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The intra-day impact of communication on euro-dollar volatility and jumps☆

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Abstract

In this paper, we examine the intra-day effects of verbal statements and comments on the FX market uncertainty using two measures: *continuous volatility* and *discontinuous jumps*. Focusing on the euro-dollar exchange rate, we provide empirical evidence of how these two sources of uncertainty matter in measuring the short-term reaction of exchange rates to communication events. Talks significantly trigger large jumps or extreme events for approximately an hour after the news release. Continuous volatility starts reacting prior to the news, intensifies around the release time and stays at high levels for several hours. Our results suggest that monetary authorities generally tend to communicate with markets on days when uncertainty is relatively severe, and higher than normal. Disentangling the US and Euro area statements, we also find that abnormal levels of volatility are mostly driven by the communication of the Euro area officials rather than US authorities.

Key words: Central bank communication, Exchange rate communication, Official statements, High-frequency data, Jump process, Volatility

JEL: E58, F31, G15

☆The views expressed in this paper are solely our own and do not necessarily reflect those of the National Bank of Belgium (NBB).

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"*....The euro area has a shared interest in a strong and stable international financial system, as excess volatility and disorderly movements in exchange rates have adverse implications for economic and financial stability.*"

(J. C. Trichet, December 08, 2010, Official Press Release)

1. Introduction

Do financial markets react to communication? Recent empirical research has focused on this question and established that oral interventions are an important source of information for the markets. Surveying the literature, Blinder et al. (2008) conclude "*communication can be an important and powerful part of the central bank's tool since it has the ability to move financial markets*".

Most of the studies in this literature examine whether monetary officials and policy-makers are indeed able to move the foreign exchange market and financial markets more broadly in the right direction by communicating verbally (see e.g. Beine et al., 2009; Conrad and Lamla, 2010; Fratzscher, 2008a,b, 2006; Jansen and De Haan, 2007, 2005; Rosa and Verga, 2008, 2007 among others). In this regard, the effectiveness of verbal policy announcements has been tested in different ways, focusing on the impact of oral interventions on both the level of the exchange rate and its volatility. Although most of these studies find that the statements are successful in affecting the level, the effect on volatility is more ambiguous. While some papers conclude that communication can effectively "calm disorderly market conditions" (e.g. Beine et al., 2009; Fratzscher, 2006; Gnabo et al., 2009), many reach the opposite conclusion (see Jansen and De Haan, 2007, 2005 among others).

From the policy-makers' standpoint, two forms of currency market responses are desirable. First, exchange rates should adjust to news contemporaneously, so that the effects on levels become transitory. In that sense, prolonged adjustment processes and long-lasting impacts may create turbulence, and even deteriorate the perception of market participants (Gnabo et al., 2012). Second, officials expect communication to lower exchange rate volatility and thus resolve market uncertainty. Nevertheless, if agents tend to interpret the same news differently, volatility is likely to surge some time after the release of an announcement (Evans, 2005). Even though market participants observe the news simultaneously and have similar views, unclear statements with ambiguous information could also prompt volatility in foreign exchange markets. Our objective is therefore to better understand how and when market uncertainty reacts to verbal statements of monetary officials.

In particular, we depart from the existing literature in three ways. First, we consider two measures of market uncertainty: *discontinuous jumps* and *continuous volatility*. While the "jumps" measure represents the sudden market reactions and tells us whether the news adjustment is contemporaneous or not, the "continuous volatility" measure describes the persistent market response to communication events. Second, we use high-frequency exchange rate data, which allows us to process more information in order to measure market uncertainty at every instant of time. Third, we focus on both US and Euro area exchange rate communication policies. We distinguish the intra-day influence of the US and Euro area statements and hence bring separate policy implications.

In general, studies use volatility as a measure of uncertainty and ignore the presence of jumps. Proceeding this way, however, may be incorrect and/or incomplete for at least three reasons. First, as Carnero et al. (2007), Charles and Darné (2005), Franses and Ghijsels (1999) and Muller and Yohai (2008) show, Gaussian quasi-maximum likelihood (QML) estimates of GARCH models, subject to the presence of additive jumps, tend to overestimate the volatility for the days following the jumps, and produce also upward-biased estimates of long-term volatility. Second, one can improve volatility forecasts by removing jumps from current and lagged volatility as documented in Andersen et al. (2007a) and Neely (1999). Third, taking the presence of jumps into account allows us to disentangle continuous movements of market volatility from sudden and short-lasting spikes. This flexibility—which we adopt in this paper—has important economic and financial implications: jump events represent tail risk and market fear, which require a premium that cannot be explained by continuous volatility movements (see e.g. Bollerslev and Todorov, 2011a,b).

To isolate jumps from the continuous volatility, we use a modified version of the non-parametric technique proposed by Andersen et al. (2007a) and Lee and Mykland (2008). This parsimonious technique allows the identification of jumps at an intra-day level. The intuition behind this technique is to consider that a jump has occurred when a return is too big to plausibly have come from pure diffusion, that is, when a return is big relative to local volatility conditions. Jumps are not necessarily large in absolute terms. If volatility is low, a relatively small return can be detected as a jump. A recent criticism that has been leveled at the Lee and Mykland approach is that it does not account for the presence of intra-daily volatility periodicity. As shown by Boudt et al. (2011), disregarding this well-known feature of the volatility pattern may have a remarkable impact on the accuracy of the jump detection method. To deal with this issue, the modified version of the Lee and Mykland's statistic—recently proposed by Boudt et al. (2011)—is applied here.

The remainder of our paper is organized as follows. In Section 2, we review the literature on central bank communication policy. Section 3 details the data description, and Section 4 presents the methodology. Section 5 reports our empirical findings. Finally, Section 6 concludes.

2. Related literature

How does communication influence exchange rate behavior? On the theoretical side, oral interventions may affect the dynamics of exchange rates via three channels. The first of these—known as the "signaling channel"—asserts that the use of communication may work as a signaling device such that market participants and investors may view communication as an indicator of future policy directions regarding exchange rates. (Kaminsky and Lewis, 1996; Mussa, 1981). As an alternative to the signaling channel, Sarno and Taylor (2001) introduce the "co-ordination channel" through which the announcements of the monetary authorities may help stabilize the imperfect knowledge of the market participants, getting the beliefs of the investors converged towards one another. Evans and Lyons (2005) take a more microstructural view, and further investigate how and when the news is transmitted to the currency markets. Following their theoretical insight, we can consider the communication as a *common knowledge* news, observed simultaneously and interpreted similarly by all market participants. As we will see in our empirical study, any departure from these assumptions will thus trigger exchange rate fluctuations.

From an empirical perspective, previous research on the influence of communication upon financial markets is rather scarce, but growing. Amongst such studies, Fatum and Hutchison (2002) considered the impact of statements made by officials after the introduction of the euro, both for and against past and future interventions by the ECB, as well as the impact of rumors of interventions and reported operations. They showed that statements denying interventions and questioning the efficacy of these operations exerted some negative effect on the level of the euro. Jansen and De Haan (2005) particularly focused on the communication of the ECB and European National Central Banks. Their results, however, showed that the mean of the euro-dollar rate does not react to the macro and FX statements substantially, whereas the conditional volatility is somewhat considerably affected. More recently, Fratzscher (2008a,b) analyzed the short-term effectiveness of verbal FX statements along with the actual interventions for the three major central banks over the period 1990-2003. He found that oral interventions are indeed successful in both lowering volatility and moving the exchange rates in the officials' desired directions contemporaneously, as well as over the medium- to long-term. Based on the same central bank study, Beine et al. (2009) provide evidence that explanatory comments by the central bankers during the periods of the official exchange rate interventions can be effective both upon the mean and the volatility. These results are confirmed by Gnabo and Teiletche (2009) using implied moments from option data.

With very few exceptions, all studies used daily data for assessing the impact of oral interventions on the exchange rate dynamics. In an intra-daily perspective, Jansen and De Haan (2007) employed an event-study approach based on the non-parametric sign test to examine the effectiveness of verbal interventions of ECB officials and found that the effects of verbal interventions are small and short-lived. In the same spirit, but using intra-daily exchange rate and official central bank intervention data, Dominguez (2006) analyzed the influence of interventions on exchange rate volatility, finding evidence of both within-day and daily impact effects, but little evidence that interventions influence longer-term volatility. Recently, Kim and Le (2010) used intra-daily data and concluded that official interventions conducted during the periods of "oral interventions" were more effective in moving the exchange rates in the desired direction.

We position our paper in the same vein, yet bring three contributions to the literature.

First, we show that oral interventions not only influence intra-day volatility but also produce abrupt exchange rate movements or jumps. This result also implies that the intra-day effects of communication are not transitory, and hence the adjustment of exchange rates to news is not simultaneous. Second, we show that different communication policies generate different market reactions. The explanation for this finding could be due to the coordination failure between monetary bodies and/or the credibility of policy-makers. Moreover, while both Euro area and US officials tend to communicate with markets during turbulent periods, we find that volatility is mostly driven by the talks of Euro area authorities. Third, using high-frequency data, we present evidence in favor of market microstructure theory, which explains how heterogeneity in interpreting news is likely to produce rapid market fluctuations. That is, statements increase currency market uncertainty because—in the short-term—agents tend to have different views on officials' statements.

3. Data description

3.1. Communication and exchange rate data

To construct communication data, we first extract the released FX news announcements from the real-time financial news database, Factiva. We then create a sample of verbal interventions from the FX announcements of the US and Euro area monetary officials. The data set covers the period from January 1995 to December 2009.[1] Verbal interventions can be defined as oral statements, speeches or comments of the policy-makers which give information on officials' desired exchange rate directions. To determine the list of the officials and classify the verbal interventions, we follow Fratzscher (2008a,b, 2006).[2] Overall, after performing the necessary data corrections and time adjustments, we end up with 323 and 320 oral FX interventions made by the US and Euro area officials, respectively.

[1] In the data set, each news is the first news released on the news-wires. We do not include the duplicated news of the same officials within the day of the announcements. For the cases where there are different announcements of the same official published at the same time (i.e. both in hour and minute), we take only one item of news from them as a news event and ignore the rest. If different announcements of the same official occur at different official publication times, we consider all these news items, and include them in our FX news database.

[2] For brevity, we do not report the evolution of the exchange rates with the classified verbal interventions over time. The patterns are in line with the ones displayed in Fratzscher (2008a,b, 2006) and the figures are available upon request.

[Insert Table 1 here]

Table 1 reports some descriptive statistics on the categorized verbal interventions. In the whole communication sample, the majority of the statements are aimed at strengthening domestic currencies, that is, to support a strong dollar (83%) and a strong euro (61%). Euro area authorities talk to markets more often than US officials do in order to weaken domestic currencies (35% vs 7%). Moreover, we observe that more than half of the statements occurred during the late 1990s, prior to the launch of the euro as a single currency in the Euro area (first row). Only 10% (US) and 4% (Euro area) of all statements are neutral statements without specific implications.

We use 5-minute intra-daily data, provided by Olsen & Associates, for the euro-dollar exchange rate over a period from January 1, 1995 to December 31, 2009. The database consists of the last mid-quotes (the average of the logarithms of bid and ask quotes) of 5-minute intervals throughout the global 24-hour trading day.[3] We follow Andersen and Bollerslev (1998) and hence one trading day extends from 21.00 GMT on day $t-1$ to 21.00 GMT on day t. This implies that each trading day in our currency sample $t = 1, 2, ..., T$ has $N = 288$ 5-minute intra-day quotes. We remove weekends, both regular and irregular holidays, too many missing values, and empty intervals from the database.[4] In addition, we adjust the data set to daylight saving time, considering the time adjustment periods of the US.

[Insert Table 2 here]

Table 2 reports the summary statistics for the 5-minute euro-dollar return series. The table confirms that the 5-minute euro-dollar returns are not normally distributed (column "Kurt" and the JB test), and exhibit autocorrelation in squared returns (the LM-test and the Q^2-test).[5] The ADF test indicates that the euro-dollar returns do not have a unit root at the 5-minute sampling frequency. Furthermore, we calculate the Ljung-Box test statistics

[3] See e.g. Bollerslev and Domowitz (1993) for a discussion on the high frequency intra-day dynamics of the foreign exchange markets.

[4] We follow the data cleaning procedure of Lahaye et al. (2011). Note that the holidays consist of New Year's Day, Martin Luther King Day, Washington's Birthday or Presidents' Day, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving Day and Christmas Day.

[5] Observed excess kurtosis is an indication of the presence of outliers or jumps.

with 20 lags, denoted $LB(20)$, to diagnose serial correlation.[6] The $LB(20)$ statistic rejects the null hypothesis of no serial correlation for the 5-minute euro-dollar returns. These statistical properties of the 5-minute exchange rate data are in line with the results reported in other studies (see e.g. Andersen and Bollerslev, 1997; Bollerslev and Domowitz, 1993 and Conrad and Lamla, 2010).

3.2. Measuring market uncertainty: jumps

We assume that the exchange rates admit a jump-diffusion process as in Andersen et al. (2007b). The log-price process $p(t)$ thus evolves as follows:

$$dp(t) = \mu(t)dt + \sigma(t)dW(t) + \kappa(t)dq(t), \qquad 0 \leq t \leq T, \tag{1}$$

where $\mu(t)$ is the drift, $W(t)$ denotes a standard Brownian motion, $q(t)$ is a counting process, possibly a non-homogeneous Poisson process independent of $W(t)$, and $\kappa(t)$ $(= p(t) - p(t-))$ is the jump size. The Brownian motion, $W(t)$, jump sizes, $\kappa(t)$, and the counting process, $q(t)$, are independent of each other. In the absence of jumps, the drift $\mu(t)$ and instantaneous volatility $\sigma(t)$ are such that the underlying DGP is an Itô process with continuous sample paths. The drift and diffusion coefficients may not change dramatically over short periods of time.

We follow Lee and Mykland (2008) to identify the intra-day arrival times of the sudden price movements, or jumps. We further apply the method of Boudt et al. (2011) to account for the intra-day periodicity of volatility. The modified test statistic to detect jumps can be then given by

$$\text{Jump}_{t,i} \equiv \frac{\mid r_{t,i} \mid}{\hat{s}_{t,i}\hat{f}_{t,i}}, \tag{2}$$

where $r_{t,i}$ is the ith intra-day return of day t, $s_{t,i}$ is the stochastic component of intra-day volatility, and $\hat{f}_{t,i}$ is the periodic component. We estimate $\hat{f}_{t,i}$ by using the non-parametric

[6] The weakness of the Ljung-Box test is that its asymptotic distribution is known under the very restrictive assumption that errors are *i.i.d.* Francq et al. (2005) propose a robust version of this test whose distribution is derived under the weaker assumption of a martingale difference sequence. This test is therefore robust to ARCH effects. See also Francq et al. (2005).

estimator of Boudt et al. (2011).[7] We treat these detected jumps as a measure of market uncertainty to analyze the evolution of jumps surrounding the statements' release times. We provide the details of the jump detection procedure in Appendix.

[Insert Table 3 here]

Table 3 reports the summary statistics on the detected euro-dollar jumps. We identify 1868 intra-day returns (out of 1070208) as jumps. The table also shows that the distribution of jumps is symmetrical, that is the proportions of positive and negative jumps are almost identical (50% and 49%, respectively). About one third of all sampling days include at least one intra-day jump (36%). In the sample, the probability of observing a jump is 0.17%, implying that there is less than a 1% chance of identifying an intra-day return as a jump (*Panel III*).

[Insert Figure 1 here]

To illustrate a detected jump, Figure 1 presents the evolution of the euro-dollar exchange rate on a communication day, September 15, 1995 (upper left). On this particular day, Dow Jones newswire reported one headline-type Euro area verbal statement. This news—which appeared at 12:15 GMT—is the comment of Jean-Claude Trichet: *"Strengthening of Dollar extremely welcome"*. Just after the release of this verbal intervention, the figure shows that the euro-dollar rate starts falling to levels below 1.30, and the test—presented in Eq. (2)—detects a significant jump at 14:30 GMT. Shortly after, the euro-dollar rate goes back to its pre-communication level. Moreover, the upper right panel of the same figure displays the euro-dollar movements on a normal day—October 12, 1995—without any comments or talks. The figure clearly shows no evidence for jumps on that day.[8]

[7] This estimation scheme is robust since it omits returns that might contain jumps to avoid biased estimates of the periodicity.

[8] Of course, it is likely that jumps may also occur in non-communication days. In Section 4, we use an event-study approach to examine whether or not the jumps—preceded by communication events—occur solely due to chance.

3.3. Measuring market uncertainty: continuous volatility

The second measure we use to model market uncertainty is "continuous volatility". Throughout, let $\sigma_{t,i}$ denote the diffusive intra-day volatility of the ith intra-day interval of trading day t. The intra-day local volatility is then estimated by:

$$\hat{\sigma}^*_{t,i} = \left(\frac{r^*_{t,i}}{\hat{f}_{t,i}} \right)^2 \tag{3}$$

where $r^*_{t,i}$ represents the "jump-cleaned" ith intra-day return of day t, and $\hat{f}_{t,i}$ is the periodicity filter proposed by Boudt et al. (2011).[9] We conduct the estimation procedure as follows. We first remove the significant jump arrivals from the raw intra-day returns $r_{t,i}$. We then construct a new intra-day returns series from the jump-filtered returns, and denote the new series as $r^*_{t,i}$. Next, we control the jump-filtered returns $r^*_{t,i}$ from the cyclical patterns using the periodicity estimator WSD. The local volatility estimate $\hat{\sigma}^*_{t,i}$ given in Eq. (3) hence becomes both robust to jumps and periodic patterns, which, in turn, allows us to examine the link between verbal interventions and continuous market volatility movements.[10]

To illustrate euro-dollar continuous volatility, Figure 1 presents the intra-day continuous volatility estimates ($\hat{\sigma}^*_{t,i}$) on a communication day (lower left), and on a non-communication day (lower right). We observe that euro-dollar volatility on the day of verbal interventions is higher than on a non-communication day.

4. Methodology

We follow Humpage (1999) and Fatum and Hutchison (2006, 2003) in carrying out an event-study analysis to investigate the intra-day effects of verbal interventions on exchange rate volatility and jumps. An event-study approach affords us much greater flexibility in terms

[9] We use the non-parametric WSD periodicity filter to estimate intra-day periodicity. For brevity, we do not detail the estimation procedure. It is, of course, available upon request.

[10] To see how jumps disturb the smooth volatility movements, we further estimate the spot volatilities without cleaning the returns from the jumps. The local intra-day volatility estimator then can be given by $\hat{\sigma}_{t,i} = \left(r_{t,i}/\hat{f}^{\text{WSD}}_{t,i} \right)^2$ where we do filter the intra-day returns from the periodic patterns via $\hat{f}^{\text{WSD}}_{t,i}$, yet jumps still remain in the returns series $r_{t,i}$. In this case, it is worth noting that *only* periodicity filtered squared returns are not robust to jumps, and hence they relatively exhibit a more spiky dispersion compared to patterns obtained by using (3). For brevity, we do no report these results and figures, yet they are available upon request.

of assessing volatility and jump dynamics around the news events without overly restrictive assumptions.[11] We take each statement as one event with a time stamp of 5 minutes. The length of the pre-event and post-event windows ranges between a 5-minute frequency to one of 4 hours (i.e. $\tau \in [-240, 240]$ in minutes). Our event-study consists of two stages.

First, we focus on the following question: does a communication event trigger any FX market turbulence in the form of rapid and short-lasting spikes? To answer this question, we compute the probability of observing a jump *conditional* on the communication events. That is,

$$p(jump|event) = \frac{\text{\# of interventions followed by jumps}}{\text{total \# of interventions}}. \tag{4}$$

Further, let $p(jump|control)$ denote the probability of observing an exchange rate jump in the control sample. To compute this quantity, we create a sub-sample of the intra-day return observations that excludes the communication event days and hence their intra-day periods.[12] The probability of observing jumps hence becomes the ratio of the number of jump occurrences to the all observations in this control sample, given by

$$p(jump|control) = \frac{\text{\# of jumps in the control sample}}{\text{\# of observations in the control sample}}, \tag{5}$$

where the jumps are identified based on Eq. (2). We compare $p(jump|event)$ with $p(jump|control)$. In other words, we check if there is a significant difference between the probability of observing jumps in normal non-event days and the probability of observing jumps conditional on the events. For both pre-event and post-event periods, we set the null and alternative hypothesis as

$$H_0 \;:\; p(jump|event) = p(jump|control) \tag{6}$$

$$H_1 \;:\; p(jump|event) \neq p(jump|control). \tag{7}$$

[11]Unlike a time-series approach, event-study analysis does not assume, for example, an underlying structure for exchange rate determination. Nor does it require any distributional assumptions for the exchange rates (see e.g. Fratzscher, 2009 and Humpage, 1999). Moreover, as documented in Swanson (2011), an event-study methodology avoids the endogeneity problem particularly at higher sampling frequencies. See also Fratzscher (2005) for an FX communication study using both event-study and time-series approaches in this context.

[12]See e.g. Fatum and Hutchison (2003) for a similar exercise.

Under the null hypothesis, conditional and unconditional jump likelihoods are identical. This means that communication events do not affect the probability of jump occurrences. To test H_0, we follow Fatum and Hutchison (2003) and use a non-parametric sign test. A rejection of the null hypothesis will indicate that events are successful in triggering jumps.

Second, we examine smooth continuous volatility patterns surrounding the communication statements. As with the idea of the jump-event test, we are interested in testing the impact of communication on volatility. Let $\text{Vol}_{i,\tau}^{event}$ denote the ith spot volatility estimate τ-minutes after the communication events. We analyze whether $\text{Vol}_{i,\tau}^{event}$ is higher (i.e. abnormal) than volatility during non-communication periods. We define the "abnormal" continuous volatility as follows:

$$\text{Vol}_{i,\tau}^{abnormal} = \text{Vol}_{i,\tau}^{event} - \text{Vol}_{\tau}^{control}, \tag{8}$$

where $\text{Vol}_{i,\tau}^{abnormal}$ denotes the ith abnormal volatility τ-minutes after the verbal interventions, $\text{Vol}_{i,\tau}^{event}$ is the ith spot volatility τ-minutes after the events, and $\text{Vol}_{\tau}^{control}$ is the average spot volatility in normal non-event days.[13] Both spot volatility estimates $\text{Vol}_{i,\tau}^{event}$ and $\text{Vol}_{\tau}^{control}$ in Eq. (8) are robust to jumps and cyclical volatility components.

Intuitively, $\text{Vol}_{i,\tau}^{abnormal}$ tells us whether or not the spot volatility patterns are significantly *abnormal* before and after the releases of the announcements.[14] We therefore define the null and alternative hypothesis as follows:

$$H_0 \quad : \quad \text{Vol}_{i,\tau}^{abnormal} = 0 \tag{9}$$

$$H_1 \quad : \quad \text{Vol}_{i,\tau}^{abnormal} \neq 0. \tag{10}$$

Under the null hypothesis, average continuous volatility during communication periods and non-communication periods are identical, implying there is no abnormality. We test the null hypothesis H_0 by using the Z-test. As with the jump analysis, we set the communication

[13]See Mackinlay (1997) as a survey on event studies within economics, and also for a further discussion on abnormality.

[14]If the abnormal volatility is zero, then there is no statistical difference between the local volatility in the announcement times and in the normal non-event days. If, however, the abnormal volatility is positive (negative), this implies that the volatility is larger (lower) in the communication periods than in the days without intervention.

window length as 4 hours around the events i.e. $\tau \in [-240, 240]$ in minutes. The next section presents our event-study results.

5. Event-study results

5.1. The intra-day effects of communication on euro-dollar jumps

Table 4 reports the conditional and unconditional jump likelihoods before the release of the announcements. Except for the pre-event windows *30-min*, *35-min* and *50-min*, we cannot reject the null hypothesis of no effect ($Z_{sign-stat}$).

[Insert Tables 4 and 5 here]

[Insert Figure 2 here]

Next, we turn our attention to the post-event windows. Table 5 reports the conditional and unconditional jump likelihoods after the release of the communication events. The results indicate that the probabilities of observing jumps after statements (i.e. $p(jump|event)$) are now significantly higher than the unconditional probabilities (i.e. $p(jump|control)$) from *5-min* to *4-hour* window lengths. For instance, $p(jump|event)$ is about 0.88% and 11.42% within *5-min* and *4-hour* after the communication events, respectively. For these particular event windows, the table reports the jump likelihoods as 0.17% and 8.16% in the absence of any news, suggesting that verbal statements increase the probability of euro-dollar jump occurrences.[15] Moreover, the lower-panel of Figure 2 illustrates that the strongest impact of the statements mostly occurs within the hour around the event times.

[Insert Tables 6 and 7 here]

We now disentangle the Euro area and US statements in our database, and examine their effects on euro-dollar jumps separately. Tables 6 and 7 report the conditional ($p(jump|event)$) and unconditional ($p(jump|control)$) jump likelihoods before and after the Euro area statements, respectively. The results presented in Table 6 indicate that—before the news release—the effects of the statements are not statistically significant. That is, the talks and comments of

[15] One reason of having low conditional and unconditional probabilities of observing jumps is related to the fact that jumps do not occur very often and hence they are indeed rare events. See Table 3.

the Euro area officials do not produce euro-dollar jumps before Factiva's news release. For the post-event period, the results reported in Table 7 suggest that the statements of the Euro area officials significantly raise the likelihood of observing jumps up to 2 hours. Thus, the probability of a jump in the euro-dollar rate is more likely to occur after a Euro area announcement rather than in days with no talks.

[Insert Tables 8 and 9 here]

Tables 8 and 9 report the event-study results before and after the US statements, respectively. Unlike the Euro area statements, Table 8 indicates that talks of the US officials significantly increase jump likelihoods within *20-min* to *1.5-hour*, even before news release. For the post-event windows, the sign test mostly rejects the null hypothesis of no news impact, suggesting that the US communication increases the probability of observing euro-dollar jumps.

[Insert Figure 3 here]

We illustrate the jump dynamics around the Euro area and US communication events in Figure 3. The main message of the figure is clear: verbal policy statements and comments on exchange rates trigger exchange rate jumps.

5.2. The intra-day effects of communication on euro-dollar volatility

The upper panel of Figure 4 displays the average rolling window continuous volatility estimates 4 hours before and after the announcements. The figure shows that the impact of the verbal interventions begins a couple of hours before the news events, and that about 20 minutes before the talks, the market volatility diminishes (upper panel of Figure 4).[16] As DeGennaro and Shrieves (1997) document, the reason for observing lower volatility before the news might be related to how traders process talks and speeches. That is, market participants tend to pause to consider unexpected news arrivals or announcements (Neely, 2011).

[Insert Figure 4 here]

[16] As we will see later, the abnormal volatility is indeed not significant just prior to news release (see the lower panel of Figure 4).

Following the news release, the upper panel of Figure 4 further shows that the continuous euro-dollar volatility increases within 1 hour around the events and exhibits a gradual adjustment for several hours. Interestingly, these results are in line with the findings of Sager and Taylor (2004) and Ederington and Lee (1993, 1995) who conclude that exchange rate volatility surges just after the news, remains high, and even becomes abnormal for some time in the announcement days.

[Insert Table 10 here]

To better understand the link between communication events and euro-dollar continuous volatility, we examine the *abnormal* continuous volatility patterns surrounding the news release times. The middle and lower panels of Figure 4 show that euro-dollar volatility is significantly abnormal around the communication events, suggesting that the volatility becomes higher before, during and after the events relative to its intra-day behavior in non-event days. Table 10 further reports the estimates of the abnormal volatility, continuous volatility and the Z-statistics for the aggregated communication events. We reject the null hypothesis of no abnormality for most of the rolling windows considered in the event-study. For instance, abnormal volatility estimates are statistically significant—ranging between 0.005 to 0.011—from 25-min to 3-hour pre-event rolling windows. Just prior to news releases (i.e. from -*(20-min)* to *(0-min)*), the estimates are not significant. Nevertheless, the abnormal euro-dollar volatility estimates statistically differ from zero following the statement times up to 4 hours. We find that the largest level of abnormal volatility is about 0.014 which occurs 20 minutes after the talks. Overall, Figure 4 and Table 10 deliver two important messages. First, monetary officials generally tend to communicate with markets on days with higher than normal continuous volatility. Second, the statements temporarily affect continuous volatility, and the impact is offset within a couple of hours.

Why does communication increase continuous volatility? One explanation could be that information content of the communication signals is likely to elevate noise in the markets, and yet does not play a substantial role in resolving fluctuations. Other possible reasons might be related to the traders' i) heterogeneity in receiving information (e.g. Bacchetta and van Wincoop, 2006), ii) heterogeneity in their beliefs (e.g. De Grauwe and Kaltwasser, 2012) as well as iii) heterogeneity in interpreting information (e.g. Dominguez, 2006). Among these possibilities, one might easily argue that heterogeneity in receiving information is irrelevant because communication announcement is simply public news. This would rule out explanation (i) above. Furthermore, even though behavioral aspects—such as interactions between FX traders—tend to create uncertainty in the currency markets (De Grauwe and Kaltwasser, 2012), the distribution of (latent) news process may not be normal at the intra-day level. The third explanation (iii) seems plausible. That is, even though the communication announcement is public news, agents are likely to have differing views about the content of the news in the very short-term. Despite the high levels of volatility following the news release, communication signals tend to be common knowledge over time such that heterogeneity among market participants vanishes as the information content of the communication becomes more clear in the markets.[17]

[Insert Figures 5 and 6 here]

How do different communication policies affect continuous volatility? Figures 5 and 6 illustrate the behavior of euro-dollar continuous volatility around the communication of the Euro area and US officials, respectively. Interestingly, while continuous volatility is significantly higher than normal after the releases of the Euro area statements (lower panel of Figure 5), we do not observe a strong abnormal volatility pattern when the US officials intervene in the exchange rates via their comments and talks (lower panel of Figure 6). In other words, FX market volatility seems to react more to the speeches of the Euro area officials, as opposed to the US monetary authorities. In fact, this result contrasts with the findings of Jansen and De Haan (2007) who conclude that verbal interventions have little effect on intra-day volatility. Rather, we show that the impact on market uncertainty depends on the choice of uncertainty measure as well as the communication policy strategies.

[Insert Table 11 here]

[17] See e.g. Bacchetta and van Wincoop (2006), De Grauwe and Kaltwasser (2012), and Dominguez (2006) for discussions on the issue of heterogeneity in foreign exchange markets.

Finally, Table 11 reports the estimates of the abnormal volatility, continuous volatility and the Z-statistics for the Euro area and US statements, separately (columns EA and US). The table conveys a similar message: Abnormal continuous volatility is mostly driven by the statements of the Euro area officials.

Overall, our findings indicate that the US and Euro area officials in general tend to communicate with markets on days when uncertainty is relatively high. This result is particularly in line with the findings of Dominguez (2003) and Dominguez (2006) which show that the actual intervention operations of central banks (e.g. the Fed operations) are also likely to occur in high volatility periods rather than in normal-tranquil days. When focusing on continuous volatility behavior, we further show that officials talk to markets during turbulent times. In a much broader perspective, our results are also consistent with the conclusions of Bonser-Neal and Tanner (1996), Baillie and Osterberg (1997), and Beine et al. (2002) who present evidence that central bank interventions are generally associated with high volatility in currency markets.

We present two main results that depart from the earlier work. First, we show that comments and verbal interventions tend to trigger sudden exchange rate jumps and hence temporarily increase market uncertainty. The adjustment of exchange rates to news arrivals—in the form of jumps—takes about 1 hour, which in turn leads to large ups and downs. Second, in contrast to the results of Jansen and De Haan (2007), we find strong evidence that verbal interventions affect euro-dollar volatility. There are at least two possible reasons behind this finding. First, the statements of the officials are not transparent enough and therefore the information content of the news tends to be ambiguous amongst market participants. Second, when the statement is released, agents interpret the comments and talks in different ways for at least several hours. Along the lines of Dominguez (2006), this, in turn, might lead a *rational confusion* in the currency markets. As a result, volatility remains elevated after the news and then mean-reverts to its pre-announcement levels.

6. Conclusion

In this paper, we study the intra-day influence of communication on the euro-dollar fluctuations using two measures. The first measure "jumps" represents the sudden market reactions, whereas the second measure "continuous volatility" describes the smooth market response to communication events. We focus on the US and Euro area communication policies, and assess separately how the statements affect euro-dollar fluctuations. Three key results stand out in our paper.

First, comments and talks on exchange rates trigger the occurrence of sudden and large euro-dollar movements for about 1 hour after the news release. Jumps constitute market fear and tail risk, which form uncertainty in the exchange rates.

Second, we find that continuous volatility—as another form of uncertainty—declines just before the news release, and climbs following the statements. The adjustment of continuous volatility to announcements is more gradual (3−4 hours), and significantly differs from the adjustment duration of the jump responses.

Third, our results suggest that the monetary officials generally tend to communicate with currency markets on days when uncertainty is higher than usual. Both jumps and volatility measures confirm these results with aggregated statements. When assessing the impact of the US and Euro area communication separately, we find that the continuous volatility is mostly driven by the Euro area officials.

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Appendix

A. Jump detection procedure

The intuition behind the jump test proposed simultaneously by Andersen et al. (2007b) and Lee and Mykland (2008) is straightforward: in the absence of jumps, instantaneous returns are increments of the Brownian motion. Standardized returns that are too large to plausibly come from a standard Brownian motion must reflect jumps.[18]

More formally, assume we have T days of $\lfloor 1/\Delta \rfloor \equiv M$ equally-spaced intra-day returns and denote the i-th return of day t by $r_{t,i} \equiv p(t + i\Delta) - p(t + (i-1)\Delta)$, where $i = 1, \ldots, M$. Andersen et al. (2007b) and Lee and Mykland (2008) propose the following test statistic for jumps in $r_{t,i}$:

$$J_{t,i} \equiv \frac{\mid r_{t,i} \mid}{\sigma_{t,i}}. \tag{11}$$

Under the null of no jumps, the test statistic, $J_{t,i}$, follows the same distribution as the absolute value of a standard normal variable. Lee and Mykland (2008) propose inferring jumps from the distribution of the statistic's maximum over the sample size. Under the null of no jumps in $t, i-1$ to t, i, then, as $\Delta \to 0$, the sample maximum of the absolute value of a standard normal (i.e. $J_{t,i}$ in (11)) follows a Gumbel distribution. We reject the null of no jump if

$$J_{t,i} > G^{-1}(1-\alpha)S_n + C_n, \tag{12}$$

where $G^{-1}(1-\alpha)$ is the $1-\alpha$ quantile function of the standard Gumbel distribution, $C_n = (2\log n)^{0.5} - \frac{\log(\pi)+\log(\log n)}{2(2\log n)^{0.5}}$ and $S_n = \frac{1}{(2\log n)^{0.5}}$, n being the total number of observations (i.e, $M \times T$). With a significance level of $\alpha = 0.1$, we reject the null of no jump if $J_{t,i} > S_n\beta^* + C_n$ with β^* such that $exp(-e^{-\beta^*}) = 1 - \alpha = 0.9$, i.e. $\beta^* = -log(-log(0.9)) = 2.25$. This conservative procedure can be expected to find only α spurious jumps in a given sample of n observations.

In order to implement this test one must to estimate the unobserved spot volatility $\sigma_{t,i}$ with a robust-to-jumps estimator. Barndorff-Nielsen and Shephard (2004) show that, under weak conditions, realized bipower variation (RBV) converges to integrated volatility under the

[18]The drift is nearly zero and can be ignored in practice.

model described by Eq. (1).

$$\operatorname*{plim}_{\Delta\to 0} BV_t(\Delta) = \int_{t-1}^{t} \sigma^2(s)ds, \tag{13}$$

where

$$BV_t(\Delta) \equiv \mu_1^{-2} \sum_{i=2}^{M} |r_{t,i}||r_{t,i-1}|, \tag{14}$$

with $\mu_1 \equiv \sqrt{2/\pi} \simeq 0.79788$.

Andersen et al. (2007b), Lee and Mykland (2008) propose replacing $\sigma_{t,i}$ in Eq. (11) by $\hat{s}_{t,i}$, i.e. the average of the RBV computed over a local window length about 1 day, preceding period t, i.

Estimating volatility using RBV rolling windows inappropriately smooths these periodic patterns, because such an estimator is necessarily slowly time-varying. Boudt et al. (2011) show that such cyclical patterns might induce the $J_{t,i}$ statistic to spuriously detect jumps. To correctly infer jumps, we must estimate and remove this deterministic periodicity with a robust-to-jumps volatility estimator.

Following Boudt et al. (2011), we assume that the instantaneous volatility in Eq. (1) is the product of a slowly varying component, $\delta(t)$, and a deterministic circadian component, $f(t)$, i.e.

$$\sigma(t) = \delta(t) f(t). \tag{15}$$

We assume, without loss of generality, this deterministic variance process integrates to one on a daily basis,

$$\int_{t-1}^{t} f^2(s)ds = 1, \tag{16}$$

and standardize the estimates of volatility periodicity accordingly.

References

Andersen, T.G., Bollerslev, T., 1997. Intraday periodicity and volatility persistence in financial markets. Journal of Empirical Finance 4, 115–158.

Andersen, T.G., Bollerslev, T., 1998. Answering the skeptics: yes, standard volatility models do provide accurate forecasts. International Economic Review 39, 885–905.

Andersen, T.G., Bollerslev, T., Diebold, F., Vega, C., 2007a. Real-time price discovery in stock, bond and foreign exchange markets. Journal of International Economics 73, 251–277.

Andersen, T.G., Bollerslev, T., Dobrev, D., 2007b. No-arbitrage semi-martingale restrictions for continuous-time volatility models subject to leverage effects, jumps and i.i.d. noise: theory and testable distributional implications. Journal of Econometrics 138, 125–180.

Bacchetta, P., van Wincoop, E., 2006. Can information heterogeneity explain the exchange rate determination puzzle? American Economic Review 96, 552–576.

Baillie, R., Osterberg, W.P., 1997. Why do central banks intervene? Journal of International Money and Finance 16, 909–919.

Barndorff-Nielsen, O., Shephard, N., 2004. Power and bipower variation with stochastic volatility and jumps (with discussion). Journal of Financial Econometrics 2, 1–37.

Beine, M., Bénassy-Quéré, A., Lecourt, C., 2002. Central bank intervention and foreign exchange rates: new evidence from FIGARCH estimations. Journal of International Money and Finance 21, 115–144.

Beine, M., Janssen, G., Lecourt, C., 2009. Should central bankers talk to the foreign exchange markets? Journal of International Money and Finance 28, 776–803.

Blinder, A.S., Ehrmann, M., Fratzscher, M., 2008. Central bank communication and monetary policy: a survey of theory and evidence. Journal of Economic Literature 4, 910–945.

Bollerslev, T., Domowitz, I., 1993. Trading patterns and prices in the interbank foreign exchange market. Journal of Finance 48, 1421–1443.

Bollerslev, T., Todorov, V., 2011a. Estimation of jump tails. Econometrica 79, 1727–1783.

Bollerslev, T., Todorov, V., 2011b. Tails, fears and risk premia. Journal of Finance 66, 2165–2211.

Bonser-Neal, C., Tanner, G., 1996. Central bank intervention and the volatility of foreign exchange rates: evidence from the options market. Journal of International Money and Finance 15, 853–878.

Boudt, K., Croux, C., Laurent, S., 2011. Robust estimation of intraweek periodicity in volatility and jump detection. Journal of Empirical Finance 18, 353–367.

Carnero, M., Pena, D., Ruiz, E., 2007. Effects of outliers on the identification and estimation of GARCH models. Journal of Time Series Analysis 28, 471–497.

Charles, A., Darné, O., 2005. Outliers and GARCH models in financial data. Economics Letters 86, 347–352.

Conrad, C., Lamla, M., 2010. The high-frequency response of the EUR-USD exchange rate to ECB communication. Journal of Money, Credit and Banking 42, 1391–1417.

Davidson, R., MacKinnon, J.G., 1993. Estimation and inference in econometrics. New York: Oxford University Press.

De Grauwe, P., Kaltwasser, P.R., 2012. Animal spirits in the foreign exchange market. Journal of Economic Dynamics and Control 36, 1176–1192.

DeGennaro, R.P., Shrieves, R.E., 1997. Public information releases, private information arrival, and volatility in the foreign exchange market. Journal of Empirical Finance 4, 295–315.

Dominguez, K.M., 2003. The market microstructure of central bank intervention. Journal of International Economics 59, 25–45.

Dominguez, K.M., 2006. When do central bank interventions influence intra-daily and longer-term exchange rate movements? Journal of International Money and Finance 25, 1051–1071.

Ederington, L.H., Lee, J.H., 1993. How markets process information: news releases and volatility. Journal of Finance 48, 1161–1191.

Ederington, L.H., Lee, J.H., 1995. The short-run dynamics of the price adjustment to new information. Journal of Financial and Quantitative Analysis 30, 117–134.

Evans, M.D.D., 2005. Foreign exchange market microstructure. Working Paper.

Evans, M.D.D., Lyons, R.K., 2005. Do currency markets absorb news quickly? Journal of International Money and Finance 24, 197–217.

Fatum, R., Hutchison, M.M., 2002. ECB foreign exchange intervention and the euro: institutional framework, news, and intervention. Open Economies Review 13, 413–425.

Fatum, R., Hutchison, M.M., 2003. Is sterilised foreign exchange intervention effective after all? An event study approach. Economic Journal 113, 390–411.

Fatum, R., Hutchison, M.M., 2006. Effectiveness of official daily foreign exchange market intervention operations in Japan. Journal of International Money and Finance 25, 199–219.

Francq, C., Roy, R., Zakoïan, J.M., 2005. Diagnostic checking in ARMA models with uncorrelated errors. Journal of the American Statistical Association 100, 532–544.

Franses, P., Ghijsels, H., 1999. Additive outliers, GARCH and forecasting volatility. International Journal of Forecasting 15, 1–9.

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

Fratzscher, M., 2006. On the long-term effectiveness of exchange rate communication and interventions. Journal of International Money and Finance 25, 146–167.

Fratzscher, M., 2008a. Communication and exchange rate policy. Journal of Macroeconomics 30, 1651–1672.

Fratzscher, M., 2008b. Oral interventions versus actual interventions in FX markets - An event-study approach. Economic Journal 118, 1–28.

Fratzscher, M., 2009. How successful is the G7 in managing exchange rates? Journal of International Economics 79, 78–88.

Gnabo, J.Y., Lahaye, J., Laurent, S., Lecourt, C., 2012. Do jumps mislead the FX market? Quantitative Finance 12, 1521–1532.

Gnabo, J.Y., Laurent, S., Lecourt, C., 2009. Does transparency in central bank intervention policy bring noise to the FX market? The case of Japan. Journal of International Financial Markets, Institutions and Money 19, 94–111.

Gnabo, J.Y., Teiletche, J., 2009. Foreign-exchange intervention strategies and market expectations: insights from Japan. Journal of International Financial Markets, Institutions and Money 19, 432–446.

Humpage, O.F., 1999. US intervention: Assessing the probability of success. Journal of Money, Credit and Banking 31, 732–747.

Jansen, D.J., De Haan, J., 2005. Talking heads: the effects of ECB statements on the Euro-Dollar exchange rate. Journal of International Money and Finance 24, 343–361.

Jansen, D.J., De Haan, J., 2007. Were verbal efforts to support the euro effective? A high-frequency analysis of ECB statements. European Journal of Political Economy 23, 245–259.

Kaminsky, G.L., Lewis, K.K., 1996. Does foreign exchange intervention signal future monetary policy? Journal of Monetary Economics 37, 285–312.

Kim, S., Le, A., 2010. Secrecy of bank of Japan's yen intervention: evidence of efficacy from intra-daily data. Journal of Japanese and International Economies 24, 369–394.

Lahaye, J., Laurent, S., Neely, C., 2011. Jumps, cojumps and macro announcements. Journal of Applied Econometrics 26, 893–921.

Lee, S., Mykland, P., 2008. Jumps in financial markets: a new nonparametric test and jump dynamics. Review of Financial Studies 21, 2535–2563.

Mackinlay, A.C., 1997. Event studies in economics and finance. Journal of Economic Literature 35, 13–39.

Muller, N., Yohai, V., 2008. Robust estimates for GARCH models. Journal of Statistical Planning and Inference 138, 2918–2940.

Mussa, M., 1981. The role of official intervention. New York: Group of Thirty.

Neely, C., 1999. Target zones and conditional volatility: the role of realignments. Journal of Empirical Finance 6, 177–192.

Neely, C.J., 2011. A survey of announcement effects on foreign exchange volatility and jumps. Federal Reserve Bank of St. Louis Review 93, 361–385.

Rosa, C., Verga, G., 2007. On the consistency and effectiveness of central bank communication: evidence from the ECB. European Journal of Political Economy 23, 146–175.

Rosa, C., Verga, G., 2008. The impact of central bank announcements on asset prices in real time. International Journal of Central Banking 23, 146–175.

Sager, M.J., Taylor, M.P., 2004. The impact of european central bank governing council announcements on the foreign exchange market: a microstructural analysis. Journal of International Money and Finance 23, 1043–1051.

Sarno, L., Taylor, M., 2001. Official intervention in the foreign exchange market: Is it effective and, if so, how does it work? Journal of Economic Literature 39, 839–868.

Swanson, E., 2011. Let's twist again: A high-frequency event-study analysis of operation twist and its implications for QE2. Working Paper.

Table 1: Verbal exchange rate interventions

	US			Euro area		
Years	Strengthen	Weaken	Neutral	Strengthen	Weaken	Neutral
1995 - 1999	53%	74%	88%	53%	65%	33%
2000 - 2004	24%	17%	9%	45%	13%	33%
2005 - 2009	23%	9%	3%	2%	22%	33%
Total % of OFXI	83%	7%	10%	61%	35%	4%

Notes: Verbal interventions of the US and Euro area officials. The verbal statements are classified based on the decision rule given in Fratzscher (2008a,b, 2006). We report the percentages of strengthening, weakening and neutral verbal interventions. The sample covers the periods from 01-01-1995 to 31-12-2009.

Table 2: Summary statistics for the 5-min euro-dollar returns

$\#Obs$	Mean	Min	Max	Std	Skew	Kurt
1070208	0.00	-1.43	2.79	0.04	0.49	59.85

	JB	$Q(20)$	$LB(20)$	$Q^2(20)$	$LM(5)$	$ADF(2)$
	1.4×10^8**	4311.82**	816.12**	24883.30**	2329.20**	-625.59**

Notes: Summary statistics and preliminary tests for the euro-dollar 5-min log-returns (in %). The sample covers the periods from 01-01-1995 to 30-12-2009. $\#Obs$ corresponds to the total number of observations. JB is the statistic of the Jarque-Bera normality test. $Q(20)$ and $Q^2(20)$ correspond respectively to the Box-Pierce test of serial correlation in the raw and squared returns with 20 lags. $LB(20)$ is the robust Ljung-Box statistic on raw returns with 20 lags and $LM(5)$ is the statistic of the ARCH-LM test for 5 lags. $ADF(2)$ denotes the Augmented Dickey-Fuller unit root test statistics with two lags, without intercept and time trend. Davidson and MacKinnon (1993) provide asymptotic critical values for the ADF tests. **: Indicates significance at the 1% level.

Table 3: Descriptive statistics on the detected euro-dollar jumps

Critical Level: $\alpha = 0.1$	
Panel I. Sample	
# of Observations	1070208
# of Sample days	3716
# of Jumps	1868
# of Jump-days	1346
Panel II. Quantities	
# of (+) Jumps	941
# of (−) Jumps	927
% of (+) Jumps	50.37
% of (−) Jumps	49.63
Std. error of (−) Jumps	1.16
Panel III. Unconditional Probabilities	
P(Jump-days)(%)	36.22
P(Jumps)(%)	0.175
P((+)Jumps)(%)	0.088
P((−)Jumps)(%)	0.087

Notes: Descriptive statistics on the detected euro-dollar jumps.

Table 4: Communication and euro-dollar jumps in pre-event windows

Matching Window (w):	*5-min*	*10-min*	*15-min*	*20-min*	*25-min*	*30-min*	*35-min*	*40-min*	*45-min*
# of matches	0	0	4	6	9	11	13	13	14
P(jump|event)(%)	0	0	0.70	1.05	1.58	1.93**	2.28**	2.28	2.46
P(jump|control)(%)	0.17	0.34	0.51	0.68	0.85	1.02	1.19	1.36	1.53
$Z_{sign-stat}$	[0.98]	[1.39]	[0.65]	[1.09]	[1.90]	[2.17]	[2.41]	[1.90]	[1.81]
	50-min	*55-min*	*1-hour*	*1.5-hour*	*2-hour*	*2.5-hour*	*3-hour*	*3.5-hour*	*4-hours*
# of matches	16	16	18	22	29	33	36	44	44
P(jump|event)(%)	2.81**	2.81	3.16	3.87	5.10	5.80	6.33	7.73	7.73
P(jump|control)(%)	1.70	1.87	2.04	3.06	4.08	5.10	6.12	7.14	8.16
$Z_{sign-stat}$	[2.05]	[1.66]	[1.90]	[1.12]	[1.23]	[0.76]	[0.21]	[0.55]	[0.37]

Notes: Euro-dollar jump dynamics before the statements. "# of matches" gives the number of verbal interventions followed by the euro-dollar jumps before the statement releases. $P(jump|event)(\%)$ is the probability of observing jumps conditional on the communication events, and $P(jump|control)(\%)$ is the probability of observing jumps in the control sample without any events. The sample covers the periods from 01-01-1995 to 30-12-2009. **: Indicates significance at the 5% level.

Table 5: Communication and euro-dollar jumps in post-event windows

Matching Window (w):	*5-min*	*10-min*	*15-min*	*20-min*	*25-min*	*30-min*	*35-min*	*40-min*	*45-min*
# of matches	5	10	11	12	13	14	14	15	17
P(jump|event)(%)	0.88**	1.76**	1.93**	2.11**	2.28**	2.46**	2.46**	2.64**	2.99**
P(jump|control)(%)	0.17	0.34	0.51	0.68	0.85	1.02	1.19	1.36	1.53
$Z_{sign-stat}$	[4.10]	[5.81]	[4.77]	[4.15]	[3.73]	[3.42]	[2.79]	[2.63]	[2.83]
	50-min	*55-min*	*1-hour*	*1.5-hour*	*2-hour*	*2.5-hour*	*3-hour*	*3.5-hour*	*4-hours*
# of matches	18	20	23	32	42	46	52	56	65
P(jump|event)(%)	3.16**	3.51**	4.04**	5.62**	7.38**	8.08**	9.14**	9.84**	11.42**
P(jump|control)(%)	1.70	1.87	2.04	3.06	4.08	5.10	6.12	7.14	8.16
$Z_{sign-stat}$	[2.70]	[2.90]	[3.38]	[3.55]	[3.98]	[3.24]	[3.00]	[2.50]	[2.84]

Notes: Euro-dollar jump dynamics after the statements. "# of matches" gives the number of verbal interventions followed by the euro-dollar jumps after the statement releases. $P(jump|event)(\%)$ is the probability of observing jumps conditional on the communication events, and $P(jump|control)(\%)$ is the probability of observing jumps in the control sample without any events. The sample covers the periods from 01-01-1995 to 30-12-2009. **: Indicates significance at the 5% level.

Table 6: Euro area statements and euro-dollar jumps in pre-event windows

Matching Window (w):	*5-min*	*10-min*	*15-min*	*20-min*	*25-min*	*30-min*	*35-min*	*40-min*	*45-min*
# of matches	0	0	1	1	2	3	3	3	4
P(jump|event)(%)	0	0	0.35	0.35	0.71	1.06	1.06	1.06	1.42
P(jump|control)(%)	0.17	0.34	0.51	0.69	0.86	1.03	1.20	1.37	1.54
$Z_{sign-stat}$	[0.70]	[0.99]	[0.38]	[0.67]	[0.27]	[0.06]	[0.21]	[0.44]	[0.17]
	50-min	*55-min*	*1-hour*	*1.5-hour*	*2-hour*	*2.5-hour*	*3-hour*	*3.5-hour*	*4-hours*
# of matches	4	4	6	7	11	12	14	18	18
P(jump|event)(%)	1.42	1.42	2.13	2.48	3.90	4.26	4.96	6.38	6.38
P(jump|control)(%)	1.71	1.89	2.06	3.09	4.12	5.14	6.17	7.20	8.23
$Z_{sign-stat}$	[0.38]	[0.58]	[0.08]	[0.59]	[0.18]	[0.68]	[0.84]	[0.53]	[1.13]

Notes: Euro-dollar jump dynamics before the Euro area officials' verbal interventions. "# of matches" gives the number of verbal interventions followed by the euro-dollar jumps before the statement releases. $P(jump|event)(\%)$ is the probability of observing jumps conditional on the communication events, and $P(jump|control)(\%)$ is the probability of observing jumps in the control sample without any events. The sample covers the periods from 01-01-1995 to 30-12-2009. **: Indicates significance at the 5% level.

Table 7: Euro area statements and euro-dollar jumps in post-event windows

Matching Window (w):	*5-min*	*10-min*	*15-min*	*20-min*	*25-min*	*30-min*	*35-min*	*40-min*	*45-min*
# of matches	2	3	4	5	6	7	7	8	8
P(jump|event)(%)	0.71**	1.06**	1.42**	1.77**	2.13**	2.48**	2.48**	2.84**	2.84
P(jump|control)(%)	0.17	0.34	0.51	0.69	0.86	1.03	1.20	1.37	1.54
$Z_{sign-stat}$	[2.18]	[2.07]	[2.12]	[2.21]	[2.31]	[2.42]	[1.98]	[2.12]	[1.76]
	50-min	*55-min*	*1-hour*	*1.5-hour*	*2-hour*	*2.5-hour*	*3-hour*	*3.5-hour*	*4-hours*
# of matches	9	10	11	16	18	20	20	23	27
P(jump|event)(%)	3.19	3.55**	3.90**	5.67**	6.38	7.09	7.09	8.16	9.57
P(jump|control)(%)	1.71	1.89	2.06	3.09	4.12	5.14	6.17	7.20	8.23
$Z_{sign-stat}$	[1.91]	[2.05]	[2.18]	[2.51]	[1.92]	[1.48]	[0.64]	[0.62]	[0.82]

Notes: Euro-dollar jump dynamics after the Euro area officials' verbal interventions. "# of matches" gives the number of verbal interventions followed by the euro-dollar jumps after the statement releases. $P(jump|event)(\%)$ is the probability of observing jumps conditional on the communication events, and $P(jump|control)(\%)$ is the probability of observing jumps in the control sample without any events. The sample covers the periods from 01-01-1995 to 30-12-2009. **: Indicates significance at the 5% level.

Table 8: US statements and euro-dollar jumps in pre-event windows

Matching Window (w):	*5-min*	*10-min*	*15-min*	*20-min*	*25-min*	*30-min*	*35-min*	*40-min*	*45-min*
# of matches	0	0	3	5	7	8	10	10	10
P(jump|event)(%)	0	0	1.05	1.74**	2.44**	2.79**	3.48**	3.48**	3.48**
P(jump|control)(%)	0.17	0.35	0.52	0.69	0.87	1.04	1.21	1.38	1.56
$Z_{sign-stat}$	[0.71]	[1.00]	[1.24]	[2.14]	[2.88]	[2.92]	[3.52]	[3.04]	[2.64]
	50-min	*55-min*	*1-hour*	*1.5-hour*	*2-hour*	*2.5-hour*	*3-hour*	*3.5-hour*	*4-hours*
# of matches	12	12	12	15	18	21	22	26	26
P(jump|event)(%)	4.18**	4.18**	4.18**	5.23**	6.27	7.32	7.67	9.06	9.06
P(jump|control)(%)	1.73	1.90	2.07	3.12	4.15	5.19	6.23	7.27	8.31
$Z_{sign-stat}$	[3.18]	[2.82]	[2.50]	[2.06]	[1.80]	[1.62]	[1.00]	[1.17]	[0.46]

Notes: Euro-dollar jump dynamics before the US officials' verbal interventions. "# of matches" gives the number of verbal interventions followed by the euro-dollar jumps before the statement releases. $P(jump|event)(\%)$ is the probability of observing jumps conditional on the communication events, and $P(jump|control)(\%)$ is the probability of observing jumps in the control sample without any events. The sample covers the periods from 01-01-1995 to 30-12-2009. **: Indicates significance at the 5% level.

Table 9: US statements and euro-dollar jumps in post-event windows

Matching Window (w):	*5-min*	*10-min*	*15-min*	*20-min*	*25-min*	*30-min*	*35-min*	*40-min*	*45-min*
# of matches	3	7	7	7	7	7	7	7	9
P(jump|event)(%)	1.05**	2.44**	2.44**	2.44**	2.44**	2.44**	2.44	2.44	3.14**
P(jump|control)(%)	0.17	0.35	0.52	0.69	0.87	1.04	1.21	1.38	1.56
$Z_{sign-stat}$	[3.55]	[6.04]	[4.52]	[3.57]	[2.88]	[2.34]	[1.90]	[1.53]	[2.16]
	50-min	*55-min*	*1-hour*	*1.5-hour*	*2-hour*	*2.5-hour*	*3-hour*	*3.5-hour*	*4-hours*
# of matches	9	10	12	16	24	27	33	34	39
P(jump|event)(%)	3.14	3.48**	4.18**	5.57**	8.36**	9.41**	11.50**	11.85**	13.59**
P(jump|control)(%)	1.73	1.90	2.07	3.12	4.15	5.19	6.23	7.27	8.31
$Z_{sign-stat}$	[1.82]	[1.96]	[2.50]	[2.40]	[3.57]	[3.22]	[3.69]	[2.99]	[3.24]

Notes: Euro-dollar jump dynamics after the US officials' verbal interventions. "# of matches" gives the number of verbal interventions followed by the euro-dollar jumps after the statement releases. $P(jump|event)(\%)$ is the probability of observing jumps conditional on the communication events, and $P(jump|control)(\%)$ is the probability of observing jumps in the control sample without any events. The sample covers the periods from 01-01-1995 to 30-12-2009. **: Indicates significance at the 5% level.

Table 10: Communication and euro-dollar continuous volatility

Rolling windows	Ab. C-Volatility	C-Volatility	Z_{stat}
−(4-hour)	0.006	0.022	0.918
−(3.5-hour)	0.002	0.018	0.938
−(3-hour)	0.009**	0.025	2.704
−(2.5-hour)	0.005**	0.021	2.392
−(2-hour)	0.010**	0.026	2.495
−(1.5-hour)	0.011**	0.027	2.512
−(1-hour)	0.006**	0.023	2.117
−(55-min)	0.008**	0.024	3.298
−(50-min)	0.005**	0.022	2.744
−(45-min)	0.006**	0.023	2.648
−(40-min)	0.010**	0.026	3.181
−(35-min)	0.006**	0.023	2.334
−(30-min)	0.010**	0.027	2.841
−(25-min)	0.007**	0.023	3.187
−(20-min)	0.003	0.019	1.736
−(15-min)	0.003	0.019	1.375
−(10-min)	0.002	0.019	1.084
−(5-min)	0.003	0.019	1.307
(0-min)	0.005	0.021	1.928
+(5-min)	0.013**	0.030	4.314
+(10-min)	0.013**	0.029	3.297
+(15-min)	0.009**	0.026	3.415
+(20-min)	0.014**	0.030	3.146
+(25-min)	0.008**	0.025	2.724
+(30-min)	0.011**	0.028	2.468
+(35-min)	0.010**	0.026	3.561
+(40-min)	0.009**	0.026	3.836
+(45-min)	0.008**	0.025	2.910
+(50-min)	0.007**	0.023	3.101
+(55-min)	0.004**	0.020	2.438
+(1-hour)	0.012**	0.029	3.969
+(1.5-hour)	0.005**	0.021	2.088
+(2-hour)	0.010**	0.027	3.518
+(2.5-hour)	0.007**	0.023	2.199
+(3-hour)	0.010**	0.027	2.721
+(3.5-hour)	0.007**	0.024	2.699
+(4-hour)	0.004**	0.020	2.075

Notes: Euro-dollar continuous volatility estimates before and after the statements. The first column represents the event windows in minutes and hours. We report mean abnormal volatility $\overline{\text{Vol}}_{i,\tau}^{abnormal}$, mean continuous spot volatility $\overline{\text{Vol}}_{i,\tau}^{event}$, and Z-test statistics. **: Indicates significance at the 5% level.

Table 11: Communication and euro-dollar continuous volatility

Rolling windows	Ab. C-Volatility EA	Ab. C-Volatility US	C-Volatility EA	C-Volatility US	Z_{stat} EA	Z_{stat} US
−(4-hour)	0.012	0.000	0.028	0.017	0.891	0.041
−(3.5-hour)	0.000	0.003	0.017	0.019	0.180	0.872
−(3-hour)	0.015**	0.002	0.031	0.019	2.500	0.902
−(2.5-hour)	0.006**	0.003	0.023	0.020	2.061	1.156
−(2-hour)	0.008	0.011**	0.024	0.028	1.322	2.216
−(1.5-hour)	0.016**	0.006	0.032	0.023	1.961	1.623
−(1-hour)	0.007	0.005	0.024	0.022	1.942	1.107
−(55-min)	0.007**	0.008**	0.024	0.025	2.049	2.518
−(50-min)	0.005	0.005	0.022	0.021	1.920	1.804
−(45-min)	0.008**	0.005	0.024	0.022	2.352	1.327
−(40-min)	0.013**	0.006	0.030	0.023	2.515	1.857
−(35-min)	0.005	0.007	0.022	0.024	1.692	1.580
−(30-min)	0.016**	0.004	0.033	0.021	2.527	1.191
−(25-min)	0.008**	0.005	0.025	0.022	2.568	1.757
−(20-min)	0.002	0.003	0.019	0.020	1.101	1.205
−(15-min)	0.004	0.001	0.021	0.018	1.136	0.583
−(10-min)	0.002	0.002	0.019	0.019	1.026	0.506
−(5-min)	0.003	0.002	0.019	0.019	1.147	0.643
(0-min)	0.005**	0.004	0.021	0.021	2.023	0.938
+(5-min)	0.012**	0.014**	0.028	0.031	3.455	2.811
+(10-min)	0.015**	0.010**	0.032	0.027	2.180	2.895
+(15-min)	0.011**	0.007**	0.028	0.024	2.639	2.053
+(20-min)	0.017**	0.010	0.034	0.027	2.765	1.643
+(25-min)	0.010	0.007**	0.026	0.024	1.867	1.976
+(30-min)	0.016	0.007	0.032	0.024	1.824	1.951
+(35-min)	0.018**	0.002	0.035	0.018	3.486	0.779
+(40-min)	0.009**	0.009**	0.025	0.026	2.945	2.467
+(45-min)	0.012**	0.004	0.029	0.021	2.366	1.642
+(50-min)	0.007**	0.007**	0.023	0.023	2.319	1.972
+(55-min)	0.003	0.005	0.019	0.022	1.452	1.810
+(1-hour)	0.018**	0.007**	0.034	0.023	3.386	1.974
+(1.5-hour)	0.004	0.004	0.021	0.021	1.377	1.446
+(2-hour)	0.015**	0.005	0.032	0.022	2.952	1.811
+(2.5-hour)	0.006**	0.007	0.023	0.023	2.469	1.212
+(3-hour)	0.014**	0.006	0.031	0.023	2.608	1.133
+(3.5-hour)	0.009**	0.005	0.025	0.022	1.982	1.740
+(4-hour)	0.006	0.001	0.022	0.018	1.944	0.649

Notes: Euro-dollar continuous volatility estimates before and after the Euro area and US statements. The first column represents the event windows in minutes and hours. We report mean abnormal volatility $\overline{\text{Vol}}_{i,\tau}^{abnormal}$, mean continuous spot volatility $\overline{\text{Vol}}_{i,\tau}^{event}$, and Z-test statistics. **: Indicates significance at the 5% level.

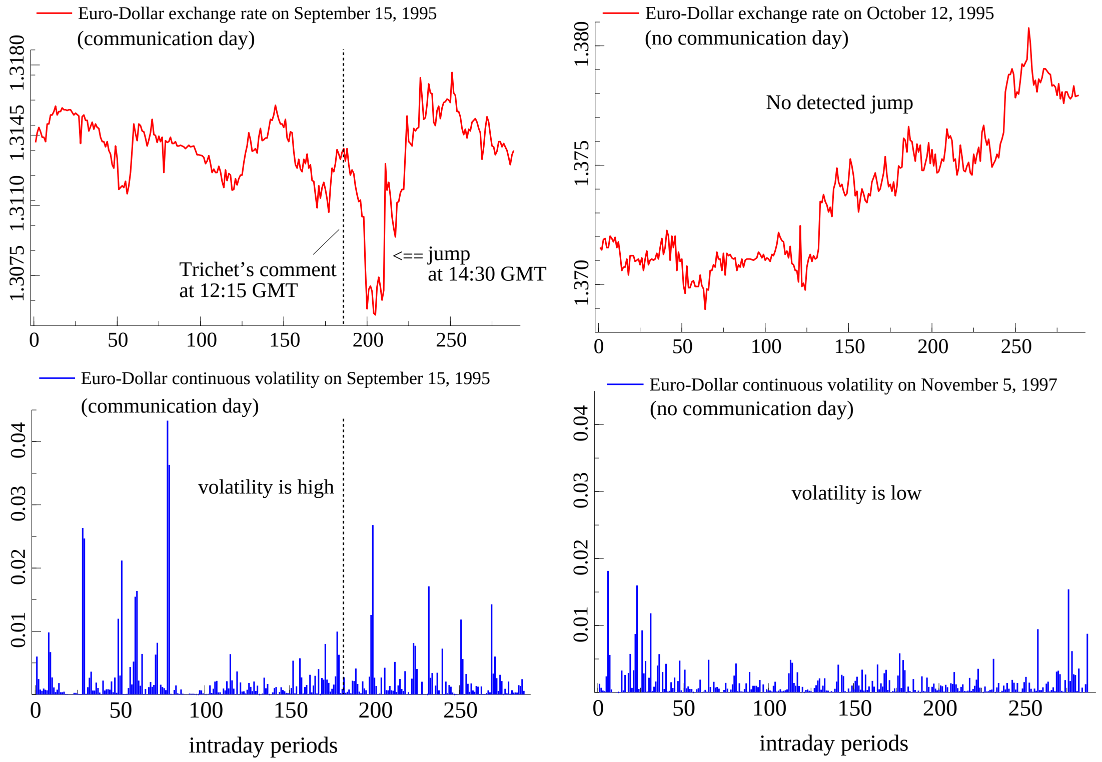

Figure 1: Illustration of two uncertainty measures on communication day: *jumps* (upper left) and *continuous volatility* (lower left). The figure also shows the euro-dollar dynamics on non-communication days (right panels).

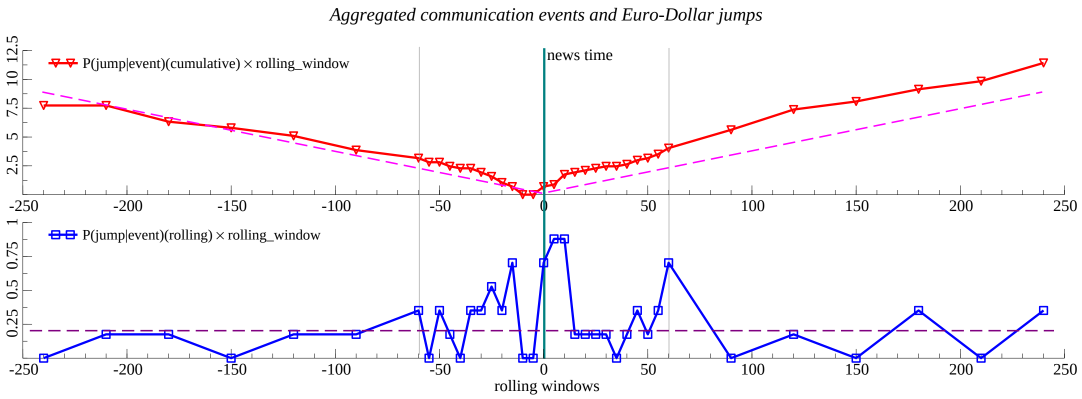

Figure 2: Intra-day effects of verbal interventions on the euro-dollar jumps. Upper panel: $p(jump|event)$ (in triangle-full line), and $p(jump|control)$ (in dashed line) around communication events. Pre-event and post-event periods are cumulative. Lower panel: $p(jump|event)$ (in square-full line), and $p(jump|control)$ (in dashed line) around communication events in rolling windows. The communication window is set to 8-hours such that $\tau \in [-240, 240]$ in minutes. The sample covers the periods from 01-01-1995 to 30-12-2009.

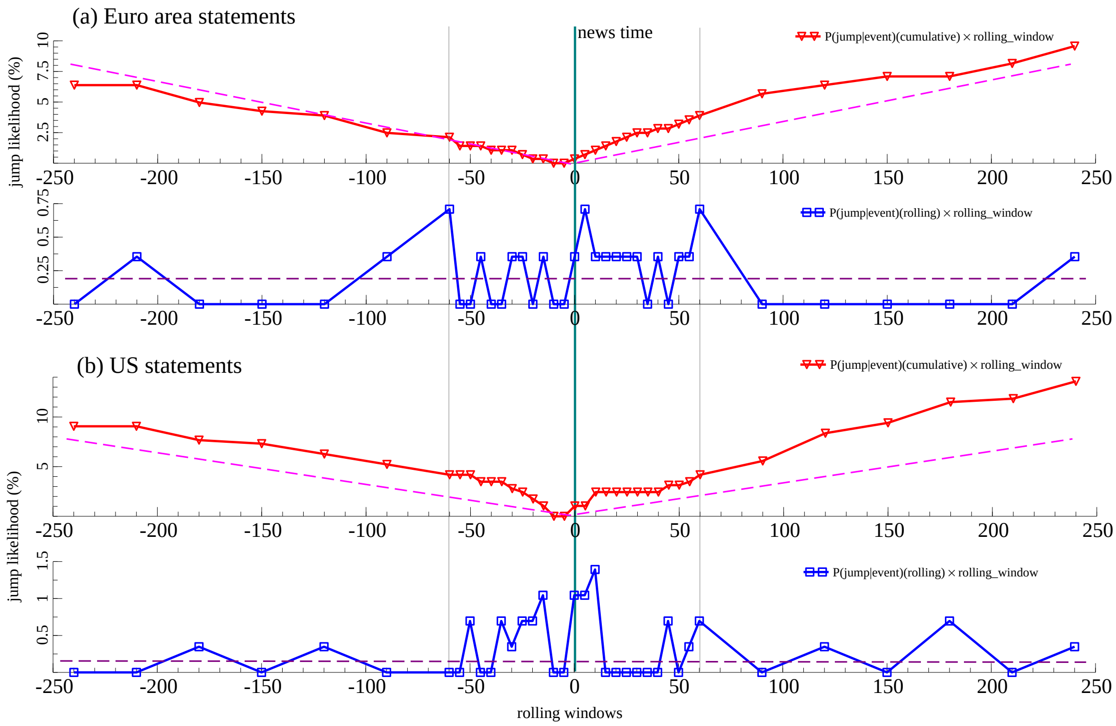

Figure 3: Intra-day effects of the Euro area and US statements on the euro-dollar jumps. Panel (a): Euro area statements. Panel (b): US statements. The communication window is set to 8-hours such that $\tau \in [-240, 240]$ in minutes. The sample covers the periods from 01-01-1995 to 30-12-2009.

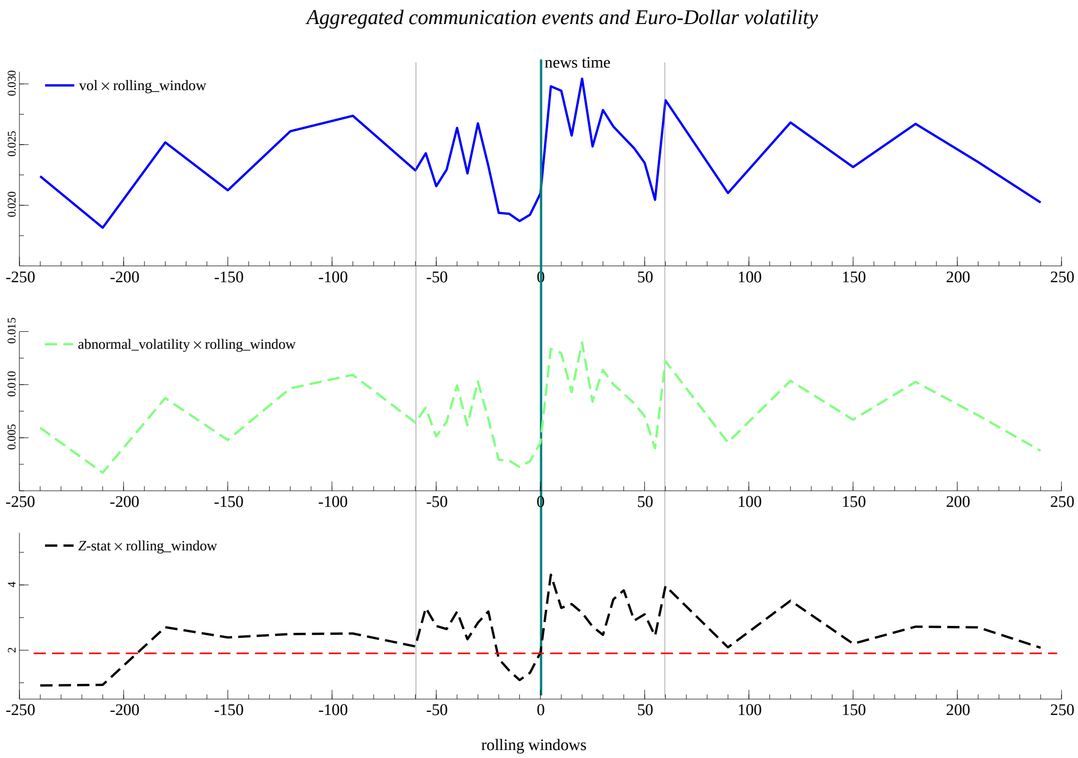

Figure 4: Intra-day effects of verbal intervention on the euro-dollar volatility. Upper panel: Euro-dollar mean $(r^*_{i,t}/f^{WSD}_{i,t})^2$ around communication events. Middle panel: mean abnormal vol, $\overline{\text{Vol}}^{abnormal}_{i,\tau}$. Lower panel: Z-statistics for $\overline{\text{Vol}}^{abnormal}_{i,\tau}$. The communication window is set to 8-hours such that $\tau \in [-240, 240]$ in minutes. The sample covers the periods from 01-01-1995 to 30-12-2009.

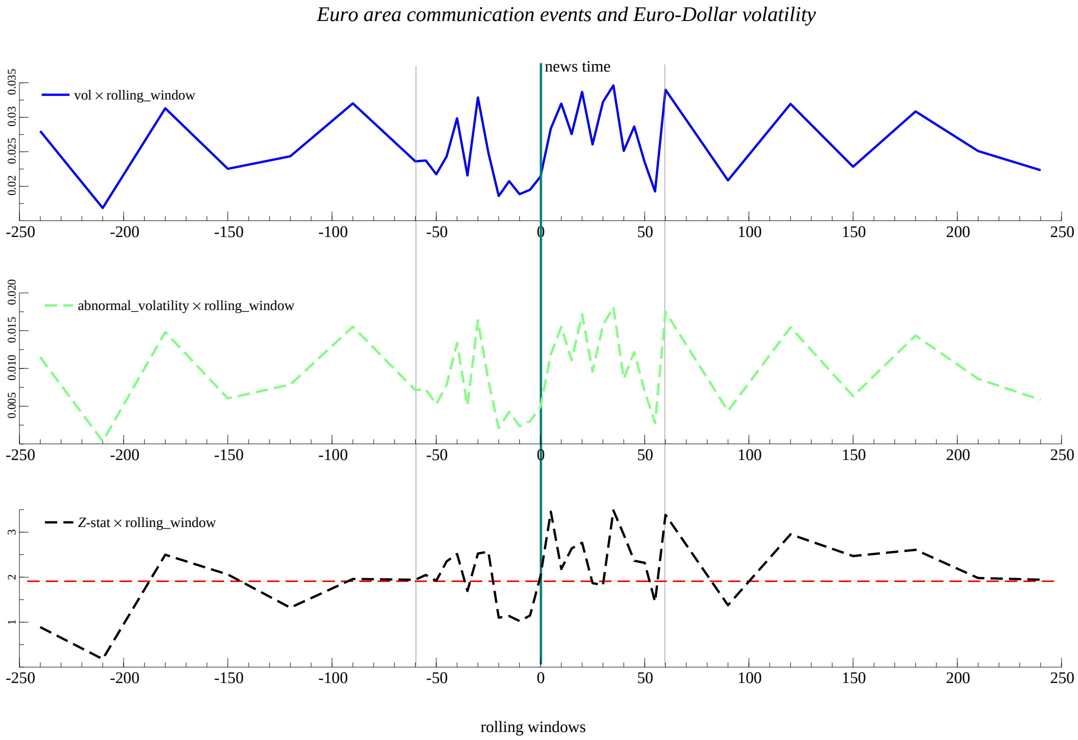

Figure 5: Intra-day effects of the Euro area verbal interventions on the euro-dollar volatility. Upper panel: Euro-dollar mean $(r^*_{i,t}/f^{WSD}_{i,t})^2$ around communication events. Middle panel: mean abnormal vol, $(\overline{\text{Vol}}^{abnormal}_{i,\tau})$. Lower panel: Z-statistics for $\overline{\text{Vol}}^{abnormal}_{i,\tau}$. The sample covers the periods from 01-01-1995 to 30-12-2009.

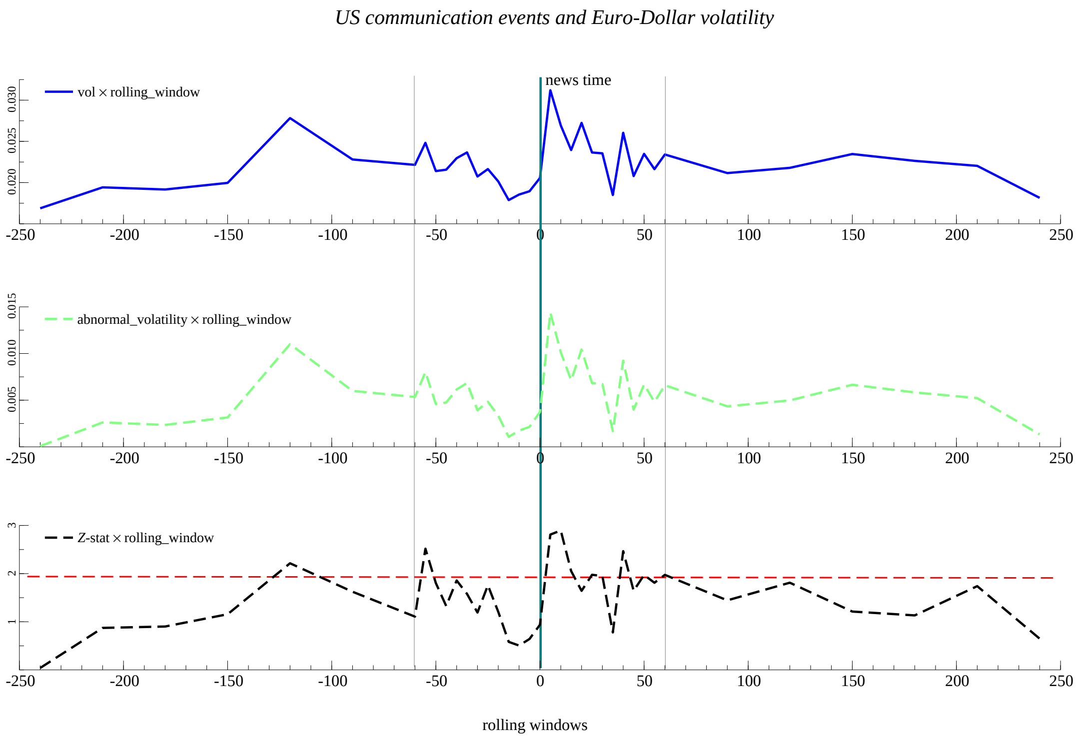

Figure 6: Intra-day effects of the US verbal interventions on the euro-dollar volatility. Upper panel: Euro-dollar mean $(r^*_{i,t}/f^{WSD}_{i,t})^2$ around communication events. Middle panel: mean abnormal vol, $\overline{\text{Vol}}^{abnormal}_{i,\tau}$. Lower panel: Z-statistics for $\overline{\text{Vol}}^{abnormal}_{i,\tau}$. The communication window is set to 8-hours such that $\tau \in [-240, 240]$ in minutes. The sample covers the periods from 01-01-1995 to 30-12-2009.