The Information Content of Individual FX Dealers' Quoting Activity*

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Abstract

We investigate the information content of dealers' quoting activity as measured by the frequency of price revisions in the Euro/Dollar foreign exchange market. We use the multivariate double autoregressive conditional Poisson model designed for time series of count data. We find that dealers react differently to the same news announcements, some dealers increasing their activity, whilst others decrease it in response to the same news. We attribute this to the heterogeneous interpretation of the news content by individual traders and to the significant influence of some dealers on others. We also find very significant interaction between dealers' quoting activity, which suggests that dealers monitor the quoting activity of others to infer their private information and their interpretation of public news announcements.

Keywords: Foreign Exchange, Market Microstructure, Time Series, Count Data.
JEL Classification codes: F31, G15, C35.

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1 Introduction

Unlike stock markets, foreign exchange markets are characterized by a very low degree of transparency. The quantities exchanged or even whether a transaction took place is only known to the transacting parties, but is not known by other market participants. Every dealer observes only his own trades. The only systematic source of information on foreign exchange markets are electronic screens, such as Reuters, Telerate and Tenfore, which transmit indicative information about the prices at which the main participants, that is large international banks, are willing to buy or sell currencies. Whenever a bank revises a spot quote of a currency, the latest quote is flashed instantaneously up on the main screen. There are other sources of information available to dealers besides electronic screens. Some dealers choose to conduct their transactions through brokers or directly via telephone. Others may prefer not to exhibit quotes on any screen even though they are active on the foreign exchange market (**?**, 1991). Nevertheless electronic screens are the only systematic source of information that each dealer has on the other dealers' quotes. Information about brokered trades for instance, will typically only consist of net volume and a price, which is not fully informative.

In this paper we use the multivariate autoregressive double Poisson model of Heinen and Rengifo (2003) to analyse the quoting activity of several large banks jointly as a system and to evaluate the effect of news announcements on quoting activity from a disaggregated point of view. By disaggregated we mean that the effect of each announcement on every bank is allowed to be different. This is new, as thus far, to the best of our knowledge, there has been no work on the response of individual banks' quoting activity to news. Our framework allows us to identify the announcements that matter for order flow, but also to see whether all banks react in the same way to the same news. Finally we can analyse interaction between different banks' quoting activity.

By looking at a sample of major dealers on the Euro/Dollar exchange rate, and by using a multivariate double autoregressive conditional Poisson model, we offer prima facie evidence of the fact that dealers' quoting activity reacts significantly to some events but differently to the same news announcements. In particular, for certain types of announcements, some banks increase their quoting activity, whilst others decrease it or keep it unchanged. This can lead to an ambiguous effect at the aggregate level implying that aggregate studies tend to underestimate the importance of public news announcements for quoting activity. In addition, using quoting activity as a proxy for market activity like in DeGennaro and Shrieves (1997), Melvin and Yin (2000) and Bauwens, Ben Omrane, and Giot (2003), allows us to classify news announcements according to Evans' taxonomy (Evans, 2002). We find that scheduled news are non-common knowledge (NCK) news whereas unscheduled news seem to belong to the category of common knowledge (CK) news.

Moreover we find that banks' quoting activity is typically affected by the quoting activity of some other dealers. This means that dealers observe the frequency of price revision of other dealers in order to infer some information. This supports the view that dealers try to infer private information or the interpretation of the news content by other dealers.

The paper is structured as follows. In Section 2 we present the literature about news announcement and inter-dealer effects on quoting activity, in Section 3 the data, in Section 4 the models and results, and in the last section we conclude.

2 The Quoting Activity Signal

During the trading period FX dealers get real time information through electronic screens about public news announcements as well as other banks' quoting activity. The latter constitutes the only information that a bank has about other banks' quotes. It is a well documented fact that dealers revise their quotes in order to reflect their reaction to public news announcements (Andersen, Bollerslev, Diebold, and Vega, 2002) or their detention of private information coming from their customers' order flow (Lyons, 1995, Evans and Lyons, 2002, Cao, Evans, and Lyons, 2003). In addition DeGennaro and Shrieves (1997) and Bauwens, Ben Omrane, and Giot (2003) show that quoting activity (assimilated to the activity of price revision) increases return volatility. They also use quoting activity adjusted from its seasonal component as a proxy for private information occurring from customers' order flow.

Given these facts, we argue that dealers can try to infer other dealers' private information or reaction to news announcements through their quoting activity. Hence, dealers could use two information channels to build their reaction to news events. The first channel takes place directly through the news broadcasters. This corresponds, in a sense, to dealers' spontaneous or direct reaction to the announcement. The second channel, which could be a source of noise to the first one, is through the quoting activity of the other dealers. In the remainder of this section we formulate the questions that we investigate and talk about some of the related literature. The first subsection deals with the link between quoting activity and news announcements, in the second we explain how we can identify which announcements are common knowledge. In the third we provide a brief summary of a relatively new literature which has been concerned with the analysis of individual banks and we talk about inter-dealer interaction.

2.1 News Announcements and Quoting Activity

News announcements and quoting activity were analysed in several studies. DeGennaro and Shrieves (1997) use three categories of news announcements (scheduled and unscheduled macroeconomic news announcements as well as interest rate reports) and six different periods around the event and analyse their impact on quoting activity. They find a significant effect of all three categories of news, but at different times relative to the announcement. Melvin and Yin (2000) work with a sample of US Dollar/Japanese Yen and US Dollar/Deutche Mark data from December 1993 to April 1995 in hourly data. They take as news variable the number of news events that happen within an hour and do not make any distinction between different categories of news. They find a significant impact of news on quoting activity, working with deseasonalised variables, and conclude that quoting activity is not self-generating. Evans and Lyons (2003) identify two channels of transmission of macro news to exchange rates: a direct effect and an indirect effect via the order flows. The news variable is the number of news announcements that occur within the period. Identification of the various effects is done by the imposition of orthogonality conditions on the various innovation terms in the model and estimation is carried out using the generalized method of moments (GMM). Changes in midquotes are regressed on order flow with two error terms, one with a constant variance, which represents information directly impounded into prices, another whose variance depends on the number of information events and represents the common knowledge effect of macro news on the exchange rate. The order flow is also the sum of two shocks, one of whose variance depends on news. This shock is interpreted as the indirect effect of news on exchange rates via induced order flow. In order to justify that macroeconomic news affects order flow, Evans and Lyons (2003) mention differences in interpretation of the news or differences in opinion as to the impact of the news on the exchange rate. Several studies have taken the number of banks quotes as a proxy for the number of transactions, which is tantamount to assuming that a fixed proportion of posted quotes correspond to actual trades. This assumption has been made, amongst others, by Goodhart and Figliuoli (1991) and Bollerslev and Domowitz (1993), who prefer to use quote arrival as a proxy for market activity, than transaction volume, because quotes signal a willingness to trade. DeGennaro and Shrieves (1997) use the same assumption, as they consider the seasonal and stochastic parts of quoting activity to be a proxy for the expected and surprise components of market activity. Furthermore, their results are suggestive of the fact that the surprise part of market activity reflects informed trading. Melvin and Yin (2000) have made the same assumption.

In this paper we analyse the reaction of individual banks to a series of news announcement. Thus far there has been to the best of our knowledge, no work on the response of individual banks' quoting activity to news. DeGennaro and Shrieves (1997) regress quoting activity on news and find a significant impact of certain types of news announcements. In our analysis we allow for different responses of individual banks to the same news and we compare the results to those of the aggregate level. We find that that the banks' reaction to news is completely heterogeneous. There are differences across banks not only in terms of which news they react to, but also in terms of how they react to the announcements. Some dealers increase their quoting activity whilst others could decrease it or keep it unchanged as a response to the same news. This suggests that banks act differently, either because they have different private information or because they interpret the public news announcements differently in terms of their implications for the exchange rate. This confirms findings of Bénassy-Quéré, Larribeau, and MacDonald (2003) of the heterogeneity of expectations of forecasters and dealers.

2.2 What announcements are common knowledge?

Evans (2002) distinguishes between two types of news: common knowledge (CK) and non-common knowledge (NCK) news. Common Knowledge (CK) news is available simultaneously to all market participants and is interpreted in the same way. News that is not known by everybody at the same time or for which interpretations are different are termed non-common knowledge news (NCK). He considers, instead of an equilibrium price, an equilibrium price distribution. He justifies this by the lack of transparency of currency markets, which makes it possible for several transactions to happen simultaneously at different prices. This can also be understood, if one considers that different dealers have different interpretations of the events that influence the exchange rate. His result suggests that CK news is not the predominant source of long term movements in the exchange rate. In the empirical part, based on prices and order flow, CK and NCK shocks are identified by the assumption that CK news leads to an immediate one-for-one change in the mean of the equilibrium price and have no effect on order flow, whereas NCK news has an impact both on prices and order flow, which may take time.

In this paper we use the taxonomy suggested by Evans (2002) to classify different categories of news announcements into two groups. Using his definition and following the literature which takes quoting activity as a proxy for the number of transactions, allows us to classify news announcements according to whether they impact quoting activity or not. If they do not, this means that they can be considered as CK news events, whereas public announcements, that have quoting activity implications, do so maybe because of heterogeneous interpretation by dealers. Indeed some banks might have different degrees of understanding of the same news, which can lead them to act on their anticipations or to stay away from the market, waiting for better-informed banks to act first.

2.3 Inter-dealer Interaction

A relatively new literature has been concerned with the analysis of individual banks. In this strand of the literature papers deal mainly with the identification of price leaders in the market around central bank interventions, but also in normal trading. Peiers (1997) analyses the midquotes of several banks on the Dollar/Mark exchange rate around the European Central Bank interventions using a vector autoregression (VAR) model and Granger causality tests to identify the price leading bank. The sample of banks includes Deutsche Bank, Société Générale, Chemical Bank, Rabobank, Den Norske and BHF Bank. Deutsche Bank is the first to react, 60 minutes prior to the announcement, followed by other banks, 25 minutes before the announcement. Wang (2001) and Sapp (2002) instead use cointegration analysis. They focus on a small subset of banks and analyse their midquotes with a cointegrated VAR model. The midquotes of all the banks are integrated of order one (I(1)) and they cannot deviate in the long run, which means that they are cointegrated. The number of cointegrating relationships is equal to the number of banks minus one, which means that there is only one stochastic trend driving the system, which can therefore be interpreted as the fundamental market price. Wang (2001) analyses price leadership amongst three leading New York-based dealers on the US Dollar/Deutche Mark market: J.P. Morgan, Chemical Bank and Citibank. Sapp (2002) works on the same market and estimates a cointegrated VAR system and deduces measures of information shares, for all the trading period as well as around central bank interventions. This is used to identify the banks whose information share is largest around central bank interventions.

In this paper we use a vector autoregressive (VAR) type structure to analyse the interactions between individual dealers' quoting activity. We establish that there are significant inter-dealer effects. This means that there are systematic lead-lag relations in the intensity of quote revision of the various banks. We offer evidence suggestive of the fact that dealers observe quoting activity of others to infer useful information like other dealers' private information or their reaction to public news announcements. If a dealer increases (decreases) his quoting activity following the publication of news this means that he intensifies (reduces) his price revision. Banks typically react to some news announcements and not to others. They also respond to the quoting activity of certain banks. We interpret this as meaning that when banks are unsure about the interpretation of certain news announcements, they tend to wait a little and watch other banks that they might perceive as being better informed in order to infer their interpretation of the news content. This means that a public news announcement could have no effect on a given bank's quoting activity either because they consider that news as irrelevant or they prefer to wait and see how better informed dealers react. In that sense we argue that quoting activity is a potentially useful information channel in an otherwise very opaque foreign exchange market.

3 Data and Descriptive Statistics

We work with a tick-by-tick data set bought from Olsen & Associates for the period May 14 to October 26, 2001. The data comes from different quoting systems. From May 14 until September 10, 2001, the data comes from Reuters, and from August 24 until October 26, 2001, it comes from Tenfore Systems.

We take into consideration two electronic screens to eliminate the quoting activity bias shown by Goodhart and Demos (1991) (i.e. all dealers do not conduct their quoting through only one electronic screen, but they choose different ones). We therefore work with two samples of banks during different periods. We selected the most active banks in our sample. Tables 1 and 2 show, that for the first sample, the 4 banks we select cover about 24.4% of the overall quotes, whereas the 6 banks of the second sample post about 45% of the total number of quotes in the sample. The reason why we focus attention on these banks is that they are the most active dealers in our data and the remaining quotes are posted by a very large number of dealers with a very small contribution. Our first sample of banks contains BG Bank, Copenhagen (BGFX), Berliner Handels- und Frankfurter Bank, Frankfurt (BHFX), Rabobank, London (RABO), Société Générale, Paris (SGOX) for the period May 14 to September 10, 2001. This corresponds to 9396 5-minute observations. The second sample of banks includes Barclay's Bank, London (BARL), Dresdner Bank, Frankfurt (DREF), Oolder & de Jong, Amsterdam (OHVA), Oko Bank, Helsinki (OKOH), SHK Bank, Hong Kong (SHKH) and Union Bank of Switzerland, Zurich (UBSZ), for the period August 24 to October 26 2001, for a total of 4968 5-minute quoting intervals.

Descriptive statistics for the first sample are shown in Table 1 and in Table 2 for the second sample. The minimum number of quotes is zero and the mean is generally quite small, which justifies the use of discrete distributions like the Poisson. Moreover, most series are overdispersed (meaning that the variance is larger than the mean), with the exception of BHFX, RABO and OHVA, which are underdispersed. This justifies the use of the double Poisson distribution, since, unlike other count distributions, it allows for both over- and underdispersion.

We use the same news announcements as in Bauwens, Ben Omrane, and Giot (2003) and we test the impact of nine categories of news. News announcements, shown in Table 3 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. This group also includes European macroeconomic figures, scheduled speeches of senior officials of the government and of public agencies, such as the president of the Federal Reserve, the European Central Bank and the economy and finance ministers, and US and European interest rate reports. The second group contains forecasts of key institutes and specialized organizations, such as the IMF, the World Bank, and the IFO institute (an influential service-based research organization in Germany). This group also contains declarations of OPEC members, rumors of Central Bank intervention and other extraordinary events (natural disasters, wars, terrorist attacks, etc.). To highlight the effect of the possible 'surprise' contained in the scheduled US macroeconomic 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 it is a figure which contributes to the growth of the economy, the news is classified as positive. If the actual figure indicates 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), who 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. As can be seen from Table 3, the total number of news announcements in the first sample is 377, the most frequent type of news event is European macroeconomic figures with 105 events, but there are only 3 occurrences of rumors of central bank interventions. In the second sample, there are 251 events, with 53 speeches of government officials and only 3 rumors of central bank intervention.

We compute averages of the quoting activity over 5-minute intervals for all banks and divide them by their cross-sectional average in order to make them comparable across banks. The seasonal patterns are shown in Figure 1. First of all, we note that the seasonality of the banks in the sample is not the same for all, which is not surprising. BGFX, SGOX, BARL, DREF, SHKH, and UBSZ all start with a small decrease in the morning until 10 AM GMT, and after that quoting activity starts increasing from around 12 PM GMT, which corresponds to the morning on the East Coast of the US, to a peak around 2 or 3 PM GMT, and then the activity decreases until 5 PM GMT, when European offices start to close. SHKH is somewhat different, as it starts the day with an increase, but then its pattern is similar to the one of the other banks. DREF is different from other banks, in that it starts closing earlier, which means that its quoting activity decreases sharply shortly before 4 PM GMT. A similar pattern is observed for other banks, but between 6 and 7 PM for most of them, which is why we chose to stop our sample at 5 PM. The remaining banks (BHFX, RABO, OHVA and OKOH) do not seem to exhibit any particular seasonality over our sample period. This is confirmed for RABO, OHVA and OKOH by the Wald test for joint significance of the seasonality variables shown in Tables 6 and 7 (see Section 4.2 for more details). Furthermore we note that DREF has a particular pattern of diurnal seasonality, with very important spikes on or around the hour.

4 Models and Results

We now turn to the empirical methodology used in this paper. We model the quote arrival of each bank in order to study its sensitivity to news announcements and to check whether there are significant interbank effects. In order to do this we use the Multivariate Double Autoregressive Conditional Poisson (MDACP) introduced by Heinen and Rengifo (2003). The first subsection draws on that paper. For more details on the econometrics we refer the reader to that paper. The second part of the section presents and discusses the results.

4.1 Modelling Quote Arrival

In the remainder of the paper we work with the number of quotes of individual banks on the Euro/Dollar exchange market. As the number of quotes for most banks is a relatively small number, usual time series models, based on the normal distribution, are not appropriate. Instead we work with time series models developed specifically for count data. In our sample, the data is not equidispersed, but it is for most series either under- and overdispersed. In order to model the dispersion in a more flexible way, we work with double Poisson distribution of Efron (1986). The Multivariate Double Autoregressive Conditional Poisson (MDACP) model assumes that the number of quotes of bank $i$in period t, $N_{i,t}$, follows a double Poisson distribution, conditionally on past information:

$$N_{i,t}|\mathcal{F}_{t-1} \sim DP(\mu_{i,t}, \phi_i)\ ,\ \forall\, i = 1, \ldots, K. \tag{1}$$

where $\mathcal{F}_{t-1}$ is the information set generated by the past of the series up to and including time $t-1$. The parameters $\mu_{i,t}$ and ϕ_i are respectively the mean and the coefficient of dispersion of the double Poisson. Its conditional variance is equal to

$$V[N_{i,t}|\mathcal{F}_{t-1}] = \sigma^2_{i,t} = \frac{\mu_{i,t}}{\phi_i}\ . \tag{2}$$

The distribution is over- or underdispersed for values of ϕ_i respectively less or greater than 1. When $\phi_i = 1$ the distribution reduces to the equidispersed Poisson. The fact that the conditional mean is autocorrelated (see below, equation (4)) leads to some overdispersion, whose magnitude depends on the autoregressive coefficients. Whereas the autocorrelation (present as long as autoregressive coefficients are non-zero) leads to overdispersion, the effect of the double Poisson is to increase or lower this dispersion, leading to either over- or underdispersed models. In most cases, though, the conditional distribution adds to the overdispersion stemming from the autocorrelation to match the overdispersion in the data (see Appendix 1 for details about the double Poisson distribution).

The vector $\mu_t = (\mu_{1,t}, \ldots, \mu_{K,t})'$ of conditional means is assumed to follow a VARMA$(1,1)$ process

$$\mu_t = \omega + A\ N_{t-1} + B\ \mu_{t-1}\ , \tag{3}$$

where A is a full rank matrix of coefficients capturing the impact of the lagged inter-dealers' quoting activity effects, and B is a diagonal matrix of autoregressive coefficients of the own lagged conditional mean. More explicitly, the equation for each mean $\mu_{i,t}$ is

$$\mu_{i,t} = \omega_i + \sum_{j=1}^{K} \alpha_{i,j} N_{j,t-1} + \beta_i \mu_{i,t-1}, \tag{4}$$

we work with a $(1,1)$ structure for the mean equation, as this is parsimonious and flexible enough.

We are interested in analysing the impact of news announcements on individual banks' quoting activity, allowing for diurnal seasonality. The news variables take the form of dummies for the presence of a certain announcement ($d_{j,t}$, $j = 1, \ldots, 9.$). The seasonality is modelled using the Fourier Flexible Form (FFF) introduced in the foreign exchange literature by Andersen and Bollerslev (1998) at daily, half daily and hourly frequencies. We modify the conditional mean in the following manner to include these exogenous regressors:

$$\mu^*_{i,t} = \mu_{i,t} \exp\big(\sum_{j=1}^{9} \eta_{i,j} d_{j,t} + \sum_{p=1,2,12} (\psi_{i,c,p} \cos \frac{2\pi p\, Re[t,T]}{T} + \psi_{i,s,p} \sin \frac{2\pi p\, Re[t,T]}{T})\big) \ ,$$

where $Re[t,T]$ is the remainder of the integer division of t by T, the number of periods in a trading session. The way we include the regressors separates the autoregressive part from the effect of seasonality and news, and this functional form guarantees the positivity of the conditional mean.

In order to estimate our model, we use a two-stage estimator as in Patton (2002). In a first step we estimate parameters of the marginal models under the assumption that conditionally on the past, the different series of individual banks' quoting activity are uncorrelated. This means that there is no contemporaneous correlation and that all the dependance between the series is assumed to be captured by the conditional mean. Consequently we estimate our equation system, equation by equation, using the maximum likelihood method with the Newey-West (HAC) standard errors and we get consistent estimators. However, to capture contemporaneous cross-correlation, we resort to copulas in a second step. Patton (2002) shows that this procedure delivers reasonable results. A one-step estimation procedure which would estimate copula parameters and parameters of the marginal models jointly is not numerically feasible due to the very large number of parameters. As far as the choice of copulas is concerned, we choose to work with the most intuitive one, which is arguably the Gaussian copula. It provides a very general way of introducing dependence among several series with known marginals. It is noteworthy that the second step does not require any optimization, as the maximum likelihood of the multivariate normal copula covariance matrix is simply the sample counterpart of the variance-covariance matrix of the inverse of the standard univariate normal distribution function (Φ^{-1}) of the probability integral transformation (z_i): $\Sigma | q_i = \Phi^{-1}(z_i)$ (see Appendix 2 for details about copulas).

In order to evaluate the quality of the model, we use tools developed in density forecast evaluation by Diebold, Gunther, and Tay (1998). The main idea is to use the cumulative distribution of the data under the estimated density and to check whether this is uniformly distributed, as it should be according to the probability integral transformation theorem (PITT) of Fisher (1932). The assumptions of the theorem are that the density is continuous, which is violated in the case of counts. We explain in the Appendix 3, how we deal with this problem using continued extensions of discrete variables.

We also test the standardized residuals

$$\varepsilon_{i,t} = \frac{N_{i,t} - \mu^*_{i,t}}{\sigma_{i,t}} = \frac{N_{i,t} - \mu^*_{i,t}}{\sqrt{\mu^*_{i,t}/\phi_i}}$$

for autocorrelation, which would indicate a failure of the model to capture the dynamics of the series, and for deviation of their variance from one, which would indicate misspecification of the dispersion.

4.2 Results

Tables 4 and 5 show the copula correlation matrix which is responsible for the contemporaneous cross-correlation and the part of the lagged cross-correlation between individual banks' quoting activity, which does not go through the time-varying mean. Cross-correlations vary between 0.04 and 0.48. This means that contemporaneous effect between different banks depends on the importance of the influence of some banks' quoting activity on others.

Estimation results are presented in Tables 6 and 7. There is evidence of diurnal seasonality in the activity of all banks except three (see end of Section 3). The three pairs of trigonometric function at the daily, half-daily and hourly frequency are always jointly significant. The effect of news announcements is generally significant for all banks, as can be seen from a Wald test of the joint significance of all announcement. What the dummy variables results of individual banks show clearly, is that their reaction to the same news announcements are different. There is variation across banks, both in whether or not they react to a certain category of news and in the way they react to it, by increasing or decreasing their activity.

The use of the double Poisson is justified by the fact that we have estimated both overdispersed distributions (the majority of them) and some underdispersed distributions. The variance of the standardized residuals is within a few percent of one for nearly all banks, except OKOH, which means that the dispersion is well captured. Upon closer inspection of its time series, we can see that there seems to be a change of regime in OKOH, which went from heavy quoting to lower levels of activity after October 8, 2001. The autocorrelations of the standardized residuals of BARL and UBSZ, shown as representative example in Figure 2, are often in the confidence band. However, some autocorrelations are a little outside of the bands, resulting in significant Q-statistics (the sample size is large). Nevertheless, the Q-statistics are very strongly reduced, compared to the raw data, even though they are still significant. Another way of testing the specification is to look at the density forecast tools. The probability integral transformation Z (PIT) of the data under the estimated distributions should be uncorrelated and uniformly distributed. Figure 3 shows the quantile plot of Z, which is very close to the 45-degree line for six banks, shown as examples.

For both samples of banks, it seems that at least one type of scheduled news event has an impact on every bank, except for OHVA. Positive and negative surprises in U.S. and European figures (respectively η_1, η_2 and η_3) seem to have the most important effects. This is in line with the findings of Andersen, Bollerslev, Diebold, and Vega (2002), that macroeconomic surprises have the most significant impact on the level of the exchange rate. According to Evans (2002), these types of announcements are therefore NCK news, as they impact order flow. Given that they are simultaneously received by all dealers, it has to be the case that they are interpreted differently. A lot of banks react to the first three scheduled news announcements. In particular SGOX and DREF increase their activity as a response to US and European macroeconomic figures, RABO and OKOH decrease it as a response to US figures but increase it to react to European figures. On the other hand, banks like BHFX, RABO and SHKH reduce their quoting in response to US figures. However, speeches of senior officials of the government (η_4) seem to pertain to the category of CK news, given that this variable is not significant for any bank. It could of course also be that this variable simply does not have any informational content, as perceived by foreign exchange dealers, but Bauwens, Ben Omrane, and Giot (2003) find that it has an impact on volatility, which is significant at the 1% level. The remaining unscheduled news (η_6, η_7, η_8 and η_9) hardly affects banks' quoting activity and we can thus consider them as CK news, unless markets don't regard them to be very informative at all.

Table 8 shows for every type of announcement the result of a Wald test of the null hypothesis that the announcement impacts all banks in the same way. The results show that US and European macroeconomic figures affect banks differently in both samples, whereas interest rate reports are only significantly different in sample 2. The remaining announcements have impacts on different banks that are not significantly different, which is not a surprise since the latter announcements are much less significant in general.

In addition, we estimate a restricted DACP model, i.e. equation (4) when $\alpha_{i,j} = 0$ for $i \neq j$, on the same banks' quoting activity. We find almost the same estimated dummy coefficients as for the general model, MDACP (results are not reported). Thus, we estimate a DACP on aggregate quoting activity, as well as those of the remaining banks (respectively "Aggregate" and "Rest" in Tables 6 and 7), adopting the same seasonality variables, an ARMA(1,1) structure and the same samples of banks, in order to compare the obtained results with those generated by MDACP. We find, for instance in the case of positive US macroeconomic figures, that there are both increases and decreases in quoting activity of individual dealers. These effects offset each other, which reduces the significance of news on quoting activity at the aggregate level. Another example is European and US interest rate reports, which are significant for three banks of sample 2, but not at the aggregate level. However, in the case of negative US and European macroeconomic figures, there are both increases and decreases in activity, but the increases seem to dominate at the aggregate level. This is strong evidence that aggregate analysis of quoting activity can miss the fact that individual banks have different reactions. In some cases, even though there is no aggregate impact of news on quoting activity, individual banks do respond, but their responses can offset each other, and in other cases, a positive coefficient at the aggregate level can conceal a less unified picture at the level of individual dealers.

Finally the results in Tables 6 and 7 show that there are significant inter-dealer effects. The quoting activity of each dealer increases or decreases in response to the lagged activity of some other dealers. Some banks do not influence the quoting activity of other banks, they are clearly followers. In sample 1 each bank's quoting activity is sensitive to at least one other bank's quotes. In sample 2, however, at least three banks' quotes have a significant impact on every dealers' quotes. This supports the hypothesis that some dealers observe the frequency of price revision of some influential dealers' quoting activity in order to infer useful information.

Consequently, the results related to dealers' quoting activity sensitivity to both news announcements and quoting activity of some other dealers, confirm the general hypothesis according to which quoting activity provides an important informative signal. Indeed, during event periods, dealers monitor quoting activity of some others in order to infer their manner of reaction to news announcements before their immediate or afterward react.

5 Conclusion

In this paper we show that foreign exchange dealers' quoting activity can play a significant role in conveying information to overall market participants. By looking at a sample of major dealers on the Euro/Dollar exchange market, we offer evidence of the fact that firstly, banks' quoting activity reacts to certain news announcements and that FX dealers' quoting activity reacts differently to the same news announcements. We take this as an indication of their heterogeneous interpretation of the news content. This confirms findings of Bénassy-Quéré, Larribeau, and MacDonald (2003) of the heterogeneity of expectations of forecasters and dealers. Moreover, the differences in reaction are more extreme than could be expected a priori, as it is not rare to see that some banks increase their activity, while others decrease it in response to the same announcement. Finally, there is significant inter-dealer interaction, as banks' quoting activity is typically affected by the intensity of quote revision of some others. This means that dealers observe the frequency of price revision of other dealers in order to infer some useful information. This offers support for the hypothesis that most FX dealers monitor quoting activity of some influential ones in order to try to infer other dealers' private information, stemming for instance from their customer order flow or their reaction to public news announcements.

Appendix 1: The Double Poisson Distribution

The double Poisson distribution, for the integer valued positive random variable y, has the following expression:

$$f(y|\mu,\phi) = c(\mu,\phi)\left(\phi^{\frac{1}{2}}e^{-\phi\mu}\right)\left(\frac{e^{-y}y^y}{y!}\right)\left(\frac{e^{\mu}}{y}\right)^{\phi y} .$$

Where $c(\mu,\phi)$ is a constant (with respect to y) such that the probabilities add to one. Efron (1986) shows that the value of $c(\mu,\phi)$ varies little with respect to μ and ϕ. He also provides the approximation $\frac{1}{c(\mu,\phi)} \approx 1 + \frac{1-\phi}{12\mu\phi}(1+\frac{1}{\mu\phi})$ and he suggests maximising the approximate likelihood (leaving out the highly nonlinear multiplicative constant) in order to estimate the parameters and using the correction factor when making probability statements using the density.

Appendix 2: Copulas

Copulas provide a very general way of introducing dependence among several series with known marginals. Copula theory goes back to the work of Sklar (1959), who showed that a joint distribution can be decomposed into its K marginal distributions and a copula, that describes the dependence between the variables. This theorem provides an easy way to form valid multivariate distributions from known marginals. A more detailed account of copulas can be found in Joe (1997) and in Nelsen (1999). Let $H(y_1,\ldots,y_K)$ be a continuous K-variate cumulative distribution function with univariate margins $F_i(y_i)$, $i=1,\ldots,K$, where $F_i(y_i) = H(\infty,\ldots,y_i,\ldots,\infty)$. According to Sklar (1959), there exists a function C, called copula, mapping $[0,1]^K$ into $[0,1]$, such that:

$$H(y_1,\ldots,y_K) = C(F_1(y_1),\ldots,F_K(y_K)) .$$

The joint density function is given by the product of the marginals and the copula density:

$$\frac{\partial H(y_1,\ldots,y_K)}{\partial y_1\ldots\partial y_K} = \prod_{i=1}^{K} f_i(y_i)\frac{\partial C(F_1(y_1),\ldots,F_K(y_K))}{\partial F_1(y_1)\ldots\partial F_K(y_K)} ,$$

while there are many alternative formulations for copulas in the bivariate case, the number of possibilities for multi-parameter multivariate copulas is rather limited. We choose to work with the most intuitive one, which is arguably the Gaussian copula, obtained by the inversion method (based on Sklar, 1959). This is a K-dimensional copula such that:

$$C(z_1,\ldots,z_k,\Sigma) = \Phi^K(\Phi^{-1}(z_1),\ldots,\Phi^{-1}(z_K);\Sigma) ,$$

and its density is given by,

$$c(z_1, \ldots, z_K; \Sigma) = \mid \Sigma \mid^{-1/2} \exp\left(\frac{1}{2}(q'(I_K - \Sigma^{-1})q\right) ,$$

where Φ^K is the K-dimensional standard normal multivariate distribution function, Φ^{-1} is the inverse of the standard univariate normal distribution function and $q = (q_1, \ldots, q_K)'$ with normal scores $q_i = \Phi^{-1}(z_i)$, $i = 1, \ldots, K$. Furthermore, it can be seen that if $Y_1, \ldots, Y_K$ are mutually independent, the matrix Σ is equal to the identity matrix I_K and the copula density is then equal to 1.

The joint density of the counts in the Double Poisson case with the Gaussian copula is:

$$h(N_{1,t}, \ldots, N_{K,t}, \theta, \Sigma) = \prod_{i=1}^{K} f_{DP}(N_{i,t}, \mu^*_{i,t}, \phi_i) \cdot c(q_t; \Sigma) ,$$

$f_{DP}(N_{i,t}, \mu^*_{i,t}, \phi_i)$ denotes the Double Poisson density as a function of the observation $N_{i,t}$, the conditional mean $\mu^*_{i,t}$ and the dispersion parameter ϕ_i. c denotes the copula density of a multivariate normal and $\theta = (\omega, vec(A), vec(B))$. The $q_{i,t}$, gathered in the vector q_t are the normal quantiles of the $z_{i,t}$:

$$q_t = (\Phi^{-1}(z_{1,t}), \ldots, \Phi^{-1}(z_{K,t}))' ,$$

where the $z_{i,t}$ are the PIT of the continuoused count data, under the marginal densities (see Appendix 3 for details).

Taking logs, one gets:

$$\log(h_t) = \sum_{i=1}^{K} log(f_{DP}(N_{i,t}, \mu^*_{i,t}, \phi_i)) + \log(c(q_t; \Sigma))).$$

We consider a two-stage estimator as in Patton (2002). Given that we use the multivariate normal copula, the second step of the two-stage procedure does not require any optimisation, as the MLE of the variance-covariance matrix of a multivariate normal with a zero mean, is simply the sample counterpart:

$$\hat{\Sigma} = \frac{1}{T} \sum_{t=1}^{T} q_t q_t^{'} .$$

It is important to realise that correct specification of the density in the marginal models is crucial to the specification of the copula, as any mistake would have as a consequence the fact that the uniformity assumption is violated, which would invalidate the use of copulas.

Appendix 3: Discrete Distributions and PITT

The problem with discrete distributions is that the probability integral transformation theorem (PITT) of Fisher (1932) does not apply, and the uniformity assumption does not hold, regardless of the quality of the specification of the marginal model. The PITT states that if Y is a continuous variable, with cumulative distribution F, then

$$Z = F(Y)$$

is uniformly distributed on $[0, 1]$.

Denuit and Lambert (2002) use continued extension to overcome these difficulties and apply copulas with discrete marginals. The main idea of continued extensions of a discrete variable is to create a new random variable Y^* by adding to a discrete variable Y a continuous variable U valued in $[0, 1]$, independent of Y, with a strictly increasing cdf, sharing no parameter with the distribution of Y, such as the uniform on $[0, 1]$ for instance:

$$Y^* = Y + (U - 1)\ .$$

As can be seen, knowing the value of Y^*, which is the new continuous variable, is equivalent to knowing the value of the underlying count. If $Y^* = 4.38275629$, then we know that $Y = 5$. Hence we do not lose any information by creating this new variable.

Using continued extension, Denuit and Lambert (2002) state a discrete analog of the PITT. If Y is a discrete random variable with domain χ, in $\mathbf{N}$, such that $f_y = P(Y = y), y \in \chi$, continuoused by U, then

$$Z^* = F^*(Y^*) = F^*(Y + (U - 1)) = F\left([Y^*]\right) + f_{[Y^*]+1}U = F(Y - 1) + f_y U$$

is uniformly distributed on $[0, 1]$, and $[Y]$ denotes the integer part of Y.

In this paper, we use the continuoused version of the probability integral transformation in order to test the correct specification of the marginal models. If the marginal models are well-specified, then Z^*, the PIT of the series under the estimated distribution and after continued extension, is uniformly distributed.

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Table 1: **Descriptive statistics of the number of quotes per 5-minute interval of the first sample of banks for the period May 14 to September 10, 2001**

	Mean	**Std. Dev.**	**Dispersion**	**Maximum**	$Q(10)$
BGFX	7.99	4.57	2.61	28	26404
BHFX	9.40	2.37	0.60	17	2822.5
RABO	6.86	2.20	0.71	20	4608.3
SGOX	15.40	6.71	2.92	46	14315
Rest	120.58	56.88	26.83	399	57444
Aggreg	162.25	64.03	25.27	472	50807

Table 2: **Descriptive statistics of the number of quotes per 5-minute interval for the second sample of banks for the period August 24 to October 26 2001**

	Mean	**Std. Dev.**	**Dispersion**	**Maximum**	$Q(10)$
BARL	11.54	4.15	1.49	22	9571.9
DREF	2.27	2.62	3.02	20	8217.9
OHVA	14.22	3.73	0.98	21	10809
OKOH	31.56	21.86	15.14	82	36956
SHKH	3.03	2.15	1.53	16	4228.3
UBSZ	10.82	5.59	2.89	44	8980.1
Rest	81.66	61.79	46.75	352	37913
Aggreg	163.2	78.81	38.06	486	34264

Table 3: **News categories**

Scheduled news announcements				
1 and 2-US macroeconomic figures	Positive	Negative	sample1	sample2
	η_1	η_2	98	54
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	η_3		105	51
4-Speeches of senior officials of the government and those of public agencies	η_4		78	53
5-US and European interest rate reports	η_5		36	25
Unscheduled news announcements				
6-Forecasts made by economic institutes	η_6		36	19
7-Declarations of OPEC members	η_7		13	25
8-Rumors of Central Bank interventions	η_8		3	3
9-Extraordinary events	η_9		8	21
Total			377	251

The events are the news headlines released on the Reuters money news-alerts.
For US macroeconomig figures, 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 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 η_j is the coefficient of the dummy variable d_j in the equations reported in Tables 6 and 7.

Table 4: **Correlation matrix of the q estimated by the MDACP model for the first sample of banks for the period May 14 to September 10, 2001**

	BGFX	BHFX	RABO	SGOX
BGFX	1.00			
BHFX	0.17	1.00		
RABO	0.28	0.19	1.00	
SGOX	0.44	0.20	0.29	1.00

The table presents the correlation matrix q, based on the probability integral transformation z, of the continued count data under the marginal densities estimated using the MDACP models by the two-step procedure (see section 4.1). It shows the contemporeneous correlations of the aggregate system of table 6.

Table 5: **Correlation matrix of the q estimated by the MDACP model for the first sample of banks for the period August 24 to October 26, 2001**

	BARL	DREF	OHVA	OKOH	SHKH	UBSZ
BARL	1.00					
DREF	0.35	1.00				
OHVA	0.21	0.15	1.00			
OKOH	0.18	0.14	0.15	1.00		
SHKH	0.07	0.04	0.06	0.04	1.00	
UBSZ	0.48	0.39	0.18	0.18	0.09	1.00

The table presents the correlation matrix q, based on the probability integral transformation z, of the continued count data under the marginal densities estimated using the MDACP models by the two-step procedure (see section 4.1). It shows the contemporeneous correlations of the aggregate system of table 7.

Table 6: **Estimation results of MDACP models for sample 1, May 14 to September 10, 2001.**

Parameters	BGFX	BHFX	RABO	SGOX	Rest	Agregate
η_1	0.091	**-0.064***	**-0.105***	**0.193****	0.044	0.046
	(13.5%)	(3.34%)	(2.50%)	(0.00%)	(9.5%)	(6.6%)
η_2	0.091	-0.060	**-0.088***	**0.185****	**0.084****	**0.082****
	(8.88%)	(6.23%)	(3.55%)	(0.00%)	(0.1%)	(0.00%)
η_3	**0.122****	-0.031	0.050	**0.135****	**0.123****	**0.110****
	(0.28%)	(18.7%)	(8.45%)	(0.00%)	(0.00%)	(0.00%)
η_4	0.014	-0.005	-0.033	0.025	0.014	0.012
	(82%)	(85.6%)	(34.51%)	(53.1%)	(59.5%)	(64.2%)
η_5	0.114	-0.029	-0.017	0.048	-0.001	0.009
	(9.53%)	(54.8%)	(78.4%)	(33.9%)	(97.7%)	(76.2%)
η_6	0.133	0.026	0.056	0.030	0.052	0.055
	(9.38%)	(61.9%)	(34.7%)	(68.0%)	(15.2%)	(13.9%)
η_7	-0.186	-0.060	0.004	0.003	-0.005	-0.020
	(6.39%)	(66.2%)	(96.1%)	(97.3%)	(94.0%)	(74.7%)
η_8	-0.439	0.251	-0.308	-0.233	-0.031	–0.044
	(24.7%)	(65.8%)	(11.7%)	(64.3%)	(83.3%)	(76.8%)
η_9	0.176	0.027	0.122	0.158	0.045	0.053
	(21.7%)	(76.5%)	(25.6%)	(8.50%)	(17.9%)	(15.7%)
α_{BGFX}	**0.203****	-0.001	0.0008	**0.025****		
	(0.00%)	(45.7%)	(63.2%)	(0.06%)		
α_{BHFX}	-0.001	**0.137****	**0.030****	**0.078****		
	(80.9%)	(0.00%)	(0.00%)	(0.00%)		
α_{RABO}	-0.004	**0.018****	**0.132****	**0.038***		
	(61.2%)	(0.02%)	(0.00%)	(1.68%)		
α_{SGOX}	**-0.007****	**0.007****	**0.009****	**0.271****		
	(0.06%)	(0.00%)	(0.00%)	(0.00%)		
ω	**0.199****	**0.272****	**0.071****	**0.616****	**5.763****	**7.217****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
β	**0.789****	**0.809****	**0.796****	**0.608****	**0.380****	**0.452****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
ϕ	**0.687****	**1.739****	**1.490****	**0.504****	**0.196****	**0.161****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
$W(\eta_j = 0)$	**26.18****	12.14	**21.04***	**59.09****	**142.52****	**116.84****
	(0.00%)	(20.5%)	(1.20%)	(0.00%)	(0.00%)	(0.00%)
$W(\psi' s = 0)$	**60.70****	**74.91****	10.62	**90.88****	**91.25****	**69.91****
	(0.00%)	(0.00%)	(10.1%)	(0.00%)	(0.00%)	(0.00%)
$W(\alpha_i = 0)$	**44.92****	**63.83****	176.3**	**89.40****	**91.25****	**69.91****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
$Var(\varepsilon_t)$	0.96	0.95	0.90	0.97	1.12	1.05
$Q(10)$	**111.45****	**19.95***	**52.08****	**74.39****	**54.15****	**84.13****
	(0.00%)	(3.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
LL	-23795.62	-21108.37	-20223.68	-20291.97	-45356.05	-42859.43

The estimated model is the MDACP model, with the following mean (see Section 4.1 for definition of variables):
$\mu^*_{i,t} = \mu_{i,t} \exp\left(\sum_{j=1}^{9} \eta_{i,j} d_{j,t} + \sum_{p=1,2,12} (\psi_{i,c,p} \cos \frac{2\pi p\, Re[t,T]}{T} + \psi_{i,s,p} \sin \frac{2\pi p\, Re[t,T]}{T}) \right)$, and
$\mu_{i,t} = \omega_i + \sum_{j=1}^{K} \alpha_{i,j} N_{j,t-1} + \beta_i \mu_{i,t-1}$,
where K is the number of banks. We show Wald tests $W(\psi' s = 0)$ for joint significance of all the seasonality variables. $W(\eta_j = 0)$ is the Wald statistic for the null hypothesis that all nine announcements are jointly non-significant, $Var(\varepsilon_t)$ is the variance of the Pearson residual, and $Q(10)$ is the Ljung-Box statistic of order 10 of the residuals. Estimation was done by MLE with Newey-West HAC standard errors. P-values are in parenthesis. Estimates that are significant at the 1% and 5% level are indicated by two and one star respectively, and they appear in bold font.

Table 7: **Estimation results of MDACP models for sample 2, August 24 to October 26, 2001.**

Parameters	BARL	DREF	OHVA	OKOH	SHKH	UBSZ	Rest	Aggregate
η_1	0.043	**0.304****	0.008	**-0.165****	**-0.300***	0.124	0.040	0.008
	(48.7%)	(0.06%)	(88.9%)	(0.05%)	(1.21%)	(5.18%)	(24.4%)	(82.1%)
η_2	**0.186****	**0.910****	0.032	**-0.088***	-0.033	**0.353****	**0.176****	**0.143****
	(0.43%)	(0.00%)	(49.2%)	(3.75%)	(80.8%)	(0.00%)	(0.00%)	(0.00%)
η_3	0.068	**0.602****	0.009	**0.074***	-0.160	0.021	**0.139****	**0.096****
	(10.1%)	(0.00%)	(81.2%)	(4.58%)	(16.8%)	(69.3%)	(0.00%)	(0.00%
η_4	0.039	-0.014	-0.043	-0.010	-0.143	0.059	0.024	0.013
	(40.1%)	(86.2%)	(31.9%)	(84.2%)	(12.4%)	(43.0%)	(49.9%)	(63.5%)
η_5	**0.162****	**0.526****	-0.015	-0.003	0.173	**0.155***	0.033	0.051
	(0.67%)	(0.00%)	(82.7%)	(96.7%)	(8.44%)	(4.03%)	(33.7%)	(8.60%)
η_6	-0.099	-0.217	0.041	0.008	-0.257	-0.023	-0.380	-0.024
	(20.6%)	(36.6%)	(65.6%)	(88.2%)	(16.1%)	(79.5%)	(46.5%)	(51.3%)
η_7	-0.034	-0.007	-0.035	-0.027	**-0.369***	-0.029	-0.001	-0.020
	(60.3%)	(97.1%)	(44.9%)	(71.0%)	(4.66%)	(70.8%)	(98.7%)	(69.9%)
η_8	0.221	0.592	0.023	-0.079	0.062	0.048	0.304	0.0149
	(87.3%)	(77.1%)	(95.1%)	(69.1%)	(96.3%)	(98.8%)	(44.3%)	(60.4%)
η_9	0.069	0.149	0.049	0.047	0.045	0.098	0.067	**0.070***
	(32.3%)	(39.4%)	(40.7%)	(48.0%)	(70.3%)	(52.6%)	(5.60%)	(2.90%)
α_{BARL}	**0.324****	0.003	**0.015***	0.012	**0.0112***	**0.043****		
	(0.00%)	(49.2%)	(2.63%)	(29.6%)	(1.47%)	(0.07%)		
α_{DREF}	**-0.042****	**0.323****	-0.007	**0.113****	-0.007	**0.059****		
	(0.00%)	(0.00%)	(38.4%)	(0.00%)	(31.0%)	(0.22%)		
α_{OHVA}	**0.044****	**0.008****	**0.426****	**-0.017***	**0.006****	**0.057****		
	(0.00%)	(0.35%)	(0.00%)	(1.90%)	(0.97%)	(0.00%)		
α_{OKOH}	**0.002***	**0.003****	**-0.003****	**0.659****	**0.001****	**0.012****		
	(3.07%)	(0.00%)	(0.07%)	(0.00%)	(0.37%)	(0.00%)		
α_{SHKH}	0.026	0.015*	0.015	**0.085****	**0.231****	0.030		
	(6.14%)	(3.48%)	(9.67%)	(0.00%)	(0.00%)	(13.6%)		
α_{UBSZ}	**0.023****	**-0.009***	**0.017***	-0.013	0.004	**0.261****		
	(0.11%)	(2.45%)	(1.87%)	(25.6%)	(31.4%)	(0.00%)		
ω	**0.177****	**0.119****	**0.229****	**0.598****	0.014	**0.191****	**1.337****	**4.405****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(13.5%)	(0.00%)	(0.00%)	(0.00%)
β	**0.576****	**0.514****	**0.538****	**0.313****	**0.667****	**0.539****	**0.587****	**0.528****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
ϕ	**0.958****	**0.609****	**1.34****	**0.455****	**0.830****	**0.559****	**0.200****	**0.169****
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
$W(\eta_j = 0)$	**22.88****	**268.21****	3.12	**27.66****	**21.08***	**46.85****	**59.92****	**73.77****
	(0.06%)	(0.00%)	(96.0%)	(0.1%)	(1.20%)	(0.00%)	(0.00%)	(0.00%)
$W(\psi's = 0)$	**24.85****	**91.57****	8.84	6.30	**79.3****	**51.42****	**33.53****	**22.63****
	(0.00%)	(0.00%)	(18.2%)	(39.0%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)
$W(\alpha_i = 0)$	**321.8****	**64.52****	190.7**	**150.0****	**91.24****	**194.3****		
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)		
$Var(\varepsilon_t)$	0.99	1.11	1.11	1.64	0.95	1.02	1.18	1.10
$Q(10)$	**44.08****	**10**	**91.36****	**77.11****	17.07	**23.47****	**42.56****	**85.78****
	(0.00%)	(44.1%)	(0.00%)	(0.00%)	(7.30%)	(0.90%)	(0.00%)	(0.00%)
LL	-12888.70	-8699.02	-12611.31	-16239.46	-9480.34	-13937.07	-21380.68	-23846.94

See caption of Table 6

Table 8: **Wald tests of equality for all banks of the effect of news**

Announcement category	Sample 1	Sample 2
Scheduled:		
η_1 - Positive US macro figures	27.64^{**}	34.49^{**}
η_2 - Negative US macro figures	26.99^{**}	147.09^{**}
η_3 - European macro figures	23.17^{**}	56.74^{**}
η_4 - Speeches of senior officials	1.31	4.60
η_5 - Interest rate reports	3.58	32.58^{**}
Unscheduled:		
η_6 - Economic institutes forecasts	1.39	3.98
η_7 - OPEC member declarations	2.49	3.24
η_8 - Central bank intervention rumors	1.08	0.21
η_9 - Extraordinary events	1.33	0.51

This table shows the results of a Wald test for the hypothesis that $\eta_{i,1} = \eta_{i,2} = \cdots = \eta_{i,K}$, where the first index refers to the announcement and the second to the bank, and K is number of banks.
One and two stars indicate rejection of the null hypothesis at the 5% and 1% respectively. The test statistic takes the following form:

$$W = (R\eta_i)^{'}(R\Sigma_i R^{'})^{-1}(R\eta_i) \; ,$$

where for sample 1,

$$R = \begin{pmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 1 & -1 \end{pmatrix} \; ,$$

$\Sigma_i = diag(\sigma^2_{i,1}, \ldots, \sigma^2_{i,5})$, $\sigma^2_{i,k}$ refers to the variance of coefficient $\eta_{i,k}$ and $\eta_i = (\eta_{i,1}, \ldots, \eta_{i,5})$. Σ_i is diagonal as there is no covariance between the effects of any announcement on two different banks.

Figure 1: **Time-of-the-day effect**

This figure presents the time-of-day effect of each bank of the two samples. The figure shows the ratio of the 5-minute means over the day relative to the overall mean. BGFX, BHFX, RABO and SGOX are observed from May 14 to September 10, 2001. BARL, DREF, OHVA, OKOH, SHKH and UBSZ are observed from August 24 to October 26, 2001.

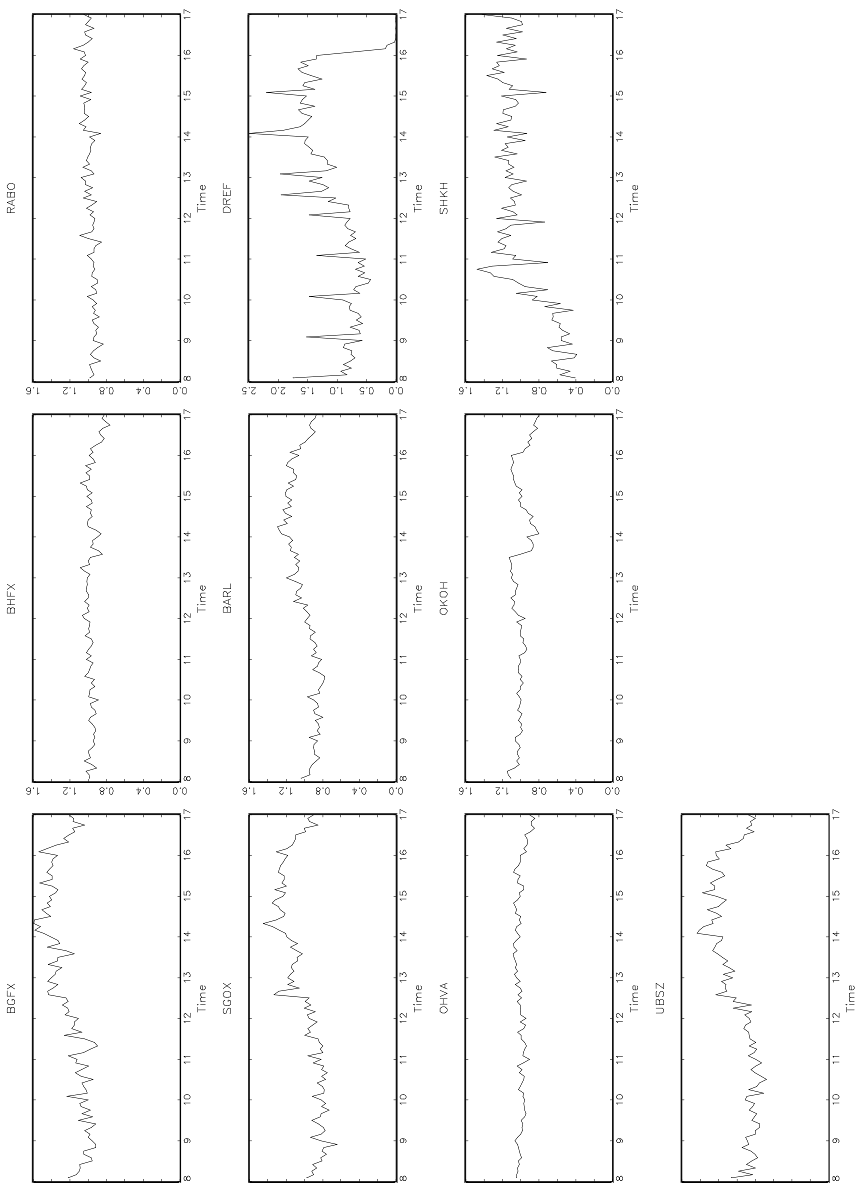

Figure 2: **Correlogram of banks' quoting and standardised residuals from DACP models**

This figure presents the correlogram of banks activity and of standardised residuals from DACP models. The standardised residuals (Pearson residuals) are defined as $\varepsilon_t = \frac{N_t - \mu_t}{\sigma_t} = \frac{N_t - \mu_t}{\sqrt{\mu_t/\phi}}$. The dashed line represents the autocorrelations of the raw series, and the solid line the autocorrelations of the Pearson residual. The 95% bounds of significance are also plotted.

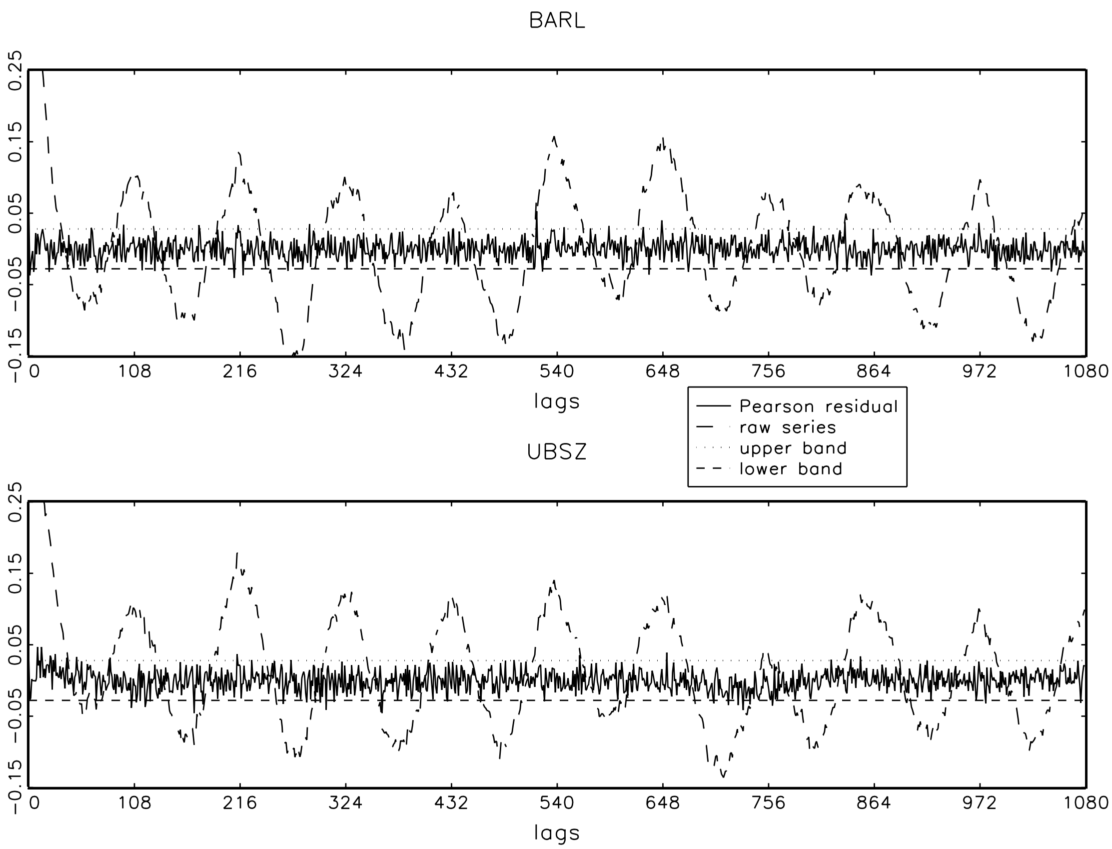

Figure 3: **Quantile plot of the Z statistic of individual banks**
This figure presents the quantile plot of the Z statistic of individual banks. This statistic is defined as the probability integral transform of the original data under the estimated density, in our case, the double Poisson: $Z_t = F^*(N_t, \mu_t)$, see Appendix 2 for more details.