returns to news

[20] Based on close inspection of the data underlying the intraday patterns presented in Figure 1, the Tokyo opening effect is afforded a linear response ($P=1$) beginning at 00:05 GMT and lasting until 00:30 GMT ($\Omega=6$) with the effect fading to zero at 00:35 GMT ($p(\Omega)=0$). 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 ($\Omega=23$) with the restriction that $p(\Omega)=0$. 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 ($\Omega=47$) with the start of the effect shifted by one hour to 16:05 GMT ($\Omega=59$) 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 ($\Omega=23$) with the restrictions $p(\Omega)=0$ 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 ($J=35$). The effect of the winter slowdown polynomial is restricted to reach zero at 00:00 GMT ($p(\Omega)=0$).

[21] These plots use the residuals from the specification of equation (1) that includes only US macroeconomic announcements for illustrative purposes. The plots based on the residuals of other specifications of equation (1), reveal an equally impressive fit to the data and are available on request.

announcements, $\hat{\beta}_{k^c,0}$, when estimated by WLS and using the entire sample of data. In order to conserve space, the table includes only those announcements generating a statistically significant response at the 5% level for at least one of the three currency pairs. The table confirms the strong influence of news on US macroeconomic fundamentals on exchange rate returns in the five-minute interval immediately following the announcements.[22] The immediate responses to US news are much larger for EUR-USD than EUR-GBP or EUR-JPY and it is interesting that news of a strengthening US economy generates a depreciation of the Euro against all three currencies. The indicators offering the largest instantaneous return responses are Consumer Confidence, Durable Goods Orders, GDP Advance, Non-Farm Payrolls, Retail Sales, Trade Balance and the Unemployment Rate with coefficient values in accordance with those presented by Andersen et al. (2003). Moreover, the differences between the WLS estimates formulated from FFF and cubic spline intraday volatility models are negligible.

In the remainder of Table 1, there are only very few non-US macroeconomic indicators causing instantaneous jumps in the conditional exchange rate mean. News relating to the Eurozone as a whole has barely any effect, whilst stronger than expected German expectations and Retail Sales lead to Euro appreciation. The announcement of inflation in France results in a slight strengthening of the EUR against GBP, but these are very small reactions compared to the influence of US news. The performance of the UK economy also causes movement in the EUR-GBP rate with GBP appreciating strongly against EUR in the intervals directly following larger than expected Retail Sales and RPI figures. Finally, although some coefficients are statistically significant for Japanese news, the coefficient estimates are very small in comparison to the news effects emanating from other countries.

[22] Indeed regressing returns on standardised news in only the intervals containing news reveals that news on US macroeconomic fundamentals explains staggering proportions of exchange rate movements (up to 70%). In order to conserve space the results of these simplistic regressions are not shown here.

The associated volatility responses derived from equation (3) are displayed in Tables 2 and 3, which report the instantaneous reaction of volatility to news announcements, $\beta_{k^c,0}$, and the cumulative volatility reaction, $\sum_{j'=0,J'} \beta_{k^c,j'}$, over the response horizon for the FFF and cubic spline specifications of the intraday volatility pattern respectively. Volatility responses are included for only those announcements producing a significant loading coefficient in the estimation of equation (3). The instantaneous volatility response measures show that US news announcements cause dramatic surges in volatility, and the cumulative volatility response measures show that this initial rise in volatility often persists for a number of five-minute intervals after the announcement. There is clear consistency between Table 1 for the conditional mean and Tables 2 and 3 for volatility in that the US announcements causing the greatest reaction in the conditional mean also cause large volatility responses. However, there are a number of announcements causing volatile exchange rate reactions, such as Existing and New Home Sales, Factory Orders, Industrial Production, the ISM (Manufacturing) Index, the Michigan Sentiment Index and PPI, but which do not give rise to systematic movements in returns that are related to the information released. This is more heavily emphasised by the consideration of the Federal Reserve's FOMC announcements of interest rate changes, which produces the largest instantaneous and cumulative volatility responses and some of the largest five-minute absolute returns in the entire sample, and yet these returns are not significantly correlated with the standardised measure of interest rate news.

There are very few non-US announcements causing surges in Euro volatility. Interest rate decisions by the ECB are the only Eurozone indicator causing sufficiently violent exchange rate reactions to warrant inclusion in Tables 2 and 3 and these reactions occur across all three exchange rate pairs. IFO Business Expectations for Germany are important, whilst UK news, including Industrial Production, Retail Sales and MPC interest rate decisions all provide significant volatility reactions in EUR-GBP, while GDP, Industrial

Production, the Tankan Index and Bank of Japan liquidity announcements cause volatile reactions in EUR-JPY. These findings are all supported in both Tables 2 and 3 which show that the measurement of volatility responses is not sensitive to the choice of intraday modelling technique. Measurement of the response of volatility to macroeconomic news announcements, however, is sensitive to the econometric framework applied, with the FFF often understating their effects compared to the cubic splines.

In order to investigate the dynamic impact of macroeconomic news announcements on conditional mean exchange rate returns, Figures 3 to 8 plot the estimated WLS coefficients, $\hat{\beta}_{k^c,j}$, for j=0, 1, 2, 3, for selected announcements, along with two standard error bands above and below the null hypothesis of a zero response to news. Figures 3 to 8 show the dynamic response coefficients for certain US, Eurozone, German, French, UK and Japanese news events, respectively. Figure 3 illustrates the very large instantaneous returns reactions to some US announcements. Another striking feature visible from the plots is the rapidity of the adjustment in the conditional mean. Response coefficients at five, ten and fifteen minutes following the announcement are very rarely large or statistically significant, suggesting that the majority of the reaction occurs in the five-minute interval containing the announcement. This very quick conditional mean jump contrasts with the volatility responses, which tend to linger for up to an hour, and sometimes two hours, after the announcement.

For many of the announcements included in Figure 3 the second response coefficient has the same sign as the first coefficient, but it is much smaller in magnitude and is very rarely statistically significant, showing that the price reaction five minutes after the announcement is in the same direction as the instantaneous response. The price adjustment process is therefore very fast with the information seemingly interpreted consistently in the following immediate intervals. The announcements exerting greatest influence on Euro exchange rate returns, and EUR-USD returns in particular are Consumer Confidence, Durable Goods Orders, GDP Advance, Non-farm Payrolls, Retail Sales, Trade Balance and the Unemployment rate. These findings are entirely consistent with the evidence presented by Andersen et al. (2003).

Although instantaneous coefficients are much smaller in Figures 4 to 8, and there are fewer statistically significant coefficients, the dynamic response patterns are very similar for non-US news announcements. Announcements of particular importance to the value of the Euro are Eurozone GDP Preliminary (although the reaction occurs five minutes after the announcement rather than instantaneously), German IFO and ZEW Expectations and UK Retail Sales and RPI.

5. Conclusions

The characterisation of the price discovery process, and investigation of the way in which news about macroeconomic fundamentals is incorporated into asset prices, are central issues in the market efficiency and market microstructure theoretical literatures, but have so far enjoyed limited empirical success. In recent years, research focused on these core areas of finance has benefited greatly from the availability of high frequency financial data. It has been well documented that volatility is driven by three components: a latent volatility factor often characterised by clustering and persistence at low frequencies; a distinctive, inherent intraday volatility pattern; and macroeconomic news announcement effects. This study has addressed these concepts by investigating the short-run reaction of exchange rate returns and returns volatility to macroeconomic news announcements. Rather than treating components in isolation, this study controls for each factor simultaneously in an attempt to isolate the response of volatility to macroeconomic news announcements. Whilst previous studies of this type typically filter intraday volatility by fitting a Fourier flexible form (FFF) to the intraday pattern, this study compares the performance of the FFF with an alternative cubic spline approach.

Under this methodology, and using a nineteen-month sample of five-minute returns for three Euro exchange rates, and therefore a new market setting, exchange rates are found to react very quickly to macroeconomic surprises, specifically, within five minutes of the release. With very little reaction thereafter, the immediate behaviour of returns can be described as conditional mean ‘jumps’. Furthermore, within this five-minute interval containing the announcement, macroeconomic innovations explain large proportions of these jumps. Construction Spending, Consumer Confidence, Durable Goods Orders, GDP Advance, GDP Preliminary, ISM Index (Manufacturing), Leading Indicators, Non-Farm Payrolls, Philadelphia Federal Reserve Index, Retail Sales, Trade Balance, Unemployment Rate and Initial Unemployment Claims are all important announcements form the US, whilst Labour Costs Revised for the Eurozone, IFO Business Expectations and ZEW Expectations for Germany, and Trade Balance, GDP Preliminary, Industrial Production, Manufacturing Output, Retail Sales, RPI and RPIX for the UK constitute the non-US announcements influencing exchange rate returns. Thus, the evidence suggests that exchange rates, and the EUR-USD rate in particular, are strongly linked to macroeconomic fundamentals in the five-minute interval including the announcements, and the conditional mean return jumps in the EUR-USD exchange rate reflect USD appreciation relative to EUR in response to unexpectedly strong US macroeconomic performance over the sample period..

Initial volatility responses to macroeconomic news are equally dramatic, but these tend to linger for up to one hour after the release and in some cases for up to two hours. Measurement of the response of volatility to macroeconomic news announcements, however, is sensitive to the econometric framework applied, with the FFF method often understating their effects compared to the cubic spline method. There are also some announcements that cause vigorous and persistent volatility reactions, but whose associated return response is not correlated with the standardised news measure of that indicator. Particularly noteworthy examples of this are interest rate decisions by the Federal Reserve, ECB and MPC and liquidity provision decisions by the Bank of Japan. Although these announcements cause the most volatile reaction of all the macroeconomic indicators, the conditional mean exchange rate return response is not systematically explained by the standardised measure of news used in this study. That is, central bank announcements alone cause volatility quite apart from the information surprise, possibly associated with foreign exchange market order flow, and especially that between traders and their customers which is publicly unobservable and may provide a source of information asymmetry among traders which is tantamount to private information.[23]

[23] See, for example, Glosten and Milgrom (1985), Lyons (1997), DeGgennaro and Shrieves (1997) and Melvin and Yin (2000).

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Figure 1. Actual and Fitted Intraday Absolute Residuals (FFF Model).

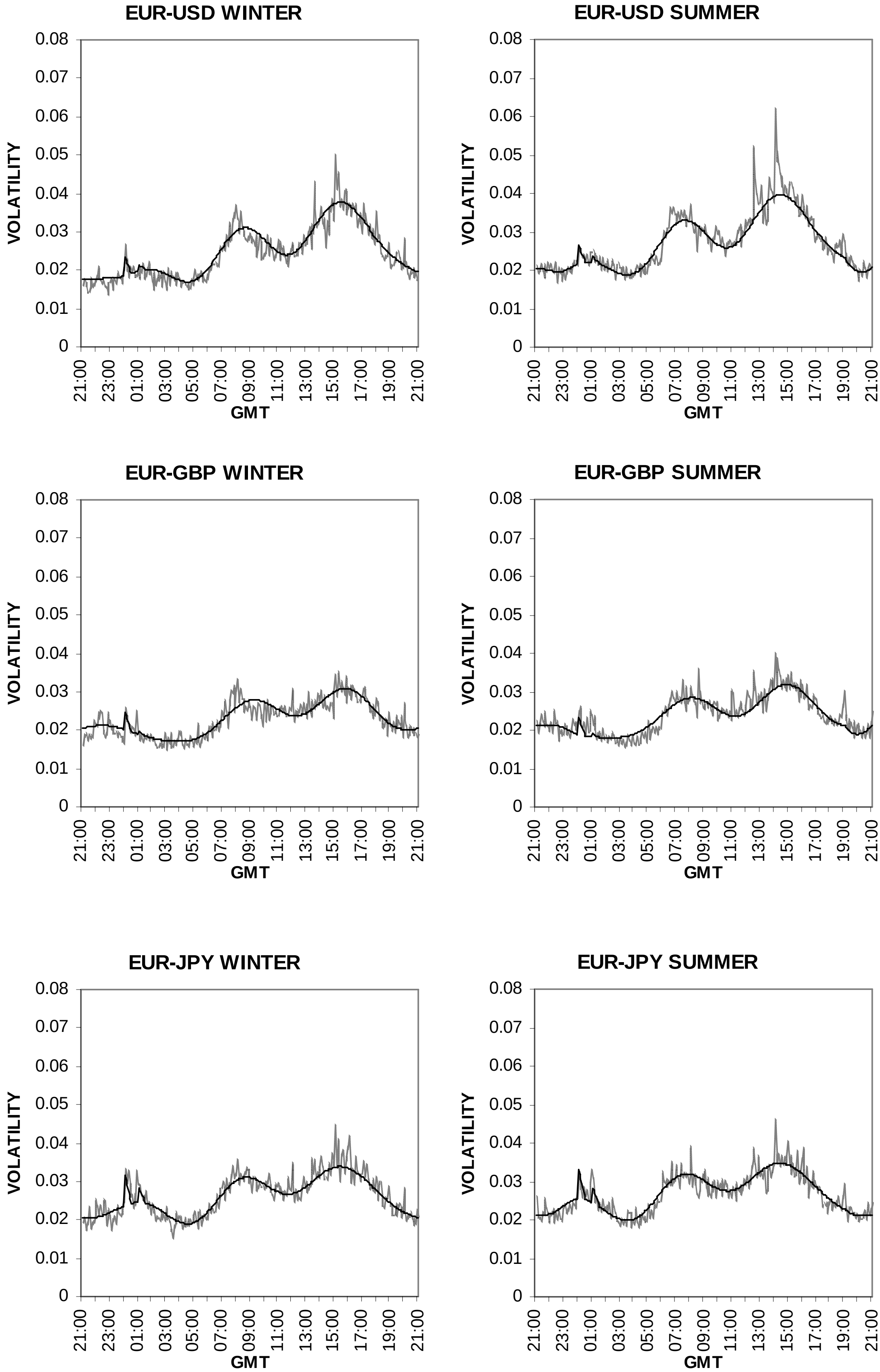


Figure 2. Actual and Fitted Intraday Absolute Residuals (Cubic Spline Model).

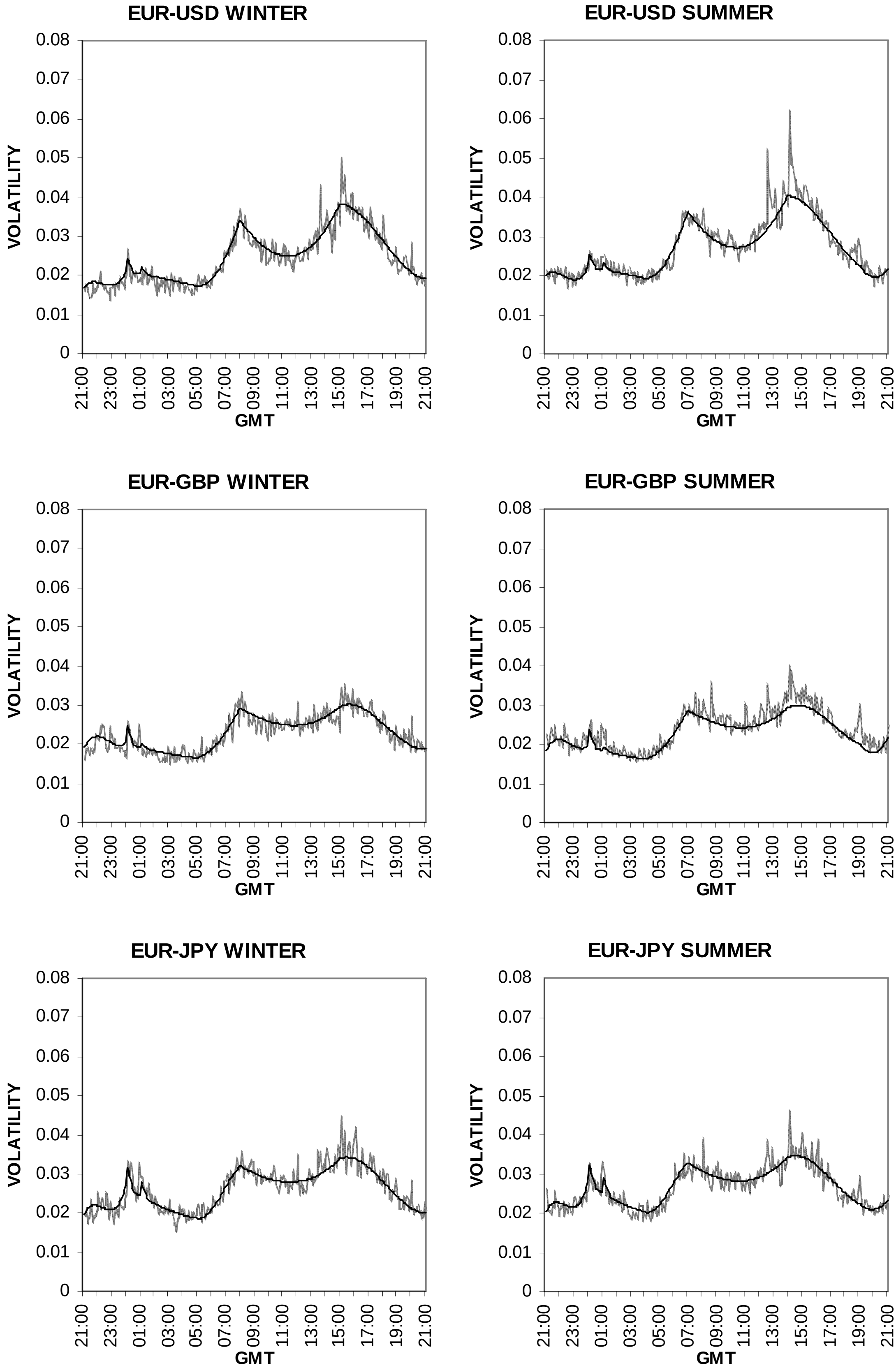


Table 1. Instantaneous Mean Response Under WLS Estimation

ANNOUNCEMENT	EUR-USD		EUR-GBP		EUR-JPY	
	FFF	SPLINE	FFF	SPLINE	FFF	SPLINE
US News						
Capacity Utilisation	-0.0216	-0.0217	-0.0086	-0.0090	-0.030*	-0.0300*
Chicago PMI	-0.0533**	-0.0532**	-0.0089	-0.0089	-0.0209	-0.0211
Construction Spending	-0.0622*	-0.0618*	-0.0266	-0.0322+	0.0118	0.0114
Consumer Confidence	-0.1285**	-0.1281**	-0.0659**	-0.0672**	-0.0260	-0.0262
Durable Goods Orders	-0.0886**	-0.0885**	-0.0464**	-0.0465**	-0.0213	-0.0208
GDP Advance	-0.1634**	-0.1630**	-0.0829**	-0.0825**	-0.0749**	-0.0750**
Leading Indicators	-0.0319*	-0.0319*	-0.0123	-0.0123	-0.0355**	-0.0358**
Michigan Sentiment (Final)	0.0010	0.0006	-0.00638	-0.0053	0.0472*	0.0486*
Non Farm Payrolls	-0.1045**	-0.1044**	-0.0506**	-0.0508**	-0.0293	-0.0292
Personal Consumption Expenditure	-0.0345**	-0.0345**	-0.0060	-0.0060	-0.0245**	-0.0252**
Philadelphia Fed Index	-0.0593*	-0.0593*	-0.0239+	-0.0238	-0.0155	-0.0155
Retail Sales	-0.0856**	-0.0863**	-0.0392**	-0.0380*	-0.0508**	-0.0515**
Trade Balance	-0.0791**	-0.0786**	-0.0361**	-0.0352**	-0.0308+	-0.0310+
Unemployment	0.1167**	0.1166**	0.0455**	0.0440*	0.0447*	0.0448*
Initial Claims	0.0364**	0.0361**	0.0114*	0.0120*	0.0125*	0.0124*
Eurozone News						
Current Account	-0.0076	-0.0056	-0.0062	-0.0053	-0.0339**	-0.0341**
Labour Costs (Preliminary)	-0.0355*	-0.0355*	-0.0214	-0.0212	-0.0066	-0.0074
Labour Costs (Revised)	0.0216+	0.0215+	-0.0262	-0.0262	0.0188*	0.0190*
German News						
Employment	-0.0211+	-0.0213+	-0.0013	-0.0010	-0.0265**	-0.0266**
IFO Business Expectations	0.0496*	0.0499*	0.0214+	0.0215	0.0325*	0.0326*
Retail Sales	0.0228*	0.0229*	0.0017	0.0013	0.0195+	0.0198+
Services Index	0.0184*	0.0182*	0.0122	0.0122	0.0123	0.0122
ZEW Expectations	0.0305**	0.0302**	0.0148	0.0150	0.0273**	0.0274**
French News						
CPI (Preliminary)	-0.0004	-0.0008	0.0210**	0.0203**	-0.0054	-0.0056
Manufacturing	0.0247+	0.0271*	0.0088	0.0110	0.0293+	0.0302+
PPI	0.0060	0.0035	0.0228*	0.0213*	-0.0059	-0.0060
Services Index	-0.0039	-0.0042	0.0211*	0.0211*	0.0056	0.0057
Trade Balance	-0.0152	-0.0171+	-0.0011	-0.0012	-0.0344**	-0.0363**
UK News						
Balance of Trade	-0.0046	-0.0046	-0.0215*	-0.0216*	0.0082	0.0079
Retail Sales	0.0115	0.0119	-0.0784**	-0.0785**	0.0076	0.0079
RPI	-0.0195	-0.0237	-0.0537**	-0.0555**	-0.0133	-0.0148
Japanese News						
Housing Starts	0.0042	0.0040	0.0095*	0.0093+	0.0122	0.0123
Industrial Production	-0.0040	-0.0035	-0.0024	-0.0022	0.0109**	0.0118**
Tankan (Non Manufacturing)	0.0002	0.0019	-0.0005	-0.0054**	-0.0060	-0.0067
Tankan (Manufacturing)	-0.0012	-0.0026	-0.0123**	-0.0098**	0.0255	0.0258

Notes: The table reports the instantaneous response to news announcements in the WLS estimation of equation (1) for the conditional exchange rate return. Only those announcements producing at least one significant coefficient at the 5% level across exchange rates and volatility models are included. **, * and + denote statistical significance at the 1, 5, and 10% levels respectively.

Table 2. Instantaneous and Cumulative Volatility Responses from FFF Model.

ANNOUNCEMENT	EUR-USD		EUR-GBP		EUR-JPY	
	INST	CUM	INST	CUM	INST	CUM
US News						
Chicago PMI	0.0357**	0.1273	0.0067*	0.0354	0.0126**	0.0513
Consumer Confidence	0.0430**	0.1532	0.0155**	0.0816	0.0186**	0.0758
Durable Goods Orders	0.0146**	0.0521	0.0070*	0.0367	0.0082+	0.0333
Existing Homes Sales	0.0123**	0.0439	-0.0027	-0.0141	-0.0013	-0.0055
Factory Orders	0.0194**	0.0693	0.0054+	0.0286	0.0070+	0.0286
GDP Advance	0.0445**	0.1587	0.0056	0.0296	0.0027	0.0112
GDP Preliminary	0.0229**	0.0815	0.0062	0.0327	0.0009	0.0038
Industrial Production	0.0139**	0.0496	0.0093**	0.0489	-0.0025	-0.0100
ISM Manufacturing	0.0499**	0.1780	0.0229**	0.1211	0.0470**	0.1915
Michigan Sentiment (Final)	0.0104*	0.0370	0.0134**	0.0705	0.0310**	0.1261
Michigan Sentiment (Prelim)	0.0275**	0.0979	0.0159**	0.0838	0.0172**	0.0699
New Homes Sales	0.0232**	0.0828	0.0028	0.0145	0.0191**	0.0779
Philadelphia Fed Index	0.0440**	0.1570	0.0109**	0.0575	0.0244**	0.0995
PPI	0.0132**	0.0470	0.0004	0.0023	0.0029	0.0117
Retail Sales	0.0392**	0.1398	0.0119**	0.0628	0.0054	0.0219
Trade Balance	0.0342**	0.1219	0.0056+	0.0294	0.0153**	0.0625
Employment Report	0.0736**	0.4859	0.0279**	0.2803	0.0349**	0.2659
Initial Claims	0.0128**	0.0456	0.0033+	0.0175	0.0056*	0.0230
Federal Reserve FOMC	0.0772**	0.5093	0.0309**	0.3104	0.0284**	0.2161
Eurozone News						
ECB	0.0422**	0.1506	0.0217**	0.1147	0.0263**	0.1071
German News						
IFO Business Expectations	0.0230**	0.0819	0.0058+	0.0307	0.0096*	0.0392
PPI	-0.0047	-0.0166	0.0073*	0.0386	0.0009	0.0037
Cost Of Living (Final)	-0.0030	-0.0109	0.0050	0.0262	0.0150**	0.0611
French News						
Non Farm Payrolls (Final)	0.0161*	0.0575	0.0027	0.0142	0.0171	0.0697
UK News						
Industrial Production	0.0085+	0.0304	0.0143**	0.0757	0.0027	0.0111
Retail Sales	0.0033	0.0118	0.0100**	0.0526	-0.0012	-0.0047
MPC	0.0070	0.0249	0.0296**	0.1564	0.0088*	0.0360
Japanese News						
GDP	-0.0060	-0.0214	-0.0082	-0.0433	0.0215**	0.0864
Industrial Production	0.0080+	0.0284	0.0107**	0.0566	-0.0069	-0.0280
Tankan	-0.0122	-0.0434	-0.0179	-0.0946	0.0207*	0.0843
Bank Of Japan	0.0042	0.0150	0.0135**	0.0711	0.0113**	0.0460

Notes: The table reports the instantaneous ($\beta_{k^c,0} = \gamma_{k^c} p_{US}(0)$) and cumulative responses ($\sum_{j'=0}^{J'} \beta_{k^c,j'}$) to news announcement dummies in equation (2), using the FFF specification for the intraday volatility pattern. Only those announcements producing at least one significant loading coefficient (γ_{k^c}) at the 5% level across exchange rates are included. **, * and + denote statistical significance of the loading coefficient at the 1, 5, and 10% levels respectively.

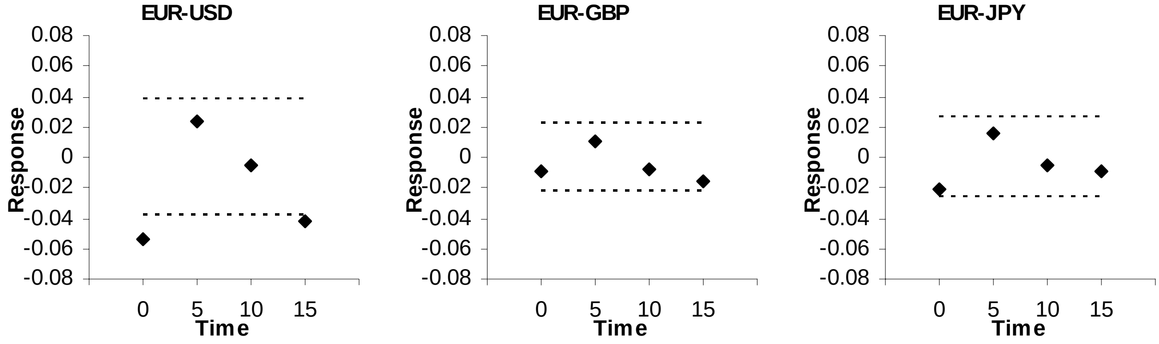
Table 3. Instantaneous and Cumulative Volatility Responses from Cubic Spline Model.

ANNOUNCEMENT	EUR-USD		EUR-GBP		EUR-JPY	
	INST	CUM	INST	CUM	INST	CUM
US News						
Chicago PMI	0.0343**	0.1279	0.0065*	0.0366	0.0111*	0.0486
Consumer Confidence	0.0416**	0.1554	0.0152**	0.0862	0.0184**	0.0804
Durable Goods Orders	0.0166**	0.0620	0.0078**	0.0444	0.0096*	0.0420
Existing Homes Sales	0.0118*	0.0442	-0.0023	-0.0131	-0.0009	-0.0039
Factory Orders	0.0181**	0.0675	0.0055+	0.0310	0.0062	0.0269
GDP Advance	0.0453**	0.1692	0.0060	0.0342	0.0035	0.0152
GDP Preliminary	0.0238**	0.0888	0.0067	0.0380	0.0020	0.0086
Industrial Production	0.0149**	0.0557	0.0106**	0.0599	-0.0010	-0.0045
ISM Manufacturing	0.0488**	0.1821	0.0226**	0.1278	0.0456**	0.1987
Michigan Sentiment (Final)	0.0098*	0.0365	0.0128**	0.0725	0.0300**	0.1307
Michigan Sentiment (Prelim)	0.0261**	0.0973	0.0155**	0.0880	0.0171**	0.0743
New Homes Sales	0.0217**	0.0811	0.0029	0.0163	0.0179**	0.0779
Philadelphia Fed Index	0.0429**	0.1600	0.0096**	0.0545	0.0234**	0.1018
PPI	0.0139**	0.0519	0.0007	0.0039	0.0038	0.0164
Retail Sales	0.0394**	0.1471	0.0123**	0.0696	0.0062	0.0272
Trade Balance	0.0350**	0.1308	0.0059+	0.0334	0.0157**	0.0684
Employment Report	0.0739**	0.5127	0.0280**	0.3026	0.0353**	0.2893
Initial Claims	0.0141**	0.0525	0.0038*	0.0217	0.0065**	0.0282
Federal Reserve FOMC	0.0765**	0.5308	0.0305**	0.3304	0.0285**	0.2336
Eurozone News						
ECB	0.0421**	0.1570	0.0207**	0.1174	0.0259**	0.1128
German News						
IFO Business Expectations	0.0251**	0.0936	0.0072*	0.0407	0.0109*	0.0473
PPI	-0.0050	-0.0185	0.0066*	0.0376	-0.0003	-0.0012
Cost Of Living (Final)	-0.0031	-0.0117	0.0042	0.0238	0.0136**	0.0592
French News						
Non Farm Payrolls (Final)	0.0124	0.0464	0.0007	0.0042	0.0149*	0.0647
UK News						
Industrial Production	0.0109*	0.0408	0.0149**	0.0844	0.0045	0.0198
Retail Sales	0.0057	0.0215	0.0109**	0.0619	0.0009	0.0038
MPC	0.0059	0.0220	0.0272**	0.1543	0.0083*	0.0362
Japanese News						
GDP	-0.0065	-0.0244	-0.0075	-0.0424	0.0199*	0.0869
Industrial Production	0.0074	0.0278	0.0103**	0.0585	-0.0078	-0.0341
Tankan	-0.0128	-0.0478	-0.0176	-0.0995	0.0172*	0.0749
Bank Of Japan	0.0039	0.0147	0.0134**	0.0760	0.0114**	0.0495

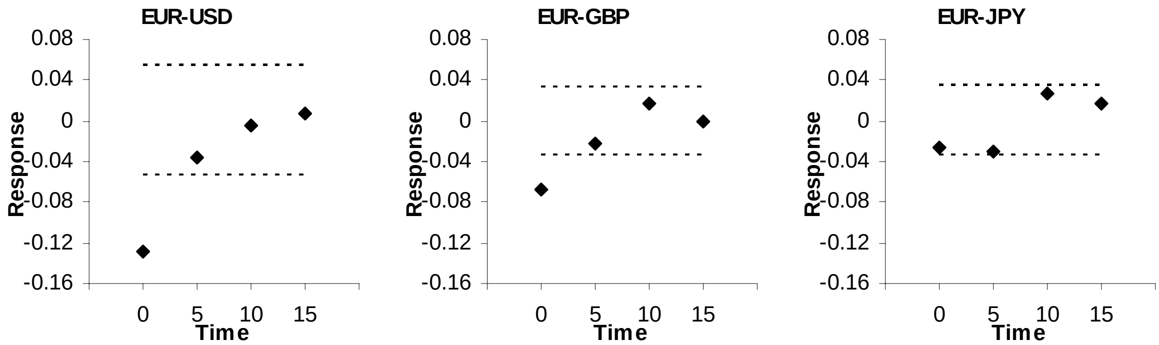
Notes: The table reports the instantaneous ($\beta_{k^c,0} = \gamma_{k^c} p_{US}(0)$) and cumulative responses ($\sum_{j'=0}^{J'} \beta_{k^c,j'}$) to news announcement dummies in equation (2), using the cubic spline specification for the intraday volatility pattern. Only those announcements producing at least one significant loading coefficient (γ_{k^c}) at the 5% level across exchange rates are included. **, * and + denote statistical significance of the loading coefficient at the 1, 5, and 10% levels respectively.

Figure 3. Dynamic Mean Response to US News.

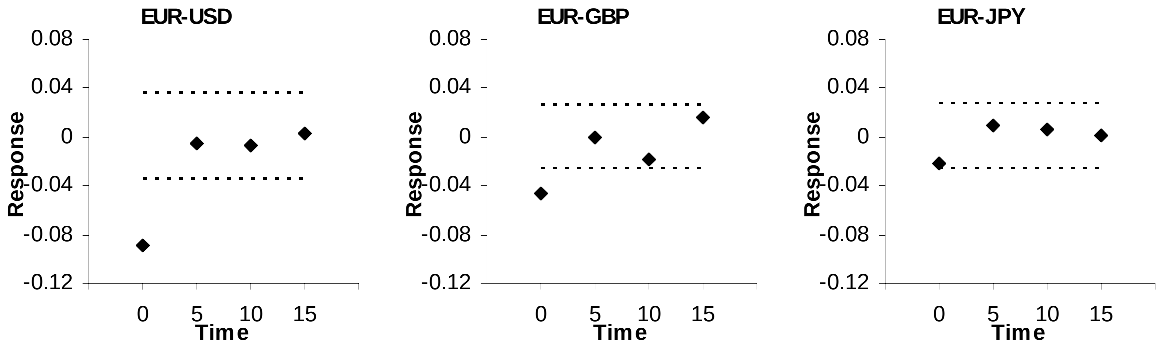
Chicago PMI



Consumer Confidence



Durable Goods Orders



GDP Advance

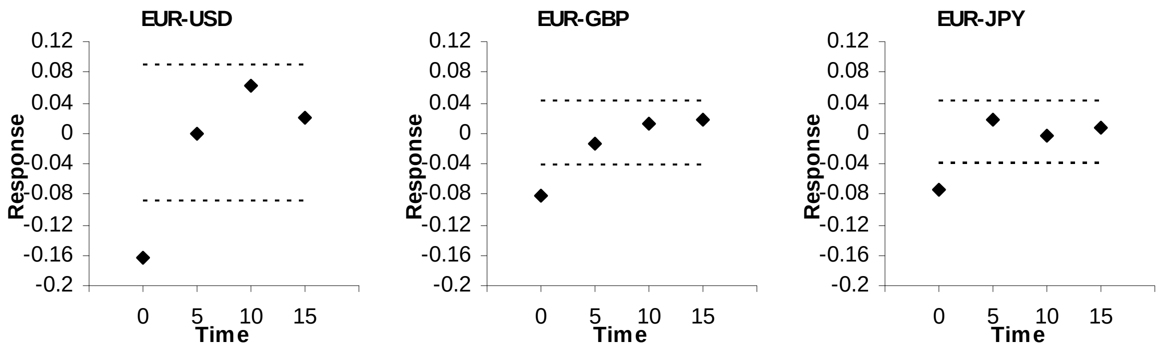
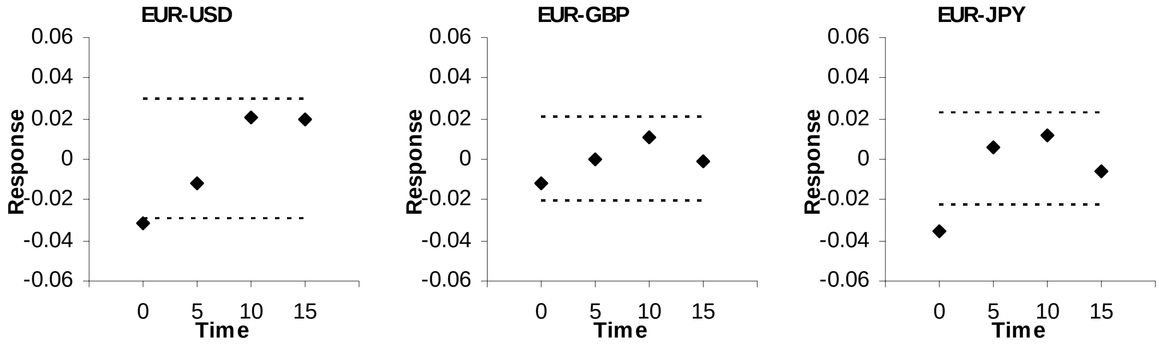
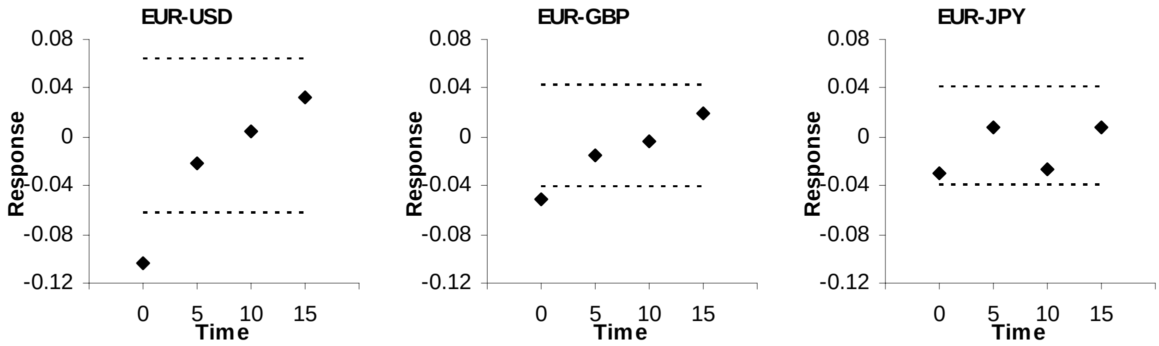


Figure 3 (Continued).

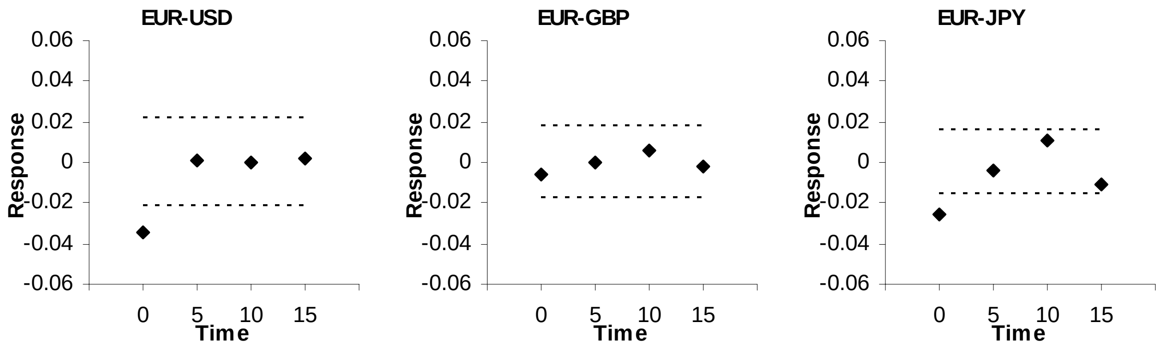
Leading Indicators



Non Farm Payrolls



Personal Consumption Expenditure



Philadelphia Federal Reserve Index

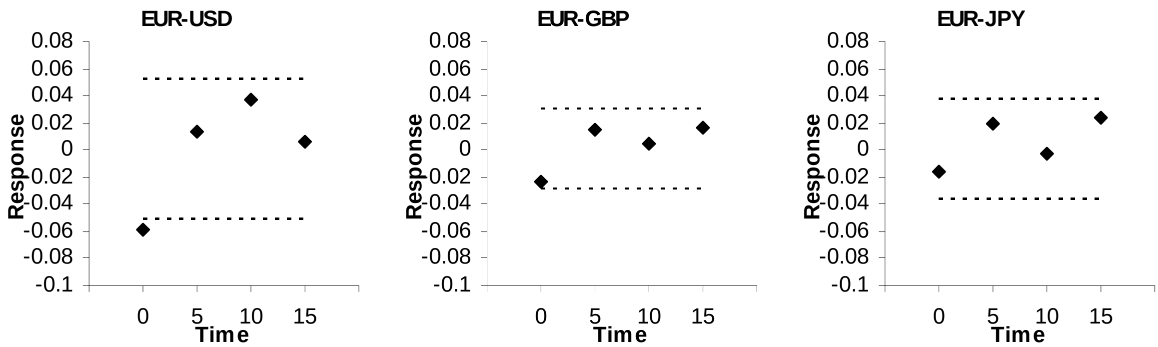
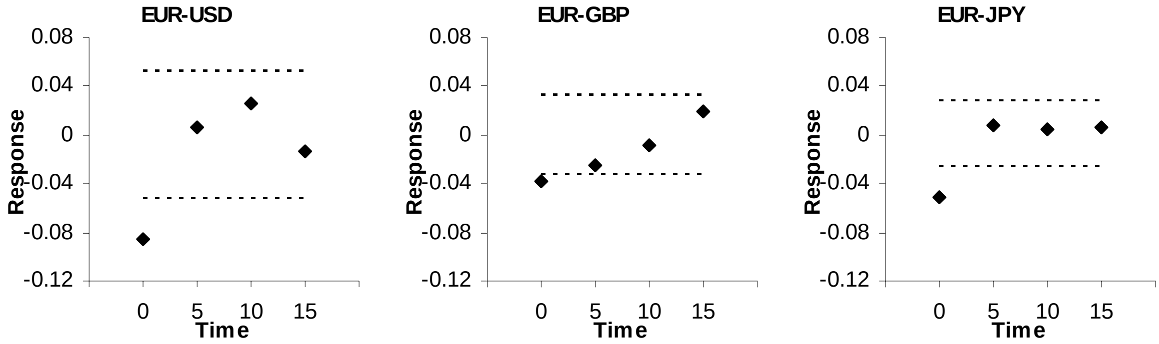
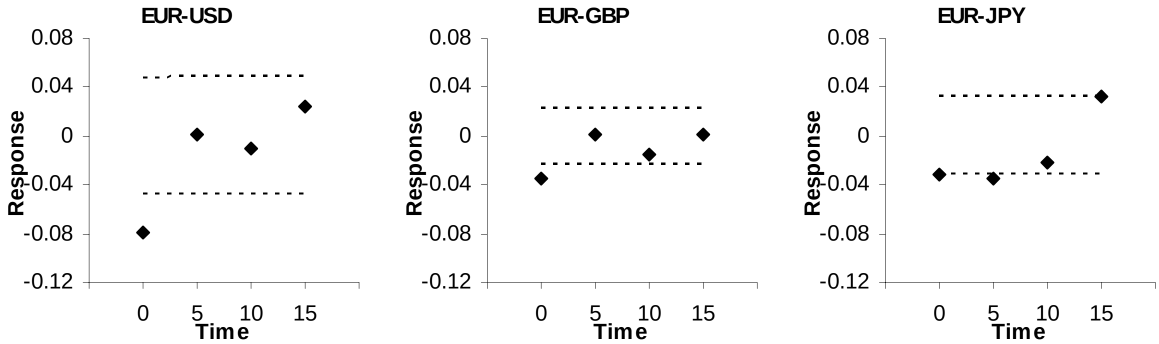


Figure 3 (Continued).

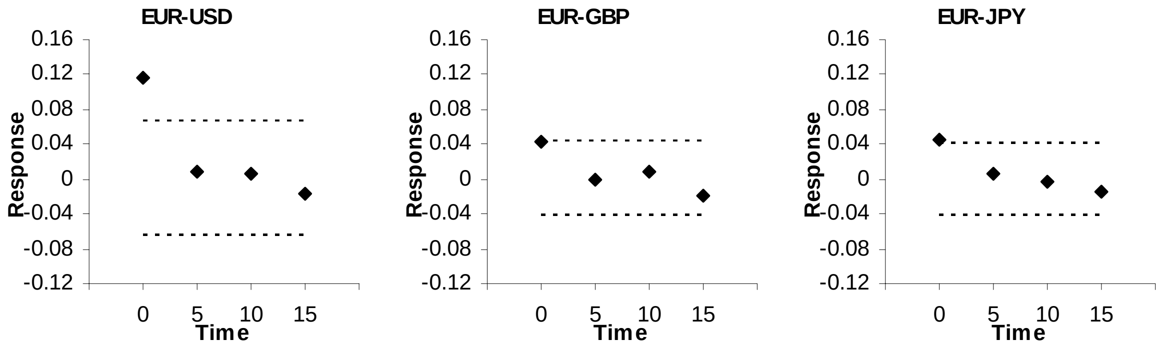
Retail Sales



Trade Balance



Unemployment Rate



Initial Unemployment Claims

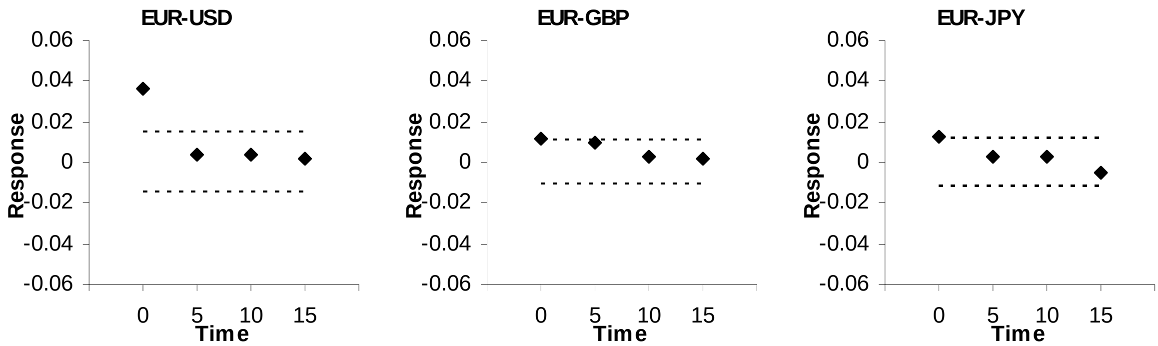
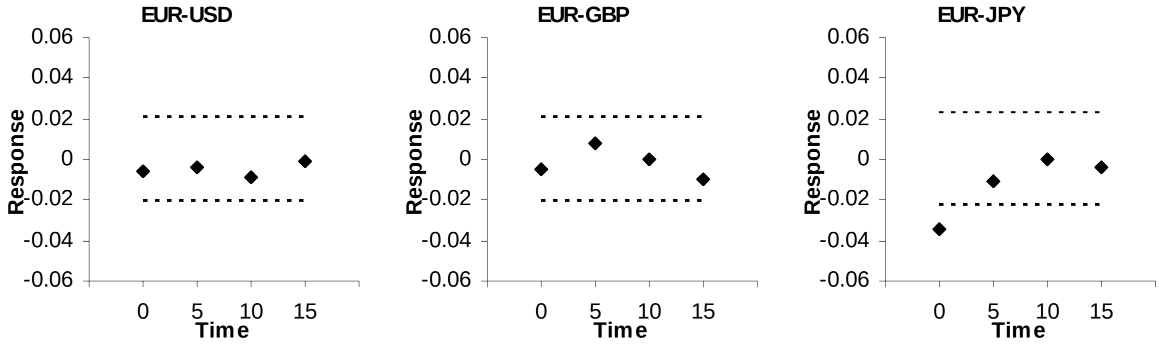
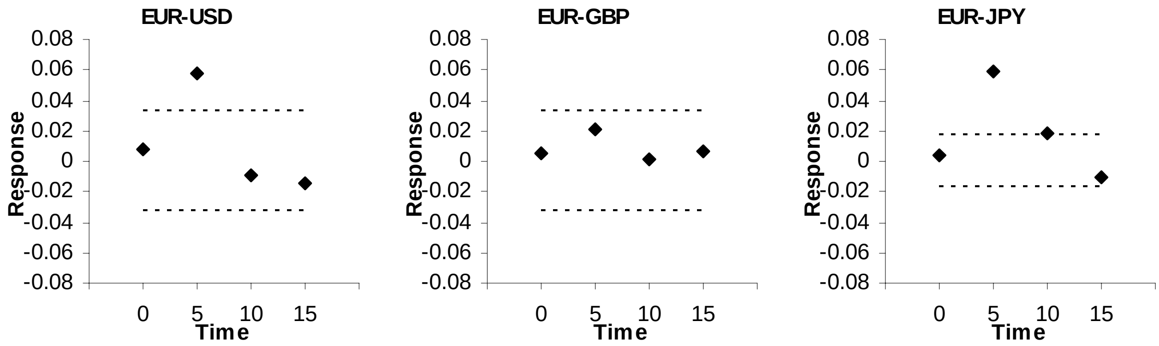


Figure 4. Dynamic Mean Response to Eurozone News.

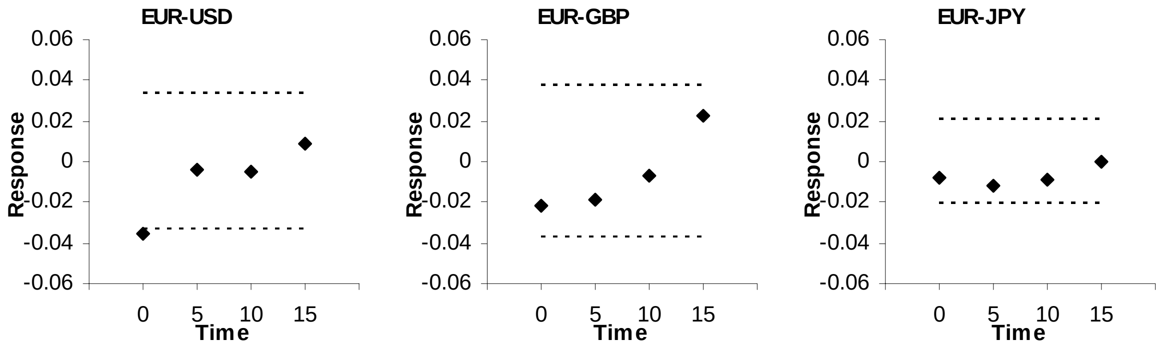
Current Account



GDP Preliminary



Labour Costs Preliminary



Labour Costs Revised

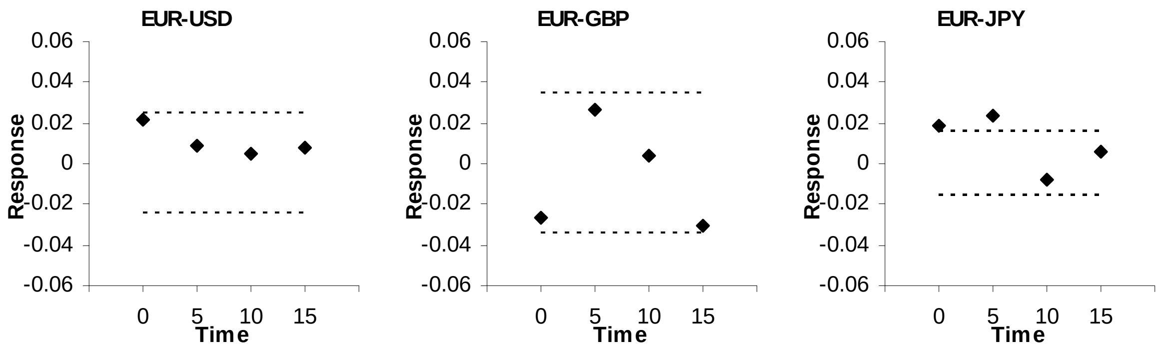


Figure 5. Dynamic Mean Response to German News.

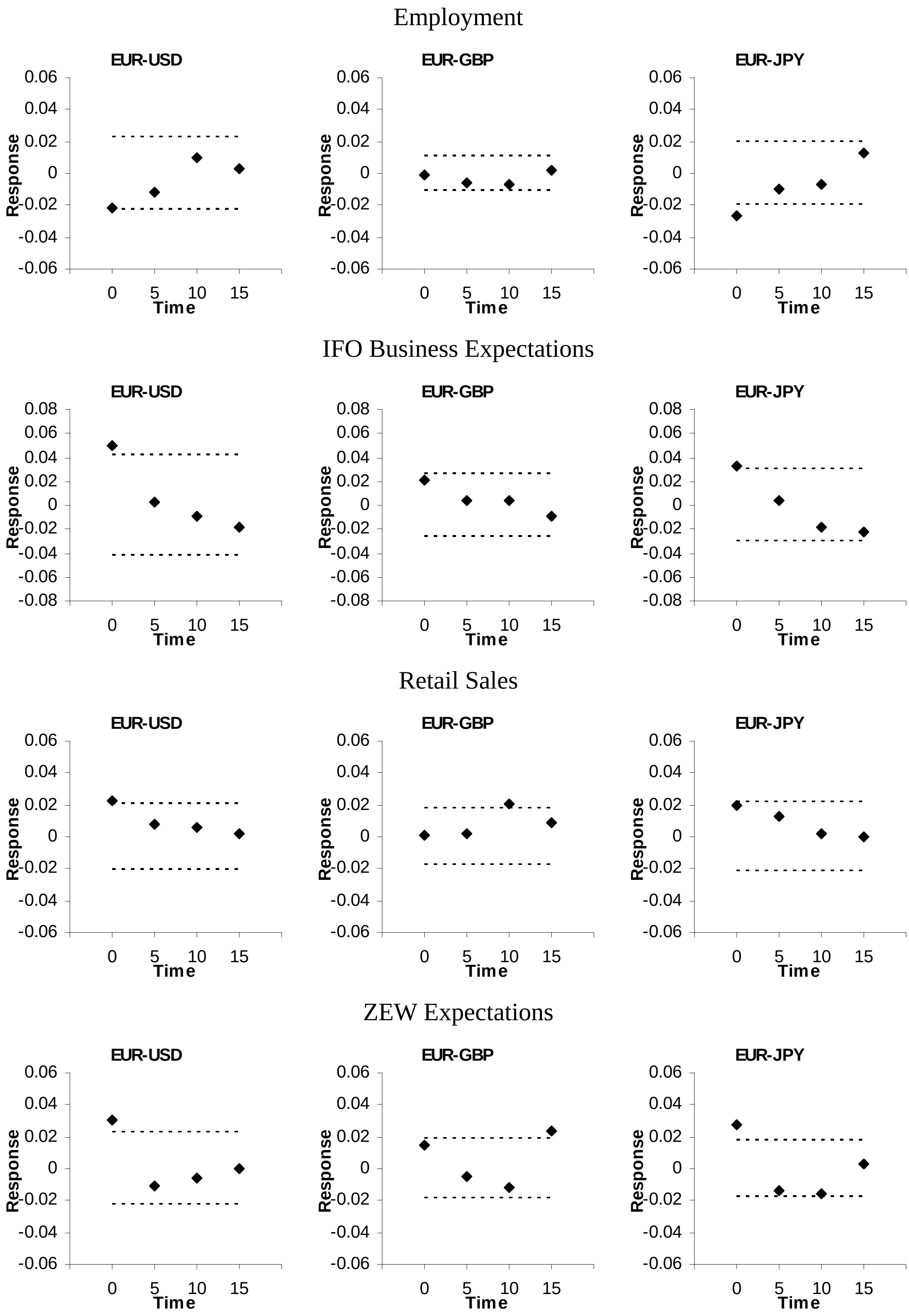
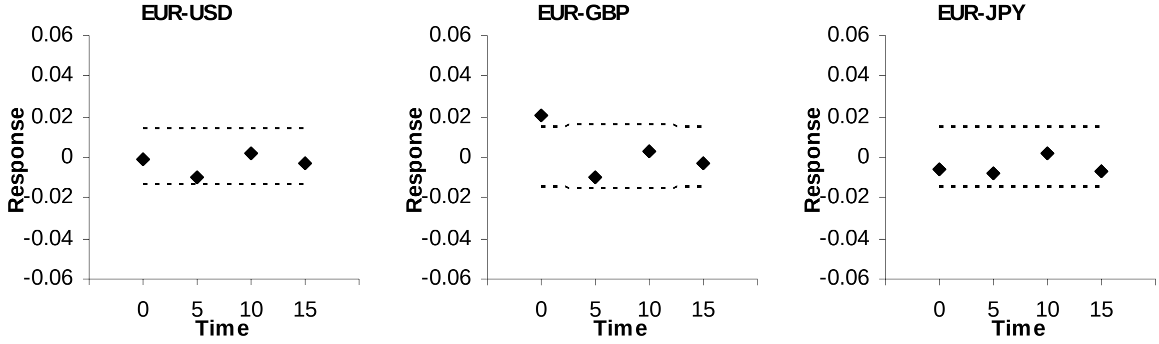
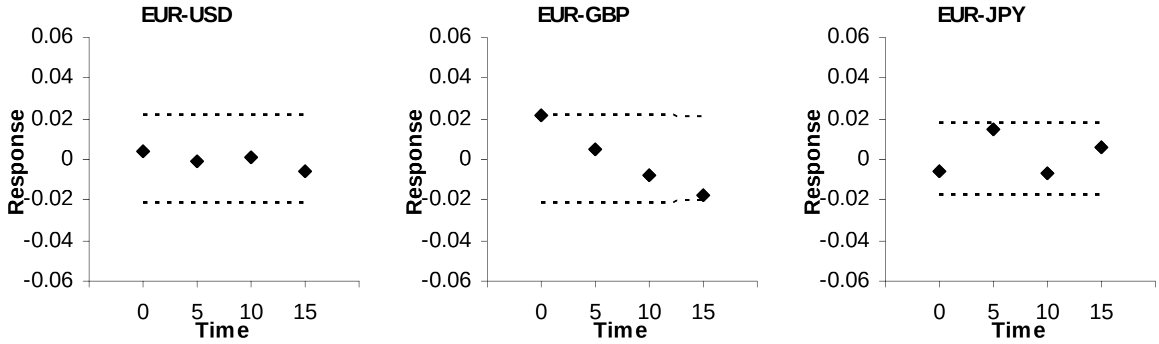


Figure 6. Dynamic Mean Response to French News.

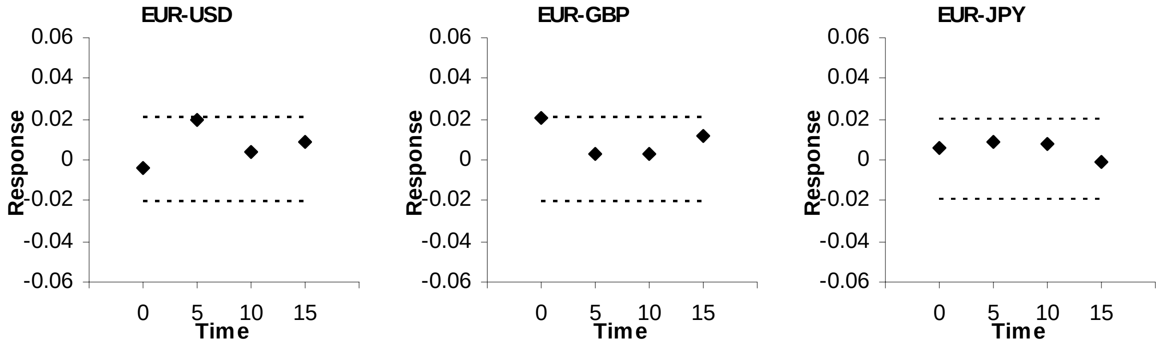
CPI Preliminary



PPI



Services Index



Trade Balance

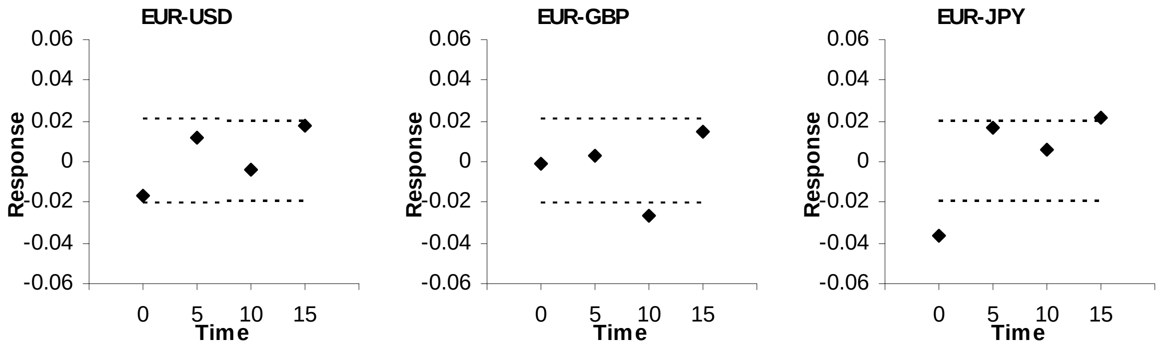


Figure 7. Dynamic Mean Response to UK News.

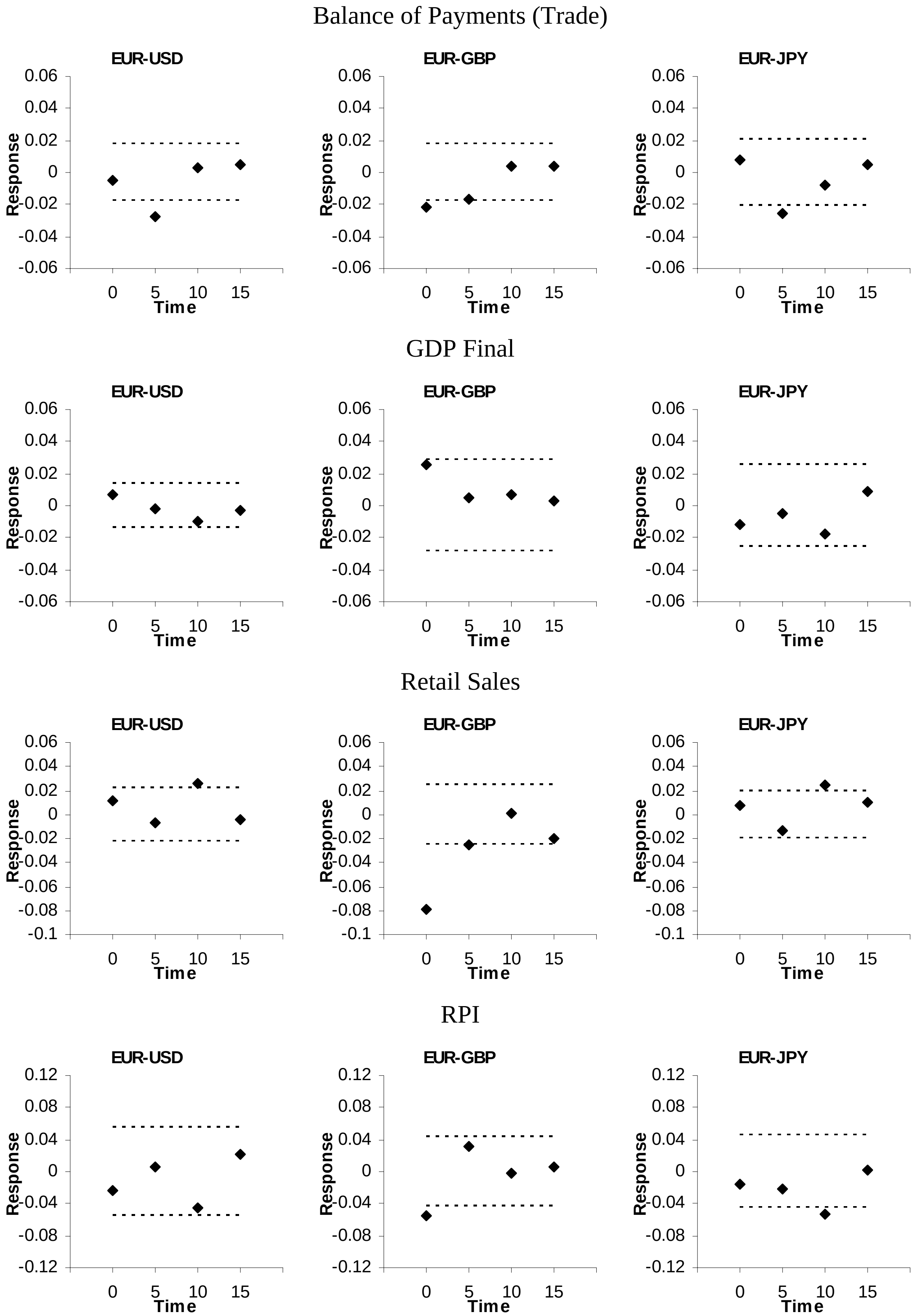
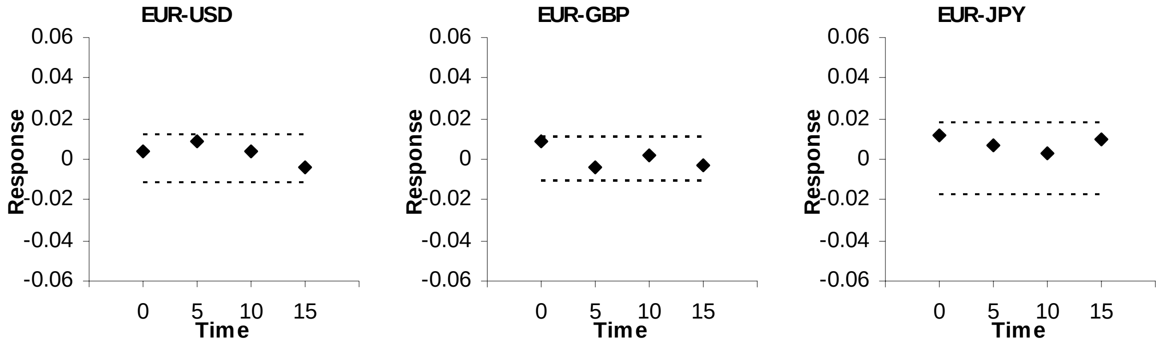
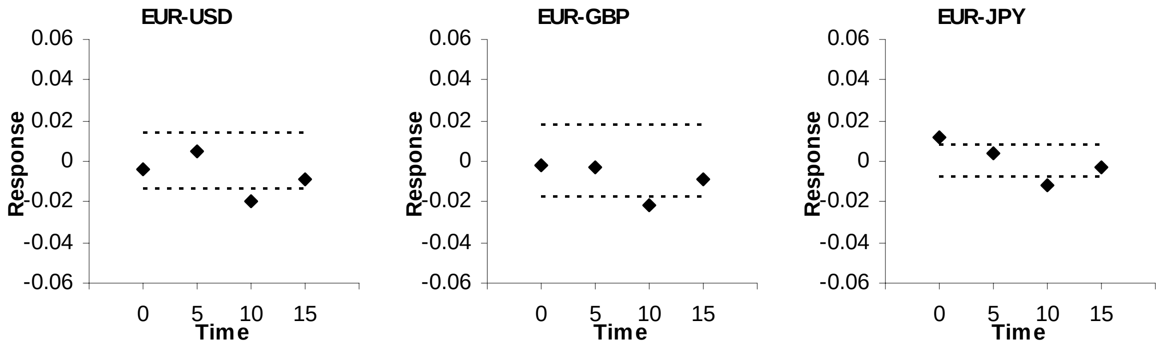


Figure 8. Dynamic Mean Response to Japanese News.

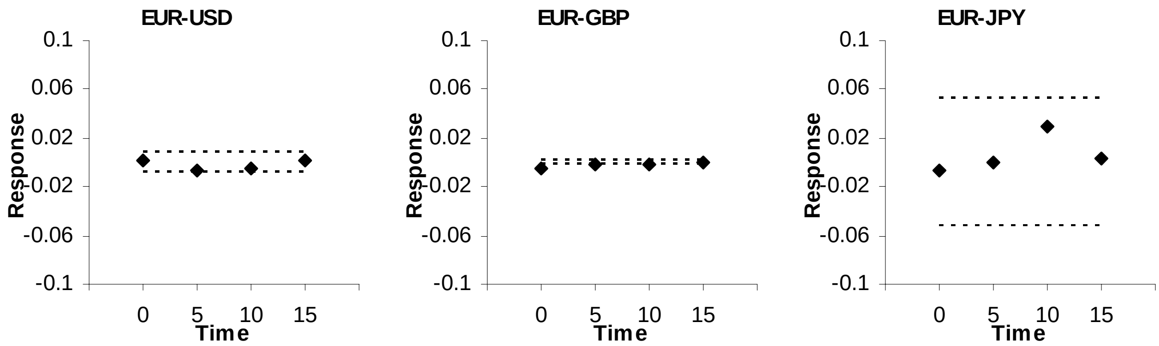
Housing Starts



Industrial Production



Tankan Non Manufacturing



Tankan Manufacturing