News announcements, market activity and volatility in the Euro/Dollar foreign exchange market

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Abstract

This paper deals with the impact of nine categories of scheduled and unscheduled news announcements on the Euro/Dollar return volatility. We highlight and analyze the pre-announcement, contemporaneous and post-announcement reactions. Using high-frequency intraday data and within the framework of ARCH-type and realized volatility models, we show that volatility increases in the pre-announcement periods, particularly before scheduled events. Market activity also significantly impacts return volatility as expected by the theoretical literature on order flow.

Key words: foreign exchange market, volatility, news announcements, high frequency data.

JEL classification: C13, C22, F31, G14

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1 Introduction

The impact of information on the volatility of foreign exchange (FOREX) returns has been theoretically and empirically dealt with in many studies, e.g. Degennaro and Shrieves (1997), Andersen and Bollerslev (1998b), Evans and Lyons (1999), Melvin and Yin (2000) and Cai, Cheung, Lee, and Melvin (2001). As stressed in the literature on market microstructure (see the book by O'Hara (1995)), the 'information' variable includes both a public and a private component. Regarding the market microstructure of the FOREX, both public and private components are strongly related to currency market news announcements. The public component is made up of announcements which take place at fixed times (which we call scheduled public announcements in this paper), or at random times (unscheduled public announcements). Regarding private information, the most recent literature on the microstructure of exchange rates allows for two types of private information. First, some market participants could have access to yet unreleased information by Central Banks or government agencies (i.e. payoff related private information in the terminology used by Lyons (2001)). Secondly the notion of private information can be extended to include the so-called unrelated payoff information, i.e. private information that a dealer has regarding interim states of the market (for example a dealer knows that another dealer is keen on selling a large Euro/Dollar position, which should depress prices in the short run). Because this second possibility is the most probable private information event in the FOREX market, private information is strongly related to order flow between traders and their customers. See Lyons (2001) and references given therein for additional information and recent developments. Most empirical studies which deal with the public and private information flow and impact of news announcements on FOREX volatility focused on currency markets that no longer exist, e.g. the Dollar/DM currency market. With the birth of the Euro, the Euro/Dollar FOREX market now subsumes the eleven 'previous' FOREX markets for the respective domestic currency against the Dollar. We present a brief review of the empirical literature in Section 2.

The aim of this paper is twofold. First, we analyze the impact of an extended set of categories of news announcements on FOREX volatility. Second, we investigate the volatility dynamics before, during and after scheduled and unscheduled news announcements. The contribution of our research therefore consists in assessing the previous results on the new Euro/Dollar market and extending these by distinguishing between the impact on volatility of scheduled and unscheduled news in three time periods centered around the release of the news, i.e. the pre-announcement, contemporaneous and post-announcement periods. We consider a much larger set of news events than the ones so far used in the literature and we classify the news releases into nine general categories. Furthermore and to highlight the effect of the possible 'surprise' contained in the most important scheduled US macro economic figures, we distinguish so-called positive from negative news by computing the difference between the expected and realized values. Consistent with the previous literature, we also take into account the effect of private information, which we measure by the deseasonalized market activity, on the volatility of the Euro/Dollar returns. More generally, the focus of this work is therefore on the economic determinants of the Euro/Dollar return volatility with particular attention paid to the links between the information flow and the market 'reactions' (measured by volatility and market activity). The econometric analysis is performed on a high frequency data set. Observations are regularly spaced and sampled at the five-minute frequency. Volatility is modelled by an EGARCH process, in which we control for intraday seasonality, news arrival (represented by dummy variables) and market activity. In a second part of our study, we also work with realized volatility measures (see Andersen, Bollerslev, Diebold, and Labys (2001a)) to determine the effect of news announcements both on volatility and on the level of market activity.

Our results show that the Euro/Dollar return volatility increases before the announcement of scheduled news, that is of news whose release date and hour are known in advance by all agents. We surmise that speculative/anticipative trades, the possible flow of private information or the re-balancing of positions by traders who prefer to avoid announcements' 'surprises' are all related to this increase in volatility. When news are not scheduled, the evidence of volatility increase or decrease during the pre-announcement phase is tenuous, except for the releases of interest rate reports and rumors of central bank intervention. Moreover, the pattern of the stochastic component of Euro/Dollar return volatility with respect to news announcements seems to be the following:(1) an increase in volatility just before the announcement; (2) a continuation of the adjustment during the announcement period; (3) relatively little reaction in the post-announcement period. When the announcement is scheduled, the seasonal component (or non stochastic component) of volatility seems to be larger. This can be explained by the fact that the market is, in most cases, surprised by the actual news, i.e. expectations do not coincide with realizations. This surprise effect also leads to an increase in market activity, but lasts a very short time.

In addition to the introduction, this paper includes five sections. The first section deals with the news categories and the econometric methods used to compute volatility and seasonality. In that section, we also detail the hypotheses that we wish to test with the econometric models. The next section presents the models used in the empirical application. Section 4 describes our data set and the way it is used. The estimation results are given in Section 5 and we conclude in Section 6.

2 News announcements and volatility

The impact of news announcements on FOREX return volatility has been studied in many empirical studies. Broadly speaking, the main goal of these studies is to determine the response of return volatility to different categories of news events (Degennaro and Shrieves, 1997; Andersen and Bollerslev, 1998; Melvin and Yin, 2000; and Cai, Cheung, Lee, and Melvin, 2001). Most studies focused on the most active currency markets, e.g. Dollar/DM, Dollar/Yen and Sterling/Dollar currency markets. Analyzing the factors (for example the news announcements) which affect FOREX volatility allows for an economic explanation of the volatility in currency markets. Thereafter, volatility measures are used by traders to manage their inventory positions, evaluate their trading risk and price FOREX derivatives.

Regarding news announcements, it is important to distinguish between scheduled announcements (the announcement is planned, e.g. US macroeconomic figures) and unscheduled ones (e.g. interest rate reports). Unscheduled announcements can lead to both public and private information, according to their market effects. If the information is public information only, then the unscheduled event is not preceded by an abnormal increase in volatility. On the other hand, an unexpected rise in volatility during the pre-announcement period indicates that informed trades (private information) take place. For scheduled announcements, an abnormal increase in volatility during the pre-announcement period can be linked to speculative trades initiated on the basis of anticipations, or to traders who close their positions to avoid 'surprises' when the news is released.

The link between volatility and private information was suggested in the theoretical work of Admati and Pfleiderer (1988), who developed their model on the basis of Glosten and Milgrom (1985) and Kyle (1985). In their model, informed traders prefer to transact during periods of high trading activity in order to maximise the potential profit that comes from their private information. In addition, liquidity motivated traders are also active during this period to profit from narrow spreads and high market activity. An important empirical implication of this model is that private information leads to increased price volatility during periods of high trading activity.

Set in the FOREX framework, this type of analysis suggests that the dynamics of currency rate quotes will therefore be shaped by the news announcements and by the information that each trader has. When no private information is at play, currency rate quotes should adjust to events after their announcements. On the other hand and in the presence of information asymmetry, FOREX quotes adjust to private information before the news announcement, continue their adjustment during the announcement and volatility then decreases during the post-announcement period. Degennaro and Shrieves (1997) undertake an empirical study in which they test the theoretical results of Admati and Pfleiderer (1988). They analyze the pattern of volatility around news announcements (grouped within three categories) and study the impact of the release of macroeconomic, economic policy and interest rate reports on the volatility of the Dollar/Yen exchange rate. They find that high market activity (seasonal component removed) leads to increases in volatility and spread, which they interpret as private information effects. These results are in agreement with Lyons (1995, 1997) and Evans and Lyons (1999), who show that a significant part of the order flow in FOREX markets is made up of deals between traders and their customers (which generate private information). The impact of news announcements on volatility appears to be significant and depends on the category of news. Volatility is also proportional to the frequency of macroeconomic and interest rate announcements. Andersen and Bollerslev (1998b) and Cai, Cheung, Lee, and Melvin (2001) analyze the sensitivity of short and long term volatility (for the Dollar/DM and Dollar/Yen FOREX quotes) with respect to US macroeconomic announcements and seasonal factors. Andersen and Bollerslev (1998b) show that announcements have a significant positive effect, but for a very short period of time. Seasonal factors, such as the opening of the local markets, lunch breaks, some specific days of the week (Thursday and Friday, i.e. days for the US macroeconomic announcements), also lead to volatility increases. The study carried out by Cai, Cheung, Lee, and Melvin (2001) confirms the results of Andersen and Bollerslev (1998b) and shows the importance of the positive effect (on volatility) of the order flow, in comparison with the news announcements. Eddelbuttel and McCurdy (1998) do not classify the news in categories but count instead the number of events in a given time interval. To get rid of the seasonal component of news announcements, they divide each count number by its cross sectional average so that the outcome then defines the surprise effect. Deseasonalized counts lead to increases in both market activity and return volatility for Dollar/Yen quotes.

2.1 News announcements and news categories

The empirical studies of Andersen and Bollerslev (1998b) and Cai, Cheung, Lee, and Melvin (2001) reviewed above analyze the specific effect of each announcement. They focus on the post-event volatility reaction. In our study, we take into account the specific effect of each news category but we also assess the volatility response before, during and after the news event. Moreover we distinguish scheduled and unscheduled news announcements. Indeed, taking into account the specific features of public and private information, the news impact on volatility can take place both before and after the announcement. Accordingly it is important to define three periods around the actual news release: a pre-announcement period, a short period just after the announcement and a post-announcement period. In case of scheduled news announcements, volatility increases in the pre-announcement period could be due to anticipatory trades by dealers who open positions to profit from some personal beliefs, i.e. they hope that the actual news outcome will coincide with their forecast of the outcome. A post-announcement volatility increase can be traced to heterogeneity of interpretations of the content of the news, surprised reactions and closing of positions based on prior anticipations. On the other hand, in case of unscheduled news announcements (i.e. not planned into any economic agenda), an increase in volatility before the announcement is probably linked (as suggested by Degennaro and Shrieves (1997)) to the presence of informed traders who exploit their privileged information.

In this paper we set our empirical analysis in this framework and test the impact of nine categories of news. Note that four of these categories are new to the FOREX literature. News announcements are classified into two groups, scheduled and unscheduled announcements. The first group contains US macroeconomic figures, more specifically employment reports, producer and consumer price indices, gross domestic product and other important figures.[1] This group also includes European macroeconomic figures, scheduled speeches of senior officials of the government and of government agencies, such as the president of the Federal Reserve, the European Central Bank and the economy and finance ministers. The second group is made up of US and European interest rate reports and the forecasts of key institutes and specialized organizations, such as IMF, the World Bank, and the IFO institute.[2] This group also contains the declarations of OPEC members,

[1] Table 1 lists all the news categories.

[2] The IFO institute is one of the largest in Germany. The IFO Institute is a service-based research organization with a three-fold orientation: to conduct economic research, to offer advice

the rumors of Central Bank intervention and other extraordinary events (natural disasters, wars, terrorist attacks,...). To highlight the effect of the possible 'surprise' contained in the scheduled US macro economic figures, we distinguish so-called positive from negative news by computing the difference between the expected and realized values. If the realization is larger than the expectation and is a figure which contributes to the growth of the economy, the news is classified as positive. If the actual figure means instead worse-than-expected inflation or a slowdown of the economy, it is regarded as negative. This methodology is also used in Andersen, Bollerslev, Diebold, and Vega (2002), where they test the effect of non anticipated news announcements on currency returns. They conclude that unanticipated events lead to jumps in the conditional mean of currency returns and that negative news have a greater impact than positive news.

2.2 Volatility and activity

In the FOREX empirical literature, the sensitivity of volatility to exogenous factors is usually assessed and quantified using GARCH models, as for example in Degennaro and Shrieves (1997) and Melvin and Yin (2000). The use of a conditional volatility model such as GARCH is justified by the key features of the distribution of FOREX returns (volatility clustering and fat tails). Note however that recent studies, such as Andersen and Bollerslev (1998) and Cai, Cheung, Lee, and Melvin (2001), set their analysis in the framework of realized volatility, i.e. the volatility computed from the sum of the squared high frequency returns.[3] In our study we first use the EGARCH specification of Nelson (1990), adding dummy variables which measure the impact of the news categories. The model is detailed in Section 3. In a second step, we test the impact of selected events on realized volatility. This second type of model is also presented in Section 3.

Next to return volatility, a second important variable is the market activity. FOREX market activity, measured by the number of trades in a given time interval, is considered by many (e.g. Bollerslev and Domowitz, 1993 and Melvin and Yin, 2000) as a proxy for volatility and should therefore be affected by the news announcements.[4] Market activity is also a proxy for private information (Degennaro and Shrieves, 1997; Evans and Lyons, 1999 and Rime, 2000). A significant part of the order flow is due to transactions between traders and their customers. Customer-dealer trades are not observable by the other market participants. Therefore they are a source of information asymmetry among dealers and can be considered as private information. Consequently, when traders execute these orders, they play a role of information intermediation/transfer between their clients and other traders. For example, Lyons (1997) shows that traders could be motivated to exploit the information contained in their own customer orders to take speculative positions that distort this information intermediation.

to economic policy-makers and to provide services for the research and business communities. The 'IFO Business Climate Index' on the business climate in Germany is perhaps their best known product.

[3]The concept of realized volatility is defined in Section 3.4.

[4]To quantify the market activity we use the number of quotes, and not the volume of transactions which is not publicly revealed. Indeed, a significant part of the FOREX market volume is made up of orders carried out between traders and their customers, which is private information.

The empirical study of Degennaro and Shrieves (1997) shows that the unexpected component of market activity (i.e. market activity adjusted from its seasonal component) can be viewed as a proxy for private information: unexpected market activity leads to an increase in volatility and a widening of the spread.[5] In our study, we test the impact of market activity on return volatility by distinguishing between the unexpected and expected components of market activity, in order to infer the possible effect of private information. We also study the impact of news announcements on market activity.

2.3 Seasonality of volatility and market activity

The literature on the volatility of FOREX returns stresses that the market openings/closings, week-ends and some days of the week lead to significant cyclical factors in the modelling of volatility (Bollerslev and Domowitz, 1993; Andersen and Bollerslev (1996, 1998); Degennaro and Shrieves (1997). For example, Andersen and Bollerslev (1998b) show that scheduled news announcements have a seasonal impact on volatility. These news events exhibit both a cyclical and a stochastic component, the latter being the news not properly anticipated by the market participants and thus is the 'surprise' effect. To remove the seasonal effects and to highlight the stochastic components, it is first necessary to detect and identify the factors that are likely to generate periodic effects. A number of methods have been recently put forward in the literature. Degennaro and Shrieves (1997) introduce the cross sectional average of market activity (this method is detailed in Section 3.1) in the volatility equation. They use dummy variables to allow for separate effects of each hour of the day but they do not discriminate between different days of the week. In order to model the seasonal impact, Andersen and Bollerslev (1998b) introduce the flexible Fourier form (FFF in what follows), i.e. a sum of sinusoids, to detect intraday cycles. Dacorogna, Muller, Nagler, Olsen, and Pictet (1993) and Eddelbuttel and McCurdy (1998) deseasonalize volatility using an adjustment factor. This factor is proportional to the (mean) absolute value of the returns over a time interval divided by the size of the time interval. To remove seasonality Melvin and Yin (2000) divide returns by their cross sectional average.

In this paper, we need to identify both the seasonal and the stochastic components of volatility and market activity. To compute the seasonal component of volatility, we use the method based on the cross sectional average, allowing for separate effects for each day of the week. We use the same method to deseasonalize market activity when we analyze its impact on volatility. On the other hand, we use the FFF technique to study the impact of news announcements on the cross sectional average volatility and on market activity. The models are detailed in Section 3.

[5] The relationship between private information and the size of the spread can be traced back to Glosten and Milgrom (1985) and many subsequent studies.

3 The models

3.1 Volatility and news announcements

To study the sensitivity of volatility with respect to the news announcements and market activity, we use the EGARCH model of Nelson (1990). Returns are modelled by a moving average process with two lags to allow for the usual (slight) autocorrelation of intraday returns:

$$q_t = \theta_0 + u_t + \rho_1 u_{t-1} + \rho_2 u_{t-2}, \tag{1}$$

where q_t is the standardized (deseasonalized) return, i.e. the return divided by the square root of the cross sectional average volatility at time t.[6] The residual term u_t follows an EGARCH(2,2) process:

$$u_t = \sqrt{h_t}\,\epsilon_t, \tag{2}$$

$$\begin{aligned} \ln(h_t) \quad &= \quad \omega + \sum_{i=1}^{2}(\beta_i \ln(h_{t-i}) + \alpha_i \left[\mid \epsilon_{t-i} \mid - \sqrt{2/\pi} \right] + \gamma_i \epsilon_{t-i}) \\ &\quad + \sum_{j=1}^{9}\sum_{\tau=1}^{3} \eta_{j,\tau} d_{j,\tau,t} + \phi\, as_{t-1} + \delta\, am_{t-1}, \end{aligned} \tag{3}$$

where h_t is the conditional variance of u_t and the innovations ϵ_t are identically and independently normally distributed. The variable as_t is the proxy for market activity divided by its seasonal index, am_t. The latter is computed as the cross sectional average of the number of quotes over each five-minute time interval for each day of the week. With these two variables in the model, we want to assess the impact of private information as proxied by the flow of orders between traders and their customers. When ϕ is significantly positive whereas δ is not statistically different from zero, an increase in deseasonalized volatility can only be due to unexpected trading activity, which basically corresponds to the flow of orders (private information) between dealers and their customers.[7] The dummy variable $d_{j,\tau,t}$ is for the event j, announced during the period τ, and for the time interval ending in t. It is equal to 1 if there is a news announcement during the time interval τ and is equal to 0 otherwise. The τ index indicates the observation window: a pre-announcement period ($\tau = 1$), a period just after the announcement ($\tau = 2$) and a post-announcement period ($\tau = 3$). In the econometric model, we also allow one lead and two lags in the dummy variable for the event j. Returns and market activity are computed on equidistantly time spaced five-minute intervals, whereas the observation windows are equal to 15 minutes before the announcement ($\tau = 1$), five minutes just after the announcement ($\tau = 2$), and 20 minutes after the announcement($\tau = 3$). The relevant news events are given in Table 1. Because we distinguish between positive and negative figures regarding the US macroeconomic

[6] The cross sectional average volatility is the average (over all days) of squared returns computed at time t, see Section 3.2 and Equation (5) for more details.

[7] Dividing returns by the square root of the average cross sectional volatility means that h_t is the deseasonalized conditional variance.

announcements, category 1 in Table 1 is thus duplicated and corresponds to $j = 1$ (positive figures) and $j = 2$ (negative figures). The other news categories start thereafter with $j = 3$.

3.2 The cross sectional average volatility and the impact of news announcements

To detect the seasonal effect of news announcements on cross sectional average volatility, we use an ARMA(1,1) model and we allow for a day-of-the-week effect. Seasonal effects which originate from the structural characteristics of the FOREX market (opening times, lunch breaks, closing times,...) are modelled by an FFF of order P.[8] The model can be written in the following way:

$$\begin{aligned} mv_t &= c_0 + \beta mv_{t-1} + \sum_{p=1}^{P} (\delta_{c,p} \cos x_{t,p} + \delta_{s,p} \sin x_{t,p}) \\ &+ \sum_{j=1}^{9} \eta_j \, z_{t,j} + \alpha \epsilon_{t-1} + \epsilon_t. \end{aligned} \tag{4}$$

To compute mv_t (the cross sectional average volatility), we divide each day into 288 five-minute intervals. For each interval per day of the week over the six-month period of our data base, we have one Euro/Dollar return. We thus compute 288 mv_t for each day of the week (except for Mondays, 287, and Fridays, 264). Each mv_t is the average of the squared returns at index n_k of day k ($k = 1$ is for Monday, $k = 5$ is for Friday). For example, the value of mv_t on Tuesday at 12h is the average of the squared returns observed every Tuesday at 12h during the six-month period. Formally,

$$mv_t = mv_{f(1,k,n_k)} = \frac{1}{S} \sum_{s=1}^{S} r^2_{f(s,k,n_k)}, \tag{5}$$

where S is the number of weeks in the sample (we have S weeks beginning on Monday and ending on Friday) and

$$f(s,k,n_k) = 1415\,(s-1) + 288\,(k-1) + n_k. \tag{6}$$

The t index is defined as the function $t = f(1,k,n_k)$, i.e. a function of k (the day index, 1 to 5) and n_k (the index of the five-minute intervals, which varies from 2 to 288 for Monday, from 1 to 264 for Friday, and from 1 to 288 for Tuesday, Wednesday and Thursday).[9] Thus, in Equation (5), the index t goes from 1 to $287 + (3 \times 288) + 264 = 1,415$, which is equal to the number of five-minute intervals in a week of five open days. On the other hand, when s varies from 1 to 26, the function $f(s,k,n_k)$ takes the values from 1 to 36,790 ($= (25 \times 1415) + 287 + (3 \times 288) + 264$), and this gives us 26 returns for the same period of day k in order

[8] We choose $P = 4$ according to Akaike criterion.

[9] The first interval of Monday and the intervals from 22h05 to 24h of Friday are deleted as explained in Section 4.1.

to compute the cross sectional average.[10] The variable mv_t, with t ranging from 1 to 1,415, is used to deseasonalize the returns $r_g = \ln(p_g/p_{g-1})$, where p_g is the Euro/Dollar currency rate at time g, by dividing these by the square root of mv_t. This yields the standardized returns q_g introduced in Equation (1). As g varies from 1 to 37,650, we use the relationship $g = 1415\,(s-1) + 288\,(k-1) + n_k$ for some value of s, k and n_k to identify the index t of mv_t corresponding to each g.

The variable $x_{t,p}$ that appears in the FFF in Equation (4) is defined by:

$$x_{t,p} = \frac{2\pi p\, n_k}{N_k} \text{ for } n_k = 1, 2, \ldots, N_k, \text{ and } k = 1, 2, \ldots, 5, \tag{7}$$

where p is the FFF expansion and N_k is the number of time intervals per day: $N_k = 288$ for all open days of the week, except for Mondays ($N_1 = 287$) and Fridays ($N_5 = 264$). Therefore, there is a one-to-one correspondence between each value of the index t of $x_{t,p}$ and a given five-minute interval in a specific day of the week (the link is made via the relationship $t = f(1, k, n_k)$.)

The variable $z_{t,j}$ of Equation (4) corresponds to nine categories of news announcements (j ranges from 1 to 9). This variable gives the number of news announcements belonging to category j that occur during the five-minute time interval indexed by t. For example, $z_{1,1}$ is the number of news announcements corresponding to positive US macroeconomic figures released every Monday between 00h05 and 00h10 over the six-month sample of our dataset.

3.3 Market activity and news announcements

To study the impact of news announcements on FOREX market activity, we regress the latter on a set of dummy variables which stand for the news announcements in the three observation windows. The dynamics of market activity is best modelled by the use of a polynomial in the lag operator. We also introduce the FFF to take into account the intraday cyclical patterns. The equation is given by:

$$A(L) f_t = c_0 + \sum_{p=1}^{P} (\delta_{c,p} \cos x_{t,p} + \delta_{s,p} \sin x_{t,p}) + \sum_{j=1}^{9} \sum_{\tau=1}^{3} \eta_{j,\tau} d_{j,\tau,t} + \epsilon_t \tag{8}$$

where f_t is the market activity, unadjusted from its seasonal component. A(L) is the lag operator polynomial (after several trials, we decided to use 8 lags). f_t is observed every five minutes for each week and the variable $x_{t,p}$, defined for the first week in Equation (7), is computed for all 1,415 observations to compute a series of the same length as f_t.

If news announcements significantly impact market activity, this would be in agreement with Melvin and Yin (2000) who show that market activity is not self-generated but is instead sensitive to (and strongly determined by) news events. In the alternative case, we can support the conclusions of Lyons (1997) and Evans and Lyons (1999) who show that public information does not have a large impact as opposed to the impact due to the behaviour of traders controlling their positions and managing the flow of orders from their clients.

[10] In our study, we have 37,650 observations, i.e. 26 full weeks and the start of the twenty-seventh week.

3.4 Realized volatility and news announcements

An alternative approach to modelling volatility is to focus on realized volatility. Although recently popularized by Andersen and Bollerslev (1998a), Merton (1980) already mentioned that, if data sampled at a high frequency are available, the sum of the squared realizations can be used to estimate the variance of the process. Taylor and Xu (1997) and Andersen and Bollerslev (1998a) (among others) show that daily realized volatility may be computed by summing up the squared intraday returns of the asset under study. Recent work on realized volatility include Andersen, Bollerslev, Diebold, and Labys (2000), Andersen, Bollerslev, Diebold, and Ebens (2001), Andersen, Bollerslev, Diebold, and Labys (2001a), Andersen, Bollerslev, Diebold, and Labys (2001b) and Giot and Laurent (2001).

In this paper, we compute the realized volatility over a grid of equidistantly time spaced hourly intervals using fifteen-minute (deseasonalized) returns. Therefore, the realized volatility rv_t computed at time t is defined by:

$$rv_t = \sum_{i=1}^{n} r_{i,t}^2, \tag{9}$$

where n is the number of regularly time spaced observations in the time interval $[t-1,\, t]$ (i.e. the timespan we integrate on) and $r_{i,t}$ is the deseasonalized return at time $t - 1 + \frac{i}{n}$ belonging to the time interval $[t-1,\, t]$. In our study, the time interval between $t-1$ and t corresponds to 1 hour and is divided into 4 sub-intervals ($n = 4$), such that $r_{i,t}$ is the return observed every fifteen minutes. Because we now work with one-hour intervals, it is necessary to redefine the three time intervals pertaining to the news announcements: one hour before the announcement, one hour around the announcement and one hour after the announcement. According to the literature on realized volatility, realized volatility is best modelled using its natural logarithm, i.e. a model for $ln(rv_t)$. This stems from the fact that the distribution of $ln(rv_t)$ is close to a normal distribution, with long memory.[11] We thus use the ARFIMA(0,d,0) model introduced by Ballie (1996), to model the long memory effect.[12] As for the EGARCH model, news announcements dummy variables, market activity and FFF are added in the model. Note that the FFF is introduced to detect possible seasonal patterns which have not be taken into account by the cross sectional average method. This yields the following model:

$$\begin{aligned}(1-L)^d \ln(rv_t) = \alpha_0 &+ \sum_{j=1}^{9}\sum_{\tau=0}^{2} \eta_{j,\tau} D_{j,\tau,t} + \phi as_{t-1} \\ &+ \sum_{p=1}^{P} (\delta_{c,p} \cos y_{t,p} + \delta_{s,p} \sin y_{t,p}) + \epsilon_t,\end{aligned} \tag{10}$$

where as_t is the deseasonalized market activity. The dummy variables for news announcements $D_{j,\tau,t}$ correspond to the same news categories presented in the previous model, except that the reference period for the dummy variables is now

[11] According to McLeod and Hipel (1978), the process is characterized as long memory if $\lim_{n\to\infty} \sum_{j=-n}^{n} \mid \rho_j \mid$ is nonfinite (ρ_j is the autocorrelation coefficient at lag j).

[12] The lag of the model was chosen according to Akaike criterion.

one hour rather than five minutes. The is also the case for the observation windows for which $\tau = 0, 1, 2$ respectively indicates the contemporaneous, leading and lagged hourly news announcements. The variable $y_{t,p}$ is equal to $2\pi p\, n_k/N_k$ and N_k indicates the number of hours per day: $N_k = 24$, for all open days of the week except for Fridays ($N_5 = 22$), and n_k takes the values $1, 2, \ldots, N_k$. The FFF expansion is limited at $P = 4$.

4 The data

The Euro/Dollar FOREX market is a market maker based trading system, where three types of market participants interact around the clock (i.e. in successive time zones): the dealers, the brokers and the customers from which the primary order flow originates. The most active trading centers are New York, London, Frankfurt, Sydney, Tokyo and Hong Kong. A complete description of the FOREX market is given by Lyons (2001).

4.1 The FOREX quotes

To estimate the econometric models, we use a high frequency intraday data set made up of 'tick-by-tick' observations for a period of 6 months (from May 15 to November 14, 2001). Our sample features 3,420,315 observations.[13] These Euro/Dollar quotes are market makers quotes and not transactions quotes, which are not widely available. However, Danielsson and Payne (2002) show that the statistical properties of such FOREX quotes, in particular Dollar/DM quotes sampled every five minutes, are similar to the statical properties of transaction quotes. The data were filtered using the filter of Dacorogna, Muller, Nagler, Olsen, and Pictet (1993).[14] More specifically, the dataset contains the date, the time of day timestamped to the second in Greenwich mean time (GMT), the dealer bid and ask quotes, the identification codes for the country, city and market maker bank and a return code indicating the filter status. If the code value is greater than 0.5, the quote is retained, otherwise it is rejected. Table 2 shows a sample of our database.

Returns are computed on the average of the bid and ask prices. As we consider five-minute sampling periods, we build a daily grid that contains 288 five-minute intervals. The total number of observations in the grid is 37,650. When we use 15-minute sampling intervals (to compute the realized volatility), the number of intervals in the grid is equal to 3,110. At the end of each interval, we use the immediately preceding and following middle quote to compute the relevant price. The quotes are weighted by their inverse relative distance to the endpoint.[15] The return at time t is then defined as the difference between the logarithms of the two

[13] The data were provided by Olsen and Associates in Zurich.

[14] Dacorogna, Muller, Nagler, Olsen, and Pictet (1993) and Guillaume, Dacorogna, Dav, Muller, Olsen, and Pictet (1994) show that, during intervals of intense trading activity, some quotes are not entered into the electronic system. If traders are too busy or the system is running at full capacity, quotations displayed in the electronic system may lag prices by a few seconds to one or more minutes.

[15] This distance is measured by the time interval between the end of interval and the time tag of the quote.

weighted middle prices computed at the endpoints of the intervals, i.e. at times $t-1$ and t, and multiplied by 10,000.[16]

Because of the scarce trading activity during the week-end (which starts on Friday evening), we exclude all returns computed between Friday 22h and Sunday 24h. In addition, we exclude the first return of each Monday to avoid possible biases due to the lack of activity during the week-end. Table 3 presents the first four moments of the Euro/Dollar returns. The characteristics of the non-standardized returns are given in the first line of the table, while the second line refers to the standardized returns. The mean of the returns is almost equal to zero and the distribution of the standardized returns is slightly skewed to the right and exhibits fat tails. Non-standardized returns are more leptokurtic however. Figure 1 tells the same story. The distribution of the standardized returns is close to the standardized normal distribution, which is not the case for the distribution of the non-standardized returns. Table 4 shows that the standardized returns are negatively autocorrelated. For Goodhart and Figliuli (1991), the negative autocorrelation stems from constraints in the control of positions; Bollerslev and Domowitz (1993) and Lo and MacKinlay (1990) claim that the construction of asynchronous price series based on the endpoints of the intervals constitutes a reasonable explanation for this negative autocorrelation. Note that the autocorrelation coefficients are not statistically significant from the third lag onwards, which justifies the dynamics of Equation (1).

4.2 The seasonality of the news announcements, volatility and market activity

Our dataset includes the news headlines that were released on the Reuters news-alert screens over the May 15 to November 14, 2001 time period. These events are timestamped to the minute and are a key feature of our news announcements analysis. In addition to the news headlines, Reuters also provides an economic agenda, which gives the day and time of some of the announcements that are scheduled in the following week. The impact of these scheduled events included both a deterministic (seasonal) component and a stochastic component. The latter reflects the surprise effect due to the actual content of the news, i.e. the focus is on the discrepancy with the expected content of the news on which the market participants agreed before the news release. Figure 2 illustrates the periodicity of four scheduled news announcements. As indicated in this table, US macroeconomic figures are usually released at 12h30 and 14h00 GMT. European macroeconomic announcements are mostly released around 7h30 and 10h00 GMT. As far as the announcement days are concerned, Table 5 presents the number of news belonging to each category for each day of the week. The number of news announcements during the 6-month period of our study is equal to 1,040. Around 61% of US macroeconomic figures are released at the end of the week, in particular on Thursdays and Fridays. European macroeconomic figures are usually released every Wednesday. Therefore, we should expect that these regularly scheduled news announcements lead to a seasonal effect on volatility.

[16]We choose this multiplier because the FOREX market quotes feature 10,000 basis points.

As mentioned above, the Euro/Dollar is almost continuously traded in FOREX markets that belong to different time zones. A look at the intraday market activity indicates periods of high and low activity. Figure 3 illustrates the seasonality of the volatility of five-minute returns, i.e. we plot the square root of the cross sectional average of the volatility computed on five-minute returns.[17] Volatility increases after midnight, i.e. at the opening of the Singapore and Hong Kong markets, one hour after the opening of the Tokyo market and two hours after Sidney. Around 4h GMT volatility decreases because of the lunch break in the four Asian financial markets. Thereafter, volatility increases again because trading activity resumes in the Asian markets and it reaches a local maximum around 7h-8h GMT, i.e. right after the opening of the key European markets such as London and Frankfurt. This pattern of volatility increases around the opening and closing times of the regional markets are in agreement with Admati and Pfleiderer (1988), who show that these periods are characterized by a sustained level of market activity, which in turn attracts different categories of traders. In addition, Lyons (1997) shows that, because traders have to control/close their positions at the end of every day, they increase their activity right before the close of trading and just after the market opening to get rid of unwanted risky positions. Because of the lunch break in Europe, volatility decreases around 11h30. A second rebound in volatility occurs at 12h GMT as New York opens for trading. Between 12h and 16h GMT volatility reaches its global maximum due to the simultaneous activity of American and European markets. Just before the New York lunch break, which is clearly visible in the figure around 17h GMT, there is a short volatility shock, reflecting the closing of the European markets. Volatility increases also around 21h GMT, i.e. when the New York trading session ends. Starting at 21h GMT, a short period of stability is then observed until the opening of the Sidney and Tokyo markets, which leads to an increase in volatility.

Figure 4 indicates that the seasonality of volatility is also day-of-the-week dependent: shocks are mainly observed on Tuesdays and Wednesdays around 8h, 10h and 16h30 (interest rate reports and European macroeconomic figures), Thursdays and Fridays around 12h, 12h30 and 16h30 (US macroeconomic figures and speeches of senior officials of the government). Therefore, some of the seasonality in volatility stems from the cyclical component of scheduled news announcements. In addition, Figure 4 shows that volatility increases for a short period of time in all markets at the beginning of the trading sessions of each Monday.[18] This volatility increase during the first minutes of trading of every week is linked to the control of positions: FOREX traders who accumulate customers' orders at the end of the Friday session and who could not settle their positions have to keep them during the week-end.[19] To minimize the risk of these positions, dealers are keen on executing their remaining orders in the first minutes of the Monday session. They do so by quoting attractive prices to attract counterparts and quickly close their positions. Figure 5 illustrates the cross sectional average activity during the

[17] See Equation (5).

[18] Volatility increases every Monday around 0h, 8h, 13h, and 22h, which are respectively the opening hours of the Asian, European, American and Australian markets.

[19] Lyons (1997) describes the position control motivated trades between dealers as "hot potato trades".

24-hour trading day. The day-of-the-week effect is weak for the American and European markets and it is almost absent for the Asian and Australian markets. Moreover, Monday is the least active day of the week. Figure 5 clearly shows the significant difference between market activity in Europe and the USA, with respect to the trading activity in the Asian and Australian markets. Figures 6 and 7 show the autocorrelograms for volatility and market activity before and after seasonal adjustments. In both cases, the deseasonalization is based on the cross sectional averaging method, which leads to better results for volatility than for market activity. Indeed, the cyclical component of volatility is relatively attenuated after the deseasonalization, but the autoregressive effect is still present. On the other hand and despite the deseasonalization, market activity still exhibits a cyclical component, which implies that the cross sectional average method is not so attractive for the market activity. Therefore, we use the FFF technique to deseasonalize market activity when it is used as a dependent variable, as in Equation (8).

5 Estimation results

5.1 The impact of news announcements and activity on volatility

Table 6 reports the estimation results for the standardized returns modelled with the EGARCH(2,2) model.[20] The residuals are not autocorrelated and the coefficients are significant, which validates our choice of the MA(2) specification. Regarding the EGARCH coefficients, the conditional variance is stationary ($\beta_1+\beta_2 < 1$) and the coefficients of asymmetric impact are not significant (γ_i). A negative shock (on the standardized returns) does not lead to a larger rise in volatility than a positive shock of the same absolute value. The total impact of the news announcements dummy variables is significant, since the Wald test for the null hypothesis that all the coefficients of the dummy variables are equal to 0 delivers a P-value lower than 1% (the Wald statistic is equal to 68.5 for 27 restrictions).

Let us first examine the impact of the scheduled news announcements.[21] Table 6 shows that US positive ($\eta_{1,1}$) and negative ($\eta_{2,1}$) macroeconomic figures significantly impact volatility during the pre-announcement period. The anticipation by the market participants of negative and positive figures lead to an increase in return volatility of the same size.[22] However, volatility significantly decreases 20 minutes after the announcement of positive US figures ($\eta_{1,3}$ is significantly negative) but volatility does not decrease significantly after a negative announcement ($\eta_{2,2}$ and $\eta_{2,3}$ are not significant). This can be traced back to the behaviour of the traders (Lyons, 1995 and 1997) and their anticipations with respect to positive

[20]The estimation is performed with the quasi-maximum likelihood (QML) algorithm. The EGARCH(2,2) dynamical structure ensures that the standardized squared residuals are not correlated.

[21]These news announcements are given in Table 1.

[22]The null hypothesis for the equality between these two coefficients is not rejected (P-value=54%). It is also the case for the full effect around the announcement, i.e. the two news categories have the same impact on volatility: the null hypothesis $H0 : \eta_{2,1} + \eta_{2,2} + \eta_{2,3} = \eta_{1,1} + \eta_{1,2} + \eta_{1,3}$ is not rejected, with a P-value equal to 24%.

and negative figures. Because of risk aversion, traders who anticipate negative figures adjust their quotes by taking positions before the announcement. Then they close these positions when they reach a predetermined level in their trading results. Thus, they do not wait for the actual news announcements to avoid possible significant price jumps which would go against their positions.[23] Despite their risk aversion, traders who anticipate positive figures adjust their quotes before the announcement to attract counterparts so that the maximum profit can be realized. Traders know that the market reaction after a release of positive figures does not yield an heterogeneity in the traders' reactions and a market panic. A volatility drop in the post-announcement period could be due to the homogeneity of positive figures interpretations.

The coefficients of the dummy variables for the European macroeconomic figures are significant in the pre-announcement period ($\eta_{3,1}$) and just after the announcement ($\eta_{3,2}$). Volatility increases in the first period and decreases in the second period. However, volatility reverts quickly to its initial level: the sum of the $\eta_{3,\tau}$ is not significantly different from zero, with a P-value equal to 71%. This is also the case for the speeches of the senior government officials and those of government agencies ($\eta_{4,\tau}$). In this case however, there is a volatility rebound in the post-announcement period, i.e. 20 minutes after the news announcement. But volatility does not revert to its initial state as the sum of the $\eta_{4,\tau}$ is significantly different from zero, with a P-value equal to 2.8%. Pre-announcement volatility increases could also be justified by anticipatory trades regarding scheduled announcements. However, a decrease in volatility just after the announcement could imply a temporary reduction in information asymmetry or simply a 'time-out' during which traders attempt to assess the news (Degennaro and Shrieves, 1997). European figures are often compared to the figures enforced by the Maastricht treaty (that is, the convergence criteria related to budget deficit, public debt, inflation rate, and long term interest rate). The volatility rebound 20 minutes after the announcement emphasizes the impact of the speeches of senior officials of the government, in particular heads of Central Banks and the economy and finance ministers, on the volatility of the FOREX market.

All the news announcements considered above are scheduled news announcements. According to our econometric results, we can therefore conclude that most scheduled news announcements lead to a rise in Euro/Dollar FOREX volatility, particularly in the pre-announcement period, an increase mainly explained by anticipatory trades. Note also that, for the same period preceding the announcements, another category of traders take part in the trading. These traders, who are characterized by a high level of risk aversion, prefer to execute their clients' orders right before the news release to avoid possible reversals of trends in the currency rate (Lyons, 1991). Volatility increases around the announcements of US macroeconomic figures and the speeches of senior officials of the government, while it reverts in average to its initial level (i.e. 20 minutes before the announcement) around the European macroeconomic figures.

Let us now consider the unscheduled news announcements. The release of

[23]Quote jumps are sometimes observed in FOREX markets, in particular when bad economic figures are released. Jumps are induced by significant news surprise and the vulnerability of participants in a market where the traders' reactions are heterogeneous and divergent.

interest rate reports increases volatility in the pre-announcement period ($\eta_{5,1}$). Though these news are not scheduled, they still generate anticipatory trades regarding the timing their announcement. Indeed, the release of these types of news occur at a given time and often on given days of the week. Taking into account their knowledge of the market, some traders enter trading positions before hypothetical announcements and hope that their anticipations will coincide with the contents of the interest rate report. The impact of the dummy variable for this news category, measured by $\eta_{5,1} + \eta_{5,2} + \eta_{5,3}$, is estimated at 0.11 (with a P-value lower than 1% for its significance), which indicates that volatility increases significantly compared to its level right before the announcement. The most significant pre-announcement increase in volatility is related to rumors of Central Bank interventions ($\eta_{8,1}$). Such an increase also takes place before the announcement of the rumor, but in this case, it is not due to anticipatory trades. Before being broadcasted by a specialized news agency, rumors of an intervention circulate for a certain period of time from one dealer to another until they become widely disseminated. Then, specialized agencies treat them seriously and announce them. It is during this circulation phase that the market react to the news, through price adjustments.

Once the rumor is refuted, volatility stabilizes or drops ($\eta_{8,2}$, estimated at -0.57, is significantly negative and negates the pre-announcement positive effect estimated at 0.45).[24] Note that this news category is very important and shows the extent of the influence which the intervention of a Central Bank can exert on the behavior of market participants. The news related to the forecast of institutes and specialized think-tanks ($\eta_{6,\tau}$), the OPEC members declarations ($\eta_{7,\tau}$), and other extraordinary events ($\eta_{9,\tau}$), despite their potential impact on the economy, do not have any significant effect on volatility. Broadly speaking, unscheduled news announcements, except those related to interest rate reports and central bank intervention rumors, have very little impact on the volatility of Euro/Dollar returns.

Last, the significant positive effect of deseasonalized market activity, along with the non-significant impact of the cross sectional average activity, implies that market activity (adjusted from its seasonal component) could be considered as a proxy for private information (Degennaro and Shrieves, 1997). Thus, volatility rises in periods of high activity. This increase is fed by information asymmetry between traders. Each trader benefits from his privileged information that originates from the order flow with his own customers (Lyons, 1997).

5.2 The impact of news seasonality on volatility

Table 7 gives the results of the estimation of Equation (4). In that model, the cross sectional average volatility (for each five-minute period throughout the week) is regressed on cyclical variables generated by the FFF (that represent daily cycles) and on variables pertaining to the seasonality of news announcement. These variables seasonally impact volatility, with a day-of-the-week effect. A Wald test shows that the null hypothesis of joint non-significance of the nine coefficients

[24]The estimated total effect, i.e. $\eta_{8,1} + \eta_{8,2} + \eta_{8,3}$, is equal to -0.24 but it is not significantly different from zero (P-value = 95%).

of these variables is rejected, with a P-value much lower than 1% (the statistic is equal to 321). More precisely, the variables for the scheduled news announcements, in particular US macroeconomic figures, European figures, and speeches of senior officials of the government, have significant coefficients. Thus these events have a seasonal impact on volatility. Interest rate reports also feature a significant seasonal impact, since they occur at given times and on given days of the week. These results confirms those of Andersen and Bollerslev (1998b) with respect to the seasonal impact of scheduled events on volatility. FFF coefficients are, but for a few exceptions, significant with a P-value lower than 1%. These coefficients take into account the remaining seasonal components, i.e. those not due to the cyclical news releases (for example the opening, closing and lunch break effects).

5.3 The impact of news announcements on market activity

The results for the market activity model are presented in Table 8. In that model, market activity is regressed against news announcements dummy variables. Most of the coefficients of the lag polynomial are significant (at the 1% level).[25] The FFF also captures a significant part of the seasonality so that regression residuals do not exhibit any significant autocorrelation. The coefficients of the dummy variables are jointly significant at the 1% level (the likelihood ratio is equal to 64.2, for 27 restrictions.). Note that the significant effects (though at a level of 5%) are for the negative US figures ($\eta_{2,2}$) and for interest rate reports ($\eta_{5,2}$). In both cases, the effect is short-lived and does not go beyond five minutes after the announcement. We conclude that the order flow is sensitive to these news categories but for a very limited time only.

5.4 The impact of news announcements on realized volatility

We report in Table 9 the estimation results for the impact of the news announcements on the realized volatility. The news announcements are computed on hourly time spaced intervals. The fractional parameter d is equal to 0.16, which confirms that the logarithm of realized volatility is a stationary long memory process ($0 < d < 0.5$). There is no evidence of any significant contemporaneous effect of news announcements (coefficients $\eta_{j,0}$). This can be explained by the limitations inherent to the hourly aggregation frequency, which leads to a significant loss of information around the announcement period. Moreover, the test for global significance of the dummy variables exhibits a P-value of 10% (the likelihood ratio is equal to 37.14, for 27 restrictions). When we consider non-contemporaneous dummy variables, there are now seven significant coefficients, one of which is related to a post-announcement variable (coefficient $\eta_{5,2}$), and the other six coefficients are related to the pre-announcement period (i.e. index $\tau = 1$). The volatility increase in the period subsequent to the release of interest rate reports can be explained by heterogeneity in the interpretation of this kind of news and by a high level of information asymmetry. Volatility increases one hour before the release of US macroeconomic positive figures ($\eta_{1,1}$), European figures ($\eta_{3,1}$) and interest rate reports ($\eta_{5,1}$). On the other hand, volatility decreases one hour before

[25] We do not report these coefficients in Table 8. They are available on request.

the announcement of US macroeconomic negative figures ($\eta_{2,1}$), OPEC members declarations ($\eta_{7,1}$), and extraordinary events ($\eta_{9,1}$). This latter effect is rather difficult to account for, because of the heterogeneous character of the exceptional events considered. However, the volatility decrease prior to US negative figures ($\eta_{2,1}$) can be explained by a reduction of trading activity when traders try to make speculative trades. Because of risk aversion, these traders prefer to postpone trading until right before the news announcement. Last, market activity (ϕ) leads to a significant rise in volatility because of the increase in the order flow between traders and their customers.

6 Conclusion

Using high frequency data sampled at the five-minute frequency, we estimate the impact of news announcements and private information on the volatility of Euro/Dollar FOREX returns. Regarding the news releases, we highlight the impact of both scheduled and unscheduled news announcements. We also take into account FOREX private information, proxied by the level of deseasonalized market activity. Our results, based on EGARCH and realized volatility type models, give similar results under two different time aggregations schemes (respectively five minutes and one hour). More precisely, the release of scheduled news lead to a pre-announcement rise in volatility (the pre-announcement timeframe ranges from fifteen to sixty minutes according to the type of model considered). This increase in volatility in the pre-announcement period is much less significant when announcements of unscheduled news are at play, except for interest rate reports and for rumors of central bank intervention. The estimation results show that volatility increases right before the announcement of scheduled news and unscheduled-but-periodic news (for example the interest rate reports): these categories of news attract traders who wish to make anticipatory trades based on their anticipations/personal beliefs. However, the reaction of volatility in the post-announcement period is muted. Indeed, most of the news announcements considered in our study have not been followed by significant volatility increases/decreases in the post-announcement period. To summarize, on the one hand, cyclical news announcements lead to a systematic rise in volatility (i.e. they impact the cyclical component of volatility). On the other hand, the adjustment of the stochastic component of volatility with respect to news announcements seems to follow this pattern: (1) volatility increases in the pre-announcement period because of speculative trades, informed trades, or because some traders close their positions to avoid 'surprises'; (2) the adjustment of volatility goes on in the contemporaneous period; (3) changes in volatility are small in the post-announcement period. In addition, the volatility of Euro/Dollar returns is positively and significantly affected by market activity (adjusted from its seasonal component). This stresses the importance of private information in FOREX markets as a main determinant of volatility, the private information stemming primarily from the flow of orders between traders and their clients.

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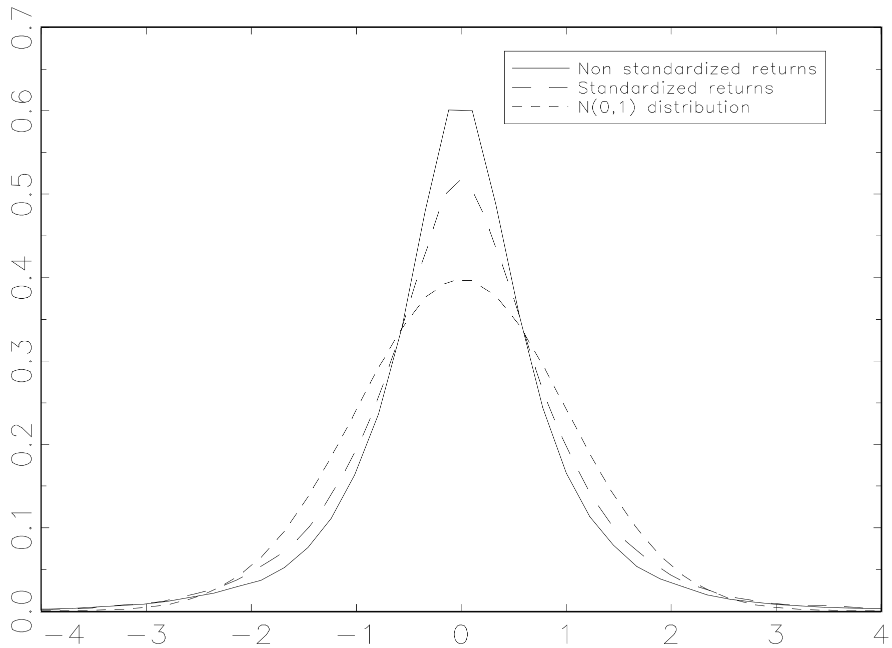
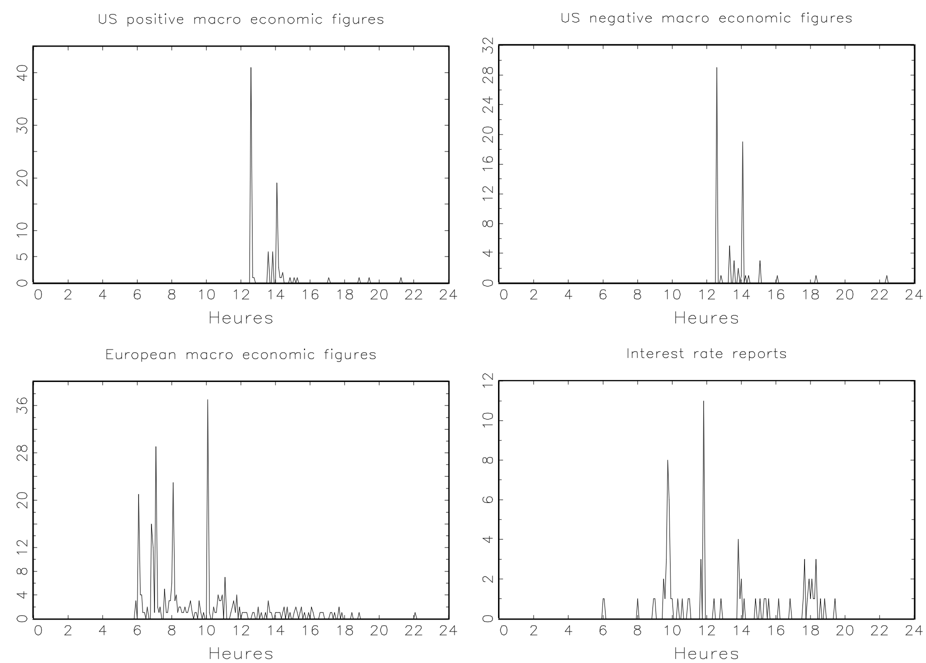


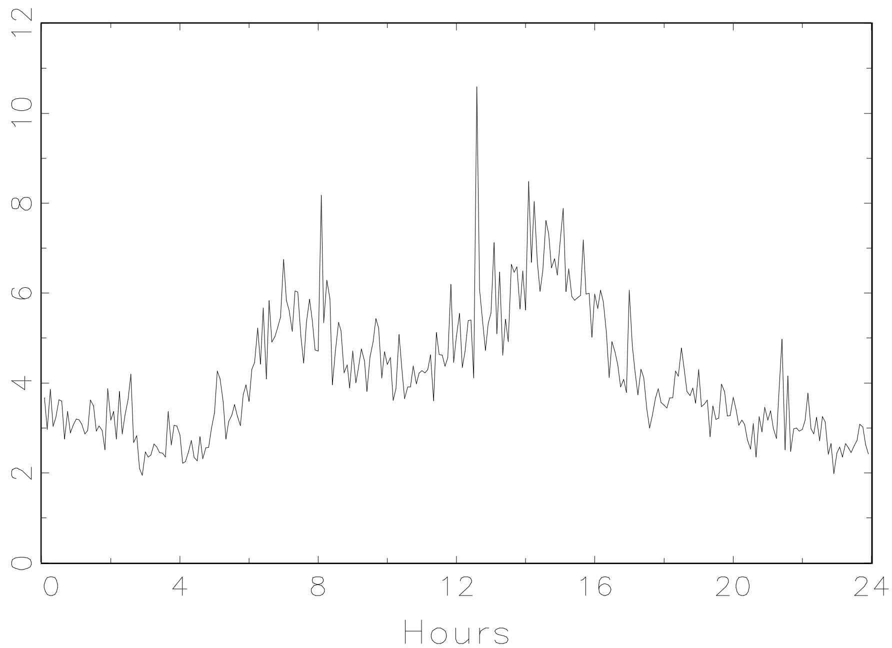
The densities of standardized returns have been estimated with
a kernel method.

Figure 1: Return densities and the standard normal distribution



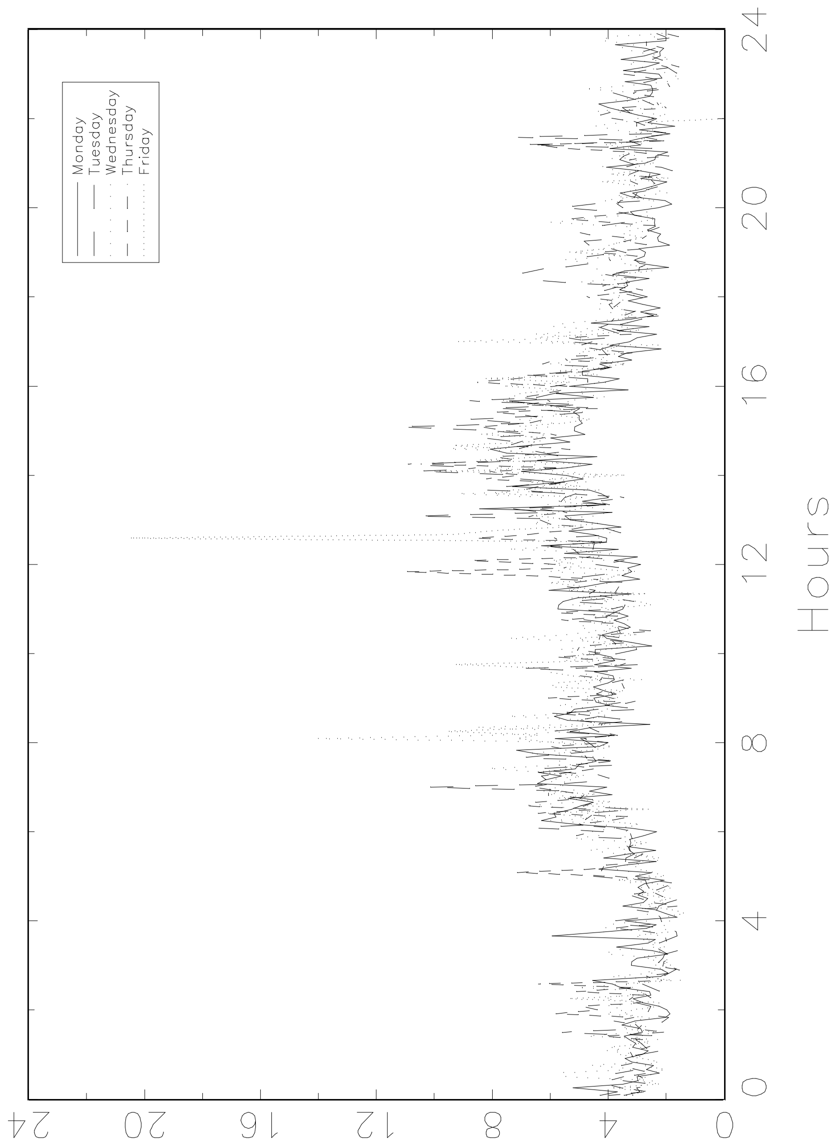
In ordinates: number of news announcements during the May 15 - November 14, 2001 period.

Figure 2: The announcements' times for four categories of events



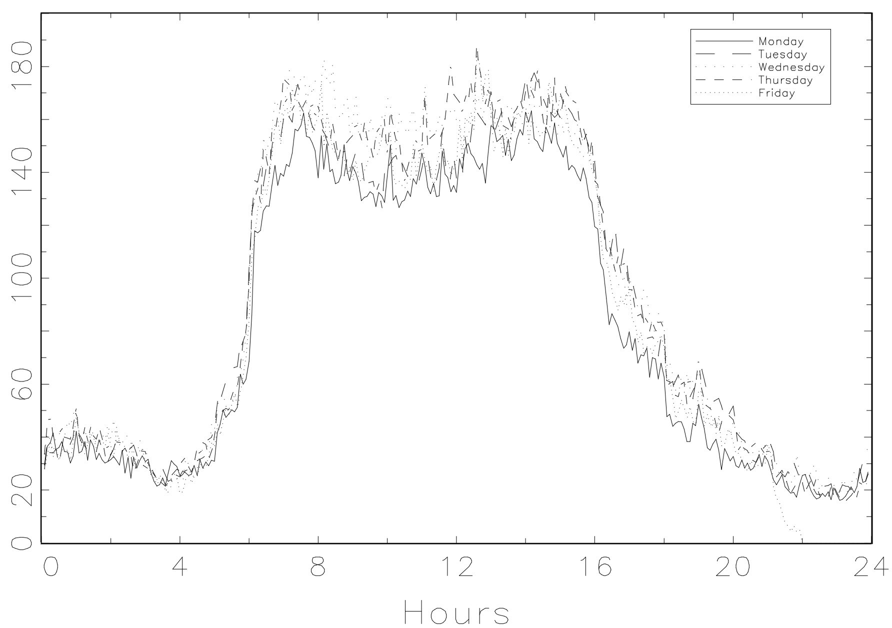
This figure presents the square root of the average cross sectional volatility (mv_t) computed as in Equation (5), all days of the week are assumed to exhibit the same volatility profile.

Figure 3: Square root of the cross sectional average intraday volatility



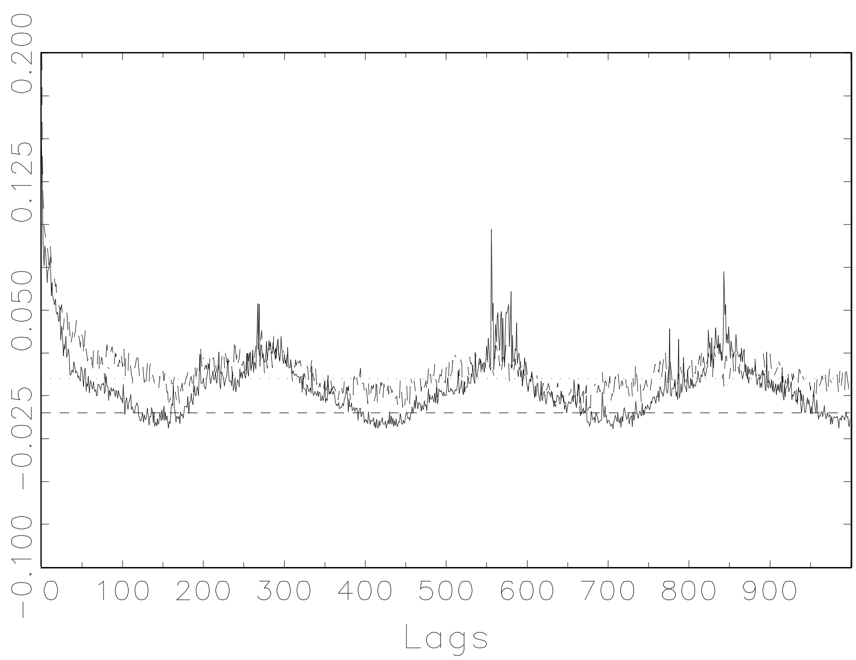
This figure presents the square root of the average cross sectional volatility (mv_t) computed as in Equation (5). A day-of-the-week effect is allowed.

Figure 4: Square root of the cross sectional average intraday volatility for each day of the week



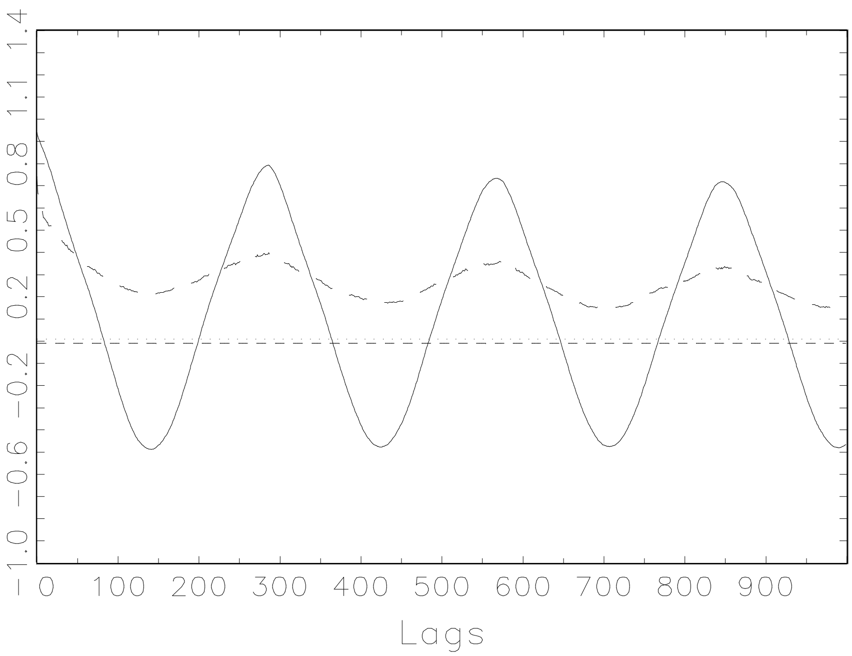
This figure shows the cross sectional average market activity for different days of the week (am_t), see also Equation (3). In ordinates, number of quotes.

Figure 5: Intradaily cross sectional average market activity for each day of the week



The solid and dashed lines display the autocorrelations of volatility respectively before and after the seasonal adjustment (method based on the cross sectional average).

Figure 6: Autocorrelogram of volatility before and after seasonal adjustment



The solid and dashed lines display the autocorrelations of market activity respectively before and after the seasonal adjustment (method of the cross sectional average).

Figure 7: Autocorrelogram of market activity before and after seasonal adjustment

Table 1: News categories

Scheduled news announcements		
1 and 2-US macroeconomic figures	Positive	Negative
	$\eta_{1,\tau}$	$\eta_{2,\tau}$
Employment report	-	+
ISM index(ex NAPM)	+	-
Whole sales	+	-
Gross domestic product (GDP)	+	-
Producer price index (PPI)	-	+
Retail sales	+	-
Housing starts	+	-
Consumer confidence index	+	-
Consumer price index (CPI)	-	+
Construction spending	+	-
Car sales	+	-
Business inventories	-	+
Housing completions	+	-
Import prices	-	+
Current account deficit	-	+
Non-farm productivity	+	-
Personal income	+	-
Real earnings	+	-
House sales	+	-
3-European macroeconomic figures	$\eta_{3,\tau}$	
4-Speeches of senior officials of the governement and those of government agencies	$\eta_{4,\tau}$	
Unscheduled news announcements		
5-US and European interest rate reports	$\eta_{5,\tau}$	
6-Forecasts made by economic institutes	$\eta_{6,\tau}$	
7-Declarations of OPEC members	$\eta_{7,\tau}$	
8-Rumors of Central Bank interventions	$\eta_{8,\tau}$	
9-Extraordinary events	$\eta_{9,\tau}$	

- The events are the news headlines released on the Reuters money news-alerts.

- For US news, we separate positive and negative news-alerts by comparing the expected and the announced numbers. If the actual numbers are larger than the expectations for economic variables that contribute to economic growth, the announcements are classified as positive (+). If the actual news release means more inflation or a forthcoming economic slowdown, it is classified as a negative news announcement (-). The expected values are given on Reuters screens a few days before the news announcements.

- The employment report also includes the unemployment figures.

- ISM is the abbreviation for the Institute of Supply Management, ex NAPM, National Association of Purchasing Management. It is a monthly composite index and gives the earliest indication of the health of the manufacturing sector.

- The symbol $\eta_{j,\tau}$ is the coefficient of the dummy variable $d_{j,\tau}$ in the equations whose estimation results are reported in Tables 6, 8, 9. In Table 7, coefficients are put as η_j.

Table 2: Example from the Olsen and Associates data base

Date	Hour	Bid	Ask	Bank	Filter
06.11.2001	11:44:43	0.89720	0.89740	UBS	1
06.11.2001	11:44:48	0.89720	0.89750	SAMH	0.98598
06.11.2001	11:44:51	0.89710	0.89750	OHVA	0.97472
06.11.2001	11:44:54	0.89730	0.89750	UBS	1
06.11.2001	*11:44:55*	*0.89720*	*0.89740*	*UBS*	*1*
06.11.2001	*11:45:06*	*0.89720*	*0.89760*	*OKOH*	*0.98337*
06.11.2001	11:45:13	0.89710	0.89810	SHKH	0.98621
06.11.2001	11:45:16	0.89730	0.89750	UBS	1
06.11.2001	11:45:18	0.89720	0.89760	BARL	0.98998
06.11.2001	11:45:21	0.89700	0.89760	OHVA	0.99117

Interpolated price measured at 11:45:00:

-Nearest previous mid-price: (0.8972+0.8974)/2 = 0.8973

-distance to 11h45: 5 secondes

-Nearest following mid-price: (0.8972+0.8976)/2=0.8974

-distance to 11h45: 6 secondes

-interpolated price: $(\frac{0.8973}{5} + \frac{0.8974}{6})/(\frac{1}{5} + \frac{1}{6}) = 0.89735$

The last column gives the output of the Dacorogna, Muller, Nagler, Olsen, and Pictet (1993) filter. The quote is accepted only if the filter output is larger than 0.5.

Table 3: Moments of the Euro/Dollar returns

	Mean	Standard deviation	Asymmetry Coefficient	Kurtosis Coefficient
Returns	0.007	4.410	0.340	15.190
Standardized returns	0.0006	1.00	0.025	4.720

Standardization involves dividing returns by the square root of the cross sectional average volatility (see Section 3.1). Returns are multiplied by 10,000. The number of observations is 37,650, and the time period ranges from May 15 to November 14, 2001.

Table 4: Autocorrelation coefficients for the standardized returns

Lags	Autocorrelation	Q-Stat	Q-Stat/$\chi^2(0.05)$
1	-0.1200	552.70	143.88
2	-0.027	579.79	96.77
3	-0.0011	579.83	74.20
4	-0.0007	579.86	61.12
5	-0.0029	580.17	52.41
6	-0.0118	585.45	46.50
7	0.0084	588.09	41.81
8	-0.0036	588.58	37.96
9	0.0028	588.87	34.81
10	-0.0015	588.95	32.17

See Table 2 for more details on data.

Table 5: Daily news announcements frequency

	Monday		Tuesday		Wednesday		Thursday		Friday		Total
Categories	Tot	%	Tot	%	Tot	%	Tot	%	Tot	%	
d1	11	12.5	13	14.77	12	13.64	23	26.14	29	32.95	88
d2	5	7.25	12	17.39	8	11.59	25	36.23	19	27.54	69
d3	42	14.05	68	22.74	76	25.42	59	19.73	54	18.06	299
d4	45	21.74	39	18.84	46	22.22	41	19.81	36	17.39	207
d5	21	25.93	27	33.33	13	16.05	15	18.52	5	6.17	81
d6	24	26.66	16	17.77	25	27.77	14	15.55	11	12.22	90
d7	21	21.21	17	17.17	24	24.24	19	19.19	18	18.18	99
d8	5	41.66	1	8.33	2	16.66	2	16.66	2	16.66	12
d9	22	23.16	14	14.74	20	21.05	24	25.26	15	15.79	95
Total	196	18.85	207	19.90	226	21.73	222	21.35	189	18.17	1040

d1: Positive US macroeconomic figures; **d2**: Negative US macroeconomic figures; **d3**: European macroeconomic figures; **d4**: Speeches of senior officials of the government and of government agencies; **d5**: US and European interest rate reports; **d6**: Economic institutes forecasts; **d7**: OPEC members declarations; **d8**: Central Bank intervention rumors; **d9**: Extraordinary events.

Table 6: Estimation results for Equations (1)-(3)

$$q_t = \theta_0 + u_t + \rho_1 u_{t-1} + \rho_2 u_{t-2} \quad (1)$$
$$u_t = \sqrt{h_t}\epsilon_t \quad (2)$$
$$\ln(h_t) = \omega + \sum_{i=1}^{2}(\beta_i \ln(h_{t-i}) + \alpha_i \left[\mid \epsilon_{t-i} \mid - \sqrt{2/\pi}\right] + \gamma_i \epsilon_{t-i}) \quad (3)$$
$$+ \sum_{j=1}^{9}\sum_{\tau=1}^{3} \eta_{j,\tau} d_{j,\tau,t} + \phi\, as_{t-1} + \delta am_{t-1}$$

Coefficient	Estimation	P-Value (%)	Coefficient	Estimation	P-Value (%)
θ_0	0.003	41	ρ_1	-0.133**	0.0
ρ_2	-0.027**	0.0	ω	-0.059**	0.0
α_1	0.294**	0.0	$\eta_{5,1}$	0.169**	0.0
α_2	-0.022**	0.0	$\eta_{5,2}$	0.009	88
γ_1	-0.001	74	$\eta_{5,3}$	-0.064	31
γ_2	0.005	39	$\eta_{6,1}$	-0.062	25
β_1	1.322**	0.0	$\eta_{6,2}$	0.018	83
β_2	-0.346**	0.0	$\eta_{6,3}$	0.024	71
$\eta_{1,1}$	0.137**	0.1	$\eta_{7,1}$	-0.070*	8.8
$\eta_{1,2}$	0.038	59	$\eta_{7,2}$	0.055	37
$\eta_{1,3}$	-0.116**	4.3	$\eta_{7,3}$	0.037	48
$\eta_{2,1}$	0.177**	0.0	$\eta_{8,1}$	0.453**	1.2
$\eta_{2,2}$	-0.027	73	$\eta_{8,2}$	-0.570**	2.0
$\eta_{2,3}$	-0.029	66	$\eta_{8,3}$	-0.124	52
$\eta_{3,1}$	0.088**	0.1	$\eta_{9,1}$	0.070	16
$\eta_{3,2}$	-0.081**	2.5	$\eta_{9,2}$	0.099	18
$\eta_{3,3}$	-0.001	96	$\eta_{9,3}$	-0.051	37
$\eta_{4,1}$	0.064*	7.1	ϕ	0.005**	0.0
$\eta_{4,2}$	-0.101*	6.4	δ	0.000	96
$\eta_{4,3}$	0.082*	5.5			
Obs.	37 650			$W(\eta_{j,\tau}=0)$	68.5**
j	1	2	12	24	
$Q(j)$	1.17	1.46	11.00	22.28	
$Q^2(j)$	1.26	2.76	8.83	24.20	

** et * indicate respectively the significant level at 5% and 10%. $W(\eta_{j,\tau}=0)$ is the Wald statistic for the null hypothesis pertaining to the global non-significance of the 27 coefficients $\eta_{j,\tau}$. $Q(j)$ and $Q^2(j)$ are the Ljung-Box statistics with lag j respectively for standardized residuals and for their square. Lags equal to 12 and to 24 are related to one and two hours. Variables in Equations (1)-(3): q_t is the standardized return (multiplied by 10,000); $d_{j,\tau,t}$ is a dummy variable for the event j announced during period τ and for the 5-minute time interval t; as_t is the deseasonalized market activity and am_t the market activity seasonal index. The estimation method is the quasi maximum likelihood (QML) method.

Table 7: Estimation results for Equation (4)

$$mv_t = c_0 + \beta mv_{t-1} + \sum_{p=1}^{4}(\delta_{c,p}\cos x_{t,p} + \delta_{s,p}\sin x_{t,p}) + \sum_{j=1}^{9}\eta_j z_{t,j} + \alpha\epsilon_{t-1} + \epsilon_t \qquad (4)$$

Coefficient	Estimation	P-Value (%)	Coefficient	Estimation	P-Value (%)
c_0	18.39**	0.0			
β	0.85**	0.0			
α	-0.69**	0.0	η_1	7.59**	0.0
$\delta_{c,1}$	-10.97**	0.0	η_2	4.41**	0.1
$\delta_{c,2}$	-1.17	30	η_3	1.30**	0.9
$\delta_{c,3}$	4.89**	0.0	η_4	-2.68**	1.3
$\delta_{c,4}$	-2.67**	0.9	η_5	3.36**	0.0
$\delta_{s,1}$	-3.75**	0.0	η_6	-1.66	30
$\delta_{s,2}$	2.97**	0.7	η_7	-0.54	73
$\delta_{s,3}$	-2.71**	1.2	η_8	-1.07	80
$\delta_{s,4}$	2.08**	4.4	η_9	3.11	4.0
Obs.	1 415	R^2	0.39	$W(\eta_j = 0)$	321**
j	1	2	12	24	
$Q(j)$	0.88	1.04	22.75	42.85	

** et * indicate respectively the significant level at 5% and 10%. $W(\eta_j = 0)$ is the Wald statistic for the null hypothesis pertaining to the global non-significance of the 9 coefficients η_j. Q(j) are the Ljung-Box statistic with lag j, for the residuals.
Variables in Equation (4): mv_t is the cross sectional average volatility for each time interval t (see Section 3.2); $z_{t,j}$ is the announcement number for the news category j fives minutes before the index t; $x_{t,p} = 2\pi p\, n_k/N_k$ where $k = 1\ldots5$, N_k is the daily time interval number (287 for Monday, 264 for Friday, 288 for the other open day of the week), and $n_k = 1\ldots N_k$. The estimation method is the quasi maximum likelihood (QML) method.

Table 8: Estimation results for Equation (8)

$$A(L)f_t = c_0 + \sum_{p=1}^{8}(\delta_{c,p}\cos x_{t,p} + \delta_{s,p}\sin x_{t,p}) + \sum_{j=1}^{9}\sum_{\tau=1}^{3}\eta_{j,\tau}d_{j,\tau,t} + \epsilon_t \quad (8)$$

Coefficient	Estimation	P-Value (%)	Coefficient	Estimation	P-Value (%)
c_0	2.61	0.	$\eta_{2,3}$	2.66	38
$\delta_{c,1}$	-2.08**	0.0	$\eta_{3,1}$	-0.99	51
$\delta_{c,2}$	-0.04	80	$\eta_{3,2}$	-0.24	87
$\delta_{c,3}$	0.33*	6.8	$\eta_{3,3}$	-1.42	34
$\delta_{c,4}$	3.08**	0.0	$\eta_{4,1}$	0.57	74
$\delta_{c,5}$	0.32**	3.4	$\eta_{4,2}$	-0.24	89
$\delta_{c,6}$	-1.38**	0.0	$\eta_{4,3}$	-0.52	79
$\delta_{c,7}$	0.94**	0.0	$\eta_{5,1}$	-3.90*	9.9
$\delta_{c,8}$	1.36**	0.0	$\eta_{5,2}$	6.23**	3.6
$\delta_{s,1}$	5.20**	0.0	$\eta_{5,3}$	1.80	55
$\delta_{s,2}$	-0.56**	0.0	$\eta_{6,1}$	0.26	92
$\delta_{s,3}$	-3.74**	0.0	$\eta_{6,2}$	-1.38	57
$\delta_{s,4}$	2.09**	0.0	$\eta_{6,3}$	-2.13	48
$\delta_{s,5}$	2.14**	0.0	$\eta_{7,1}$	-2.10	38
$\delta_{s,6}$	-1.31**	0.0	$\eta_{7,2}$	-1.53	37
$\delta_{s,7}$	-0.31*	5.6	$\eta_{7,3}$	-2.68	22
$\delta_{s,8}$	0.87**	0.0	$\eta_{8,1}$	-0.51	91
$\eta_{1,1}$	4.35*	6.7	$\eta_{8,2}$	-4.32	54
$\eta_{1,2}$	3.46	25	$\eta_{8,3}$	1.27	84
$\eta_{1,3}$	-1.26	67	$\eta_{9,1}$	0.11	96
$\eta_{2,1}$	0.70	83	$\eta_{9,2}$	-1.26	61
$\eta_{2,2}$	9.42**	1.3	$\eta_{9,3}$	-2.32	27
Obs.	37 650	R^2	0.91	$LR(\eta_{j,\tau}=0)$	64.2**
j	1	2	12	24	
$Q(j)$	0.002	0.03	2.90	39.16	

** et * indicate respectively the significant level at 5% and 10%. $LR(\eta_{j,\tau} = 0)$ is the likelihood ratio statistic for the null hypothesis pertaining to the global non-significance of the 27 coefficients $\eta_{j,\tau}$. Q(j) is the Ljung-Box statistic with lag j for the residuals.
Variables in Equation (8): f_t is the deseasonalized market activity; $d_{j,\tau,t}$ is a dummy variable for the event j announced during period τ and for the 5-minute time interval t; $x_{t,p} = 2\pi p\, n_k/N_k$ where $k = 1\ldots5$, N_k is the daily time interval number (287 for Monday, 264 for Friday, 288 for the other open day of the week), and $n_k = 1\ldots N_k$ (see Section 3.3). The estimation method is the ordinary least square (OLS) method with Newey-West HAC standard errors. This table does not report the estimation results for the $A(L)$ parameters.

Table 9: Estimation results for Equation (10)

$$(1-L)^d \ln(rv_t) = \alpha_0 + \sum_{j=1}^{9} \sum_{\tau=0}^{2} \eta_{j,\tau} D_{j,\tau,t} + \phi\, as_{t-1} + \sum_{p=1}^{8} (\delta_{c,p} \cos y_{t,p} + \delta_{s,p} \sin y_{t,p}) + \epsilon_t \quad (10)$$

Coefficient	Estimation	P-Value (%)	Coefficient	Estimation	P-Value (%)
α_0	0.16	0.0	$\eta_{5,1}$	0.08**	0.1
d	0.16	0.0	$\eta_{5,2}$	0.10**	4.6
$\eta_{1,0}$	0.01	73	$\eta_{6,0}$	-0.004	87
$\eta_{1,1}$	0.10**	0.0	$\eta_{6,1}$	0.03	30
$\eta_{1,2}$	-0.04	40	$\eta_{6,2}$	0.01	86
$\eta_{2,0}$	-0.01	77	$\eta_{7,0}$	0.005	84
$\eta_{2,1}$	-0.07**	1.7	$\eta_{7,1}$	-0.07**	1.0
$\eta_{2,2}$	0.06	28	$\eta_{7,2}$	0.04	42
$\eta_{3,0}$	0.01	69	$\eta_{8,0}$	-0.04	0.59
$\eta_{3,1}$	0.06**	0.0	$\eta_{8,1}$	-0.01	93
$\eta_{3,2}$	-0.02	47	$\eta_{8,2}$	-0.07	59
$\eta_{4,0}$	-0.001	92	$\eta_{9,0}$	-0.01	79
$\eta_{4,1}$	0.03	15	$\eta_{9,1}$	-0.16**	0.0
$\eta_{4,2}$	0.01	69	$\eta_{9,2}$	0.001	98
$\eta_{5,0}$	-0.004	86	ϕ	0.19	0.0
Obs.	3 110			$LR(\eta_{j,\tau}=0)$	37.14*
j	1	2	12	24	
$Q(j)$	0.28	0.48	5.47	14.64	

** et * indicate respectively the significant level at 5% and 10%. $LR(\eta_{j,\tau}=0)$ is the likelihood ratio statistic for the null hypothesis pertaining to the global non-significance of the 27 coefficients $\eta_{j,\tau}$. Q(j) is the Ljung-Box statistic with lag j, for the residuals.
Variables in Equation (10): $\ln(rv_t)$ is the logarithm of realized volatility; $D_{j,\tau,t}$ is a dummy variable for the event j announced during period τ and for the 60-minute time interval t; $y_{t,p} = 2\pi p\, n_k/N_k$ where $k = 1\ldots5$, N_k is the number of hours per day (22 for Friday and 24 for the other open days of the week), and $n_k = 1\ldots N_k$; as_t is the deseasonalized market activity. The estimation method is the maximum likelihood method with a normal distribution. FFF estimated coefficients are not reported in this table because there is only one significant coefficient at the 5% level (the coefficient for the first cosine, corresponding to hourly seasonality).