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Abstract

This paper analyses the volatility of euro money market interest rates and tests for the existence of volatility transmission from overnight rates to longer-term rates. The results suggest that a significant proportion of the volatility of the EONIA is transmitted to 1-month and 3-month interest rates during most days. However, the abnormally high volatility during the last two days of the maintenance period does not seem to be transmitted to longer-term rates.

1 Introduction

Achieving some minimum degree of stability in very short-term interest rates is normally one of the goals of the design of the operational framework of monetary policy. Implicitly, it is assumed that volatility is not internalised in the short-term money markets, but is instead transmitted to the longer-term rates, which are more relevant to investment and consumption decisions. In practice, there are basically two types of techniques to stabilise short-term interest rates: more or less continuous interventions in the money markets by central banks, or averaging reserve requirements. Both systems have advantages and drawbacks. The main problem with the first technique is that it tends to discourage market activity in the money markets whereas with the second, short-term interest rate volatility tends to rise at the end of the maintenance period. The US Federal Reserve is an example of a central bank that continuously intervenes in the markets. By contrast, other central banks such as the Bundesbank and the Banco de España used the averaging reserve system before EMU.

Like most central banks, the Eurosystem has also adopted an operational framework aimed, among other things, at stabilising the very short-term interest rates in the euro area. More specifically, its operational framework includes an averaging reserve requirement system while direct interventions in the money markets are kept to a minimum. Against this background, and once enough time has elapsed to undertake an empirical analysis, it is worth testing whether interest rate volatility is transmitted along the yield curve, paying special attention to what occurs at the end of the maintenance period.

So far there is little empirical evidence documenting the existence of a significant transmission of volatility along the yield curve either in the euro area or in other countries. Ayuso et al. (1997) estimate the volatility of money market rates for various European countries before EMU –their sample covers the period 1988 to 1993– using an EGARCH model and introducing an estimate of the overnight rate volatility as an additional exogenous variable. They find a significant volatility transmission from overnight to longer-term money market rates for France, Spain and the UK. However, Vila (2002), using a similar methodology, does not find evidence of transmission of volatility from short-term interest rates to longer-term rates in the UK in her database, which covered the period between 1994 and 2001. After EMU, to the best of our knowledge, there are only two papers that analyse these issues for the euro area. Navarro Azorín (2001) estimates a multivariate GARCH model for various maturities and finds evidence of some volatility transmission from overnight rates to long-term rates and also in the other direction. However, he did not analyse to what extent these patterns remain unchanged at the end of the maintenance periods. Cassola and Morana (2003) estimate a multivariate unobserved components model that allows for both long-memory and stationary cyclical dynamics, and they find that two common long-memory factors drive the long-run evolution of money market interest rate volatilities. They interpret the first factor as measuring the intensity of the shock to the short-term interest rates and the second factor as measuring the intensity of its transmission along the term structure. The reported evidence suggests that liquidity effects were confined to the end of reserve maintenance periods and not transmitted along the money market yield curve. However, their definition of volatility transmission is different from that analysed in previous papers. They define transmission as shocks that simultaneously affect both short and long-term rates, and there is no causality relationship. This contrasts with previous papers, in which volatility transmission means that long-term rate volatility is caused by short-term rate volatility.

Against this background, the goals of this paper are to model the volatility of euro money market interest rates and to test for the existence of volatility transmission from overnight rates to longer-term rates. To do so we use the methodology followed by Ayuso et al. (1997).

The rest of the paper is structured as follows. Section 2 briefly describes the monetary policy framework of the Eurosystem and the available information on euro money market interest rates. Section 3 outlines the methodology used to estimate the volatility of interest rates and their transmission. Section 4 presents the results for the mean equation. Section 5 discusses the main properties of the volatility of overnight rates. Section 6 explores the existence of volatility transmission along the yield curve. Sections 7 and 8 analyse the robustness of results to data used to proxy overnight rates and to the specification of the mean model, respectively, and, finally, the last section draws the main conclusions.

2 The monetary policy framework of the Eurosystem and the information on euro money market interest rates

2.1 The operational framework of the Eurosystem

The operational framework of the Eurosystem includes three main instruments: reserve requirements, open market operations and standing facilities. The minimum reserve system pursues the stabilisation of money market interest rates and the creation (or enlargement) of a structural liquidity shortage in the banking system. Reserve holdings with the Eurosystem are remunerated and compliance is determined on the basis of the counterparties' average daily reserve holdings over the maintenance period, which, till February 2004, started on the 24^{th} of each month and ended on the 23^{rd} of the following month. Since then, the maintenance period has begun on the settlement day of the first main refinancing operation (MRO) following the meeting of the Governing Council at which the monthly assessment of the monetary policy stance is pre-scheduled, and has ended on the day preceding the corresponding settlement day in the following month. By averaging daily reserve holdings during the maintenance period, the system provides a buffer against liquidity shocks in that counterparties might use their reserves to absorb any shock and, therefore, it is not normally transmitted to interest rates. This property, however, vanishes after the last MRO as the end of the maintenance period approaches.

As regards open market operations, the Eurosystem has four available types of transactions, with MROs playing a pivotal role. These operations are regular liquidity-providing reserve transactions with a weekly frequency and their maturity was two weeks till February 2004 and a week thereafter. These operations are normally executed on Tuesdays and settled on Wednesdays. Since June 2000, they have been implemented through variable-rate tenders with a pre-announced minimum bid rate. A fixed-rate tender was previously used. The minimum bid rate (and the fixed interest in the fixed-rate tenders) plays an important role in signalling the monetary policy stance. The other operations include the longer-term refinancing operations, fine-tuning operations and the structural operations.[1] Fine-tuning operations consist of interventions in the market to absorb or provide liquidity, but they had hardly been used during the sample period analysed in this paper.

The two aforementioned changes decided by the Governing Council in 2003 that were effective as of March 2004 –the change in the timing of the start of the reserve maintenance period and the shortening of the maturity of the MROs to one week– are aimed at preventing changing interest rate expectations during a maintenance period from affecting very short-term money market conditions. In particular, the change in the timing of reserve maintenance periods ensures the lack of expectations of movements in key ECB rates during the maintenance period, whereas the reduction of the maturity of the MROs eliminates the spillover of interest rate expectations from one reserve period to the next. Before 2003 the Governing Council had already taken another measure aimed at reducing the effects of interest rate expectations on short-term money market rates and on the bidding behaviour of counterparties. More specifically, it was decided that after November 2001 the assessment of the monetary policy stance would only be undertaken in the first meeting of the month –i.e. with a monthly frequency. Up until then that assessment was undertaken in the two monthly meetings.

1. See ECB (2004) for more information on the operational framework of the Eurosystem.

Finally, standing facilities aim to provide and absorb overnight liquidity, signal the general stance of monetary policy, and bound overnight interest rates. More specifically, there are two types of standing facilities: the marginal lending facility and the deposit facility. Counterparties may use the first to obtain overnight liquidity from national central banks against eligible assets at a pre-specified interest rate, which provides a ceiling for the overnight market interest rates. Since April 1999 the interest rate of this instrument has always been 100 basis points above the minimum bid rate (or the fixed rate) of the MROs. The deposit facility allows counterparties to make overnight deposits with national central banks at a pre-specified interest rate, which provides a floor for overnight market interest rates. Since April 1999 this interest rate has always been 100 basis points below the minimum bid rate (or the fixed rate) of the MROs.

2.2 The available information on deposit interbank interest rates

The EONIA is an index, computed by the ECB, representative of the euro overnight deposit interbank interest rates. It is computed with a daily frequency as a weighted average of all overnight unsecured lending transactions in the interbank market, initiated within the euro area by the reporting panel banks. For longer-term money market interest rates, the European Banking Federation computes, also with a daily frequency, the EURIBOR indexes for maturities ranging from one week to twelve months. Unlike the EONIA, these indexes are computed as an average of the offered rates of the contributing banks around 10:45 am (CET), after eliminating the highest and lowest 15% of all quotes collected. The panel of reporting banks is the same as for the EONIA. Finally, some agencies, such as REUTERS, publish on-line indicative bid and ask quotes for various maturities from overnight to a maturity of 12 months.

3 Modelling the euro money market interest rates and their volatility

In this paper we focus on the following money market interest rates: overnight –proxied by the EONIA–, 1-month, 3-month, and 12-month EURIBOR. We also consider the minimum bid rate of the MROs (the fixed rate before June 2000), giving its signalling role. We will refer to this as the official rate. The period we cover goes from the start of Monetary Union (2nd January 1999) to 6th November 2003, i.e. 1241 trading days.

Chart 1 depicts all the interest rate series we use. The EONIA rate is on average very close to the official rate. However, it shows some spikes, normally around the end of the maintenance periods. Its volatility is much higher than that of the other series considered.

Augmented Dickey-Fuller unit root tests suggest the existence of a unit root in all our series of interest rates, i.e. they are all I(1) processes (see Table 1). The Johansen cointegration test is carried out for the five interest rates series. The null hypothesis that the rank of the cointegrating space is no more than 4 cannot be rejected at standard levels (see Table 2), thus revealing the existence of four cointegrating relationships. We also tested for the existence of a unit cointegration between the official and money market rates. The null was not rejected at standard significant levels.

We follow a two-step procedure to model interest rates. In the first step we estimate an equation for the mean and, in the second step, we estimate an equation for the variance. This procedure guarantees asymptotically consistent estimates of parameters.

Taking into account the previous evidence, the mean equation is modelled as a VECM in first differences with four ECMs made up of the four cointegrating relationships. Given the results of the test, we impose a unit cointegration. In other words, the cointegrating equations are the four spreads between the money market and the official rates. We augment the model, when appropriate, to include seasonal dummies. Thus, the model we estimate is the following:

$$\Delta r_{j,t} = \alpha_0 + \sum_{j=1}^{4} \alpha_j \left(r_j - o\right)_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{m} \beta_{j,i} \Delta r_{j,t-i} + \sum_{i=1}^{m} \varphi_i \Delta o_{t-i} + \sum_{i=1}^{l} \gamma_i Z_{i,t} + \varepsilon_{j,t} \quad (1)$$

where $r_{j,t}$ is the interest rate j at period t (j=1: EONIA, j=2: 1-month EURIBOR, j=3: 3-month EURIBOR and j=4: 12-month EURIBOR), o_t is the official interest rate at period t (minimum bid rate in variable rate tenders and fixed rate in fixed-rate tenders), Z_i are a set of exogenous dummy variables and $\varepsilon_{j,t}$ is the innovation.

We model the conditional variance of the interest rates as an EGARCH process. This specification, originally proposed by Nelson (1991), allows us to deal with non-linearities and asymmetric responses of conditional variances to negative and positive shocks, which seem to be relevant in explaining the behaviour of short-term interest rates. Another advantage of these models as compared with GARCH models is that they allow exogenous variables to be included in an unrestricted way. Again, when appropriate, we augment the model to include seasonal dummies.

In our specification of the conditional volatility we restrict the extent of possible spillovers to those arising from the EONIA to the other rates. In other words, we follow a univariate specification for the conditional variance and include the (log of the) estimated volatility of the EONIA in the other volatility equations. This procedure, which coincides with the approach followed by Ayuso et al. (1997), is supported by the anchor role played by overnight rates for the term structure of interest rates, in the sense that other rates are formed taking into account overnight rates. Causality-in-variance tests proposed by Cheung and Ng (1996) provide empirical support for the assumption of lack of causality in variance from 1-month, 3-month and 12-month interest rates to the EONIA (see Table 3).

We estimate the conditional volatility by maximum likelihood using the residuals of the mean model and compute Bollerslev-Wooldrige robust standard errors. The EGARCH(p,q) model we estimate is the following:

$$\log(\sigma_{j,t}^{2}) = \omega_0 + \sum_{i=1}^{p}\left(\omega_i\left|\frac{\varepsilon_{j,t-i}}{\sigma_{j,t-i}}\right| + \mu_i\frac{\varepsilon_{j,t-i}}{\sigma_{j,t-i}}\right) + \sum_{i=1}^{q}\lambda_i\log(\sigma_{j,t-i}^{2}) + \sum_{i=1}^{r}\delta_i Z_{i,t} \quad (2)$$

where $\sigma_{j,t}^2$ is the variance of the interest rate j (j=1: EONIA, j=2: 1-month EURIBOR, j=3: 3-month EURIBOR, and j=4: 12-month EURIBOR) at period t conditional to information up to period t-1, $\varepsilon_{j,t}$ is the unexpected component of the interest rate j, and Z_i are exogenous variables including dummy variables and, for interest rates other than the EONIA, the (log of the) estimated conditional variance of the EONIA.

4 The mean equation

Table 4 reports the results of the estimation of the mean equation. The number of lags is set following the Akaike information criteria. Ljung-Box-Portmanteu tests on residual autocorrelation suggest that the number of lags considered is enough to remove any correlation in the residuals. Standard errors are heteroskedastic-consistent [White (1980)].

Some of the results of Table 4 are worth commenting. The rate of convergence of EONIA to official rates is very high (34%), meaning that the EONIA tends to revert quickly towards the level of official rates whenever it deviates from it. The (lagged) official rate is significant at 5% for all the money market rates except the EONIA. The positive value of the parameter means that movements of official rates were not completely anticipated by the market. However, the low value of the coefficients means that, on average, more than 80% of the movement was anticipated by the market.[2] By contrast, in the case of the EONIA, the coefficient is not significant. This result reflects that part of the reaction to the official rate movement is captured contemporaneously since a proportion of the transactions used to compute this rate occurs after the announcement.

In the EONIA model some seasonal dummy variables turn out to be significant. This is the case of the maintenance period dummies. In particular, the dummy variable that takes value 1 the last day of the maintenance period is negative and significant, suggesting that the EONIA has tended to fall, on average, 6 basis points on the last day of the maintenance period. The dummy variable that takes value 1 the first day of the maintenance period is positive and significant, meaning that, on average, the EONIA has raised 10 basis points on these days. This behaviour suggests that, on average, there has been an excess liquidity in the banking system at the end of the maintenance period. The end-month, end-semester and end-year dummy variables are all positive and significant at 5%, meaning that the EONIA tends to rise at the end of each month, semester and year. This movement is, on average, 6 basis points at end-month, 15 basis points more at end-semester and an additional rise of 26 basis points at end-year. This behaviour is thought to be mainly attributable to the reluctance of institutions to lend funds during these dates due to window dressing. The dummy variables for the beginning of the month, semester and year are all significant –only at 10% in the case of the beginning of the month– and negative, suggesting that these movements are reversed the following day. Some of these effects in the mean level of the overnight rate have also been observed in other papers analysing the euro money market [Gaspar et al. (2001)] and other markets [Prati et al. (2001)].

Over the last quarter of 1999, 1-month and 3-month EURIBOR rates were significantly affected by fears over the year-2000 effects. This was reflected in a jump in rates for operations starting in 1999 and ending in 2000. To capture these effects we introduce a dummy variable that takes value 1 the day the rate jumped (29-November-99 and 29-Sep-99 for the 1-month and 3-month rates, respectively) and value -1 the date the rate reversed (29-Dec-1999). The coefficients of these variables appear to be positive and statistically significant in both equations (0.40 and 0.29 in the 1-month and 3-month equations, respectively).

2. The fact that the lag is significant is not surprising if we take into account that the EURIBOR rates are computed before the announcement of the official rates

The mean models in Table 4 are only able to explain a small proportion of interest rate variability, as shown by the relatively low adjusted R^2. This is a common result in the literature which, as such, explains why variance models tend to be quite robust to alternative mean specifications.[3]

3. As a matter of fact, similar results for the variance equations are found when the interest rates are modelled as an unrestricted VAR –i.e. without ECMs.

5 The volatility of the EONIA

The analysis of residuals suggests the existence of heroskedasticity non-linearities in the conditional variance of the EONIA,[4] validating the decision to use an EGARCH model. Table 5 reports the main results of the estimation of the conditional variance of the EONIA. Our preferred model is an EGARCH(3,3) process, which seems sufficient to eliminate any residual heteroskedastic effects. In fact, the Ljung-Box-Portmanteu test for autocorrelation of standardised squared residuals shows no sign of residual autocorrelation. Similarly, sign tests and the non-linearity test proposed by Engle and Ng (1993) do not show any sign of misspecification.

The coefficient of the first lagged standardised shock is positive and statistically significant at 10%, providing some evidence that positive shocks tend to have a higher impact on volatility than negative shocks of the same absolute size.

Some seasonal dummy variables appear to be significant. In particular, it is found that volatility of the EONIA tends to be lower on Mondays and, especially, on Thursdays than on any other day of the week. It is also found that volatility is higher during the last 5 days of the maintenance period and, during these days, it tends to increase as the end of the maintenance period approaches, and is especially high for the last two days. This pattern mainly captures the fact that, during the sample period, liquidity shocks were not normally absorbed by the Eurosystem after the last MRO. However, a model that includes a dummy variable that takes value 1 after the last MRO performs worse than that presented in Table 5, in which a dummy that takes value 1 the last 5 days is used instead. This evidence suggests that other factors apart from the fact that there are no more MROs might have played a role in explaining the higher volatility of the EONIA at the end of the maintenance period. Similarly, volatility also tends to be higher around the end of the semester. The volatility is also higher than average the day of the meeting of the Governing Council in which the monetary policy stance is assessed. By contrast, on the first day of January and July EONIA volatility falls. This type of seasonality has also been found in other papers. For instance, Gaspar et al. (2001) report an increase in volatility of EONIA around the end of the maintenance period, at the end of the month, and at end-year. Cassola and Morana (2003) find evidence of higher volatility at end-month and at the end of the maintenance period. Similarly, Prati et al. (2001) document some seasonality in the volatility of overnight rates in a number of countries. Pérez and Rodríguez (2001) and Bartolini et al. (2002), among others, present theoretical models of overnight interest rates with the existence of reserve requirements that reproduce the upward path of volatility during the last days of the maintenance periods.

A closer look at the behaviour of the EONIA shows that a significant proportion of the average volatility is explained by the movements of the EONIA around the end of the maintenance period (see Chart 2). In particular, the average volatility of the last 5 days of the maintenance period is almost 3.5 times as high as the volatility of the other days.

4. To check this we have run non-linearity tests proposed by Engle and Ng (1993).

6 Volatility transmission

The average estimated conditional volatility of the interest rate at the other maturities considered in this paper is much lower than that of the EONIA, even if we eliminate observations around the end of maintenance periods.[5] Chart 3 shows the term structure of average conditional volatilities, which proxies the unconditional volatility, in two sub-periods: 4/1/1999 to 7/11/2001 and 8/11/2001 to 6/11/2003. During the first period the Governing Council assessed the monetary policy stance twice a month, whereas in the second period the assessment only took place in the first meeting of the month –i.e. with a monthly frequency. Two main results emerge from Chart 3. First, the time structure of volatilities appears U-shaped in both sub-periods, a pattern similar to that found by Ayuso et al. (1997) for a number of countries. Second, the inconditional volatility of short-term interbank rates fell in the second sub-period, especially in the case of the EONIA rate, a result that might be connected with the change in the number of Governing Council meetings in which the monetary policy stance is assessed.

Table 6 reports the main results of the estimation of the conditional volatility for 1-month, 3-month and 12-month maturities. In all cases our preferred model is an EGARCH(1,3) process. The diagnosis tests we use do not show any sign of misspecification. To test for volatility transmission we include interactions of the (log of the) conditional variance of the EONIA with various dummies. In particular, Table 6 reports the results of the interaction of the (log of) the volatility of the EONIA with three different dummies which take value 1, respectively, all days before the last MRO, the days after this operation except the last two, and the last two days of the maintenance period. This procedure, which is similar to that followed by Ayuso et al. (1997), allows us to test whether the volatility transmission in these three sub-periods is the same or not. The distinction between the volatility on normal days and volatility around the end of the maintenance period seems relevant for at least two factors. First, as we have shown, the volatility of the EONIA tends to be much higher around the end of the maintenance periods, especially the last two days. In this regard, it would be more worrying to observe volatility transmissions at the end of the maintenance periods. Second, the source of volatility is different. At the end of the maintenance periods liquidity shocks will normally drive volatility of the EONIA, whereas during the other days interest rate expectations will probably be more important as a source of volatility. Again, when appropriate, we extend the model to include seasonal dummies.

In the 1-month EURIBOR volatility equation, we find that the parameter of the volatility of the EONIA during normal days is positive and statistically significant, suggesting the existence of volatility transmission during these days. The value of the coefficient (0.16) indicates that 16% of the (log of the) EONIA volatility is transmitted to the 1-month EURIBOR during these days. The coefficient of the volatility of the EONIA on the last two days of the maintenance period turns out to be non-significantly different from zero at standard levels, suggesting that during the last two days there is no spillover of volatility from the EONIA to the 1-month EURIBOR. Finally, there is also evidence of transmission of volatility the days after the last MRO excluding the last two. The size of this effect is even higher than that of the

5. The different level of estimated volatility between EONIA and EURIBOR rates might partly reflect the different procedure used to compute these rates. EURIBOR rates eliminate the highest and lowest 15% of all quotes before averaging them. By contrast, all trades are considered when computing the EONIA.

days before the last MRO, although the Wald test suggests that these coefficients are not statistically different. An analysis by subsamples shows, however, that this latter result is not robust to the period chosen. In particular, in the first half of the sample the coefficient is not statistically different from zero. Accordingly, this result should be taken with caution.

We have also investigated to what extent these results may have been driven by the seven underbidding episodes in our sample. In these episodes expectations of an imminent rate cut in the key ECB interest rates led counterparties to submit bids that on aggregate fell short of the expected amount needed to ensure that the reserve requirements were met. To investigate this issue, we interact the variables capturing the volatility spillover with a dummy that takes value 1 for days between the underbidding episode and the end of the maintenance period. The results suggest that, with the exception of the last two days of the maintenance period, the transmission of volatility was unchanged by the existence of underbidding. Nonetheless, it is found that, during underbidding episodes, 68% of the (log of the) EONIA volatility on the last two days was transmitted to that of the 1-month EURIBOR. This effect is also reported in Cassola and Morana (2003).

Some seasonal dummies appear to be significant in the 1-month EURIBOR volatility equation. More specifically, it is found that volatility tends to be higher on Wednesdays and, in contrast with the EONIA, it tends to be lower on the very last day of the maintenance period. It is found that volatility tends to be lower on the very last day of the month. Finally, it is also found that volatility tends to be higher the day after the meeting of the Governing Council in which the monetary policy stance is assessed, reflecting the impact of news of the press conference. Note that this effect appears the day after rather than the same day because EURIBOR rates are computed before the press conference is held.

As regards the volatility spillover from the EONIA to the 3-month EURIBOR, similar results are found. The coefficients that capture these effects are also similar in size, although slightly smaller. As regards the seasonal dummies, there is also evidence of higher volatility after the Governing Council meeting in which the monetary policy stance is assessed, and lower volatility on the very last day of the maintenance period. However, in contrast with the 1-month EURIBOR, none of the weekday dummies appear to be significant at standard levels.

Finally, no significant volatility spillovers from the EONIA to the 12-month EURIBOR are observed either before or after the last MRO. The seasonal dummies suggest that the volatility of the 12-month rate tends to be lower on Mondays and Tuesdays. Also, like the 1-month and 3-month EURIBOR, the volatility of the 12-month EURIBOR tends to be lower on the very last day of the maintenance period and higher the day after the meeting of the Governing Council in which the monetary policy stance is assessed. But, in contrast with the 1-month EURIBOR, the volatility rises on the very last day of the month.

All in all these results suggest that the volatility of the EONIA is partly transmitted to the 1-month and 3-month EURIBOR for days before the last MRO of the maintenance period. On the last two days of the maintenance period, in which the EONIA volatility is normally much higher, there is no spillover effect. On days after the last MRO excluding the last two there is some evidence of volatility spillover from the EONIA to the short-term money market rates. However, this result should be taken with caution since it is not robust to the period chosen and it is estimated with very few observations. Finally, the volatility of the EONIA is not transmitted to the 12-month EURIBOR. The fact that the volatility of the EONIA is only transmitted for short maturities of the money market and before the end of the maintenance period could mean that the volatility transmission we observe is related to uncertainty over short-term monetary policy decisions. This type of uncertainty will normally have a higher impact on the EONIA before the end of the maintenance period and will be more relevant for short-term maturities.

7 Robustness to non-synchronous data

One potential problem with the previous analysis is the lack of synchrony between the EONIA and the other money market rates. More specifically, the EONIA reflects the average overnight tes during the day, whereas the EURIBOR rates reflect the money market rates at 10:45 am. In this regard, news appearing during the day after 10:45 am will be reflected in the EONIA the same day and on the following day in the EURIBOR rates. This would tend to bias results in favour of volatility transmission from the overnight rate to long-term rates. To check the robustness of our results to this non-synchronicity problem, in this Section we replicate the previous exercises using the average of the bid and ask quotes for the overnight rate observed on the REUTERS screens at the same time as the EURIBOR rates are computed (10:45 am). We will refer to this series as the overnight rate. Unfortunately, we only have data for the period 4th December 2000 to 6th November 2003, i.e. 740 trading days.[6]

The average difference between the EONIA and the overnight rate is only 1.6 basis points, probably capturing the average size of the bid-ask spread.[7] The average absolute difference between both rates is also very low (2.8 basis points), suggesting that their information content is very similar. However, there are a few days in which both rates depart significantly from each other. Interestingly, the volatility of the EONIA, measured as the standard deviations of daily changes, is somewhat higher than that of the overnight rate.

Table 7 shows the results of our preferred model for the conditional volatility of the overnight interest rate, which is an EGARCH(2,3) process. Standard tests do not show any sign of misspecification. In contrast to the EONIA, there is no evidence of asymmetric effects. Seasonal dummies show some differences as compared to results for the EONIA. It should be noted that differences between both might not only reflect the fact that series are computed at different times but also that the sample period is not the same. The only weekday dummy that appears significantly different from zero is the one that takes value 1 on Fridays and shows a negative sign, meaning that on these days overnight rate volatility is lower than on other weekdays. Regarding the effect related to the Governing Council meeting in which the monetary policy stance is assessed, it appears the day after rather than the same day as the meeting as with the EONIA, given that the overnight rate we use is taken before the press conference. During the last five days of the maintenance period the volatility of the overnight rate tends to increase. Like with the EONIA, the effect between four and two days before the end of the maintenance period appears even before the last MRO, although, in contrast with the evidence for the EONIA, the size is higher if this operation has taken place. Finally, the first day of the maintenance period also turns out to display a higher volatility than the average.

Table 8 reports the main results of the estimation of the conditional volatility for 1-month, 3-month and 12-month maturities. In this case our preferred specification is an EGARCH(2,3) for the 1-month and 3-month EURIBOR and an EGARCH(1,3) for the 12-month EURIBOR. The coefficients of variables that capture the spillover effects along the money market yield curve are similar to those reported in the analysis of the previous section. Given that in this case the volatility of the overnight rate on the first day of the maintenance period appears significantly higher than the other days, we also test for

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6. We are very grateful to Nuno Cassola, from the ECB, for providing us these data.
7. Recall that the EONIA rate is an average of offered rates.

the existence of volatility transmission during that day. The evidence suggests that this volatility is not transmitted to longer-term rates. Finally, the impact of underbidding and results for the seasonal variables are also very similar to the ones reported in the previous section.

8 Robustness to possible structural change in the mean model

Arguably, the change in the frequency of meetings in which the monetary policy stance is assessed by the Governing Council could have affected the model of the mean. To check the robustness of our results to the possible structural change in the mean model, in this Section we split the sample into two sub-periods (4/1/1999 to 7/11/2001 and 8/11/2001 to 6/11/2003), estimate the mean model for each of these sub-periods, and use the residuals to re-estimate the conditional volatilities. During the first of these periods the Governing Council assessed the monetary policy stance twice a month, whereas in the second period the assessment was carried out with a monthly frequency.

Table 9 shows the results of the estimation of the conditional variance of the EONIA. The specification and point estimates are similar to those reported previously, in which the mean model was estimated without splitting the sample (Table 5). More specifically, our preferred model continues to be an EGARCH(3,3), which according to diagnosis tests we use, seems sufficient to eliminate any residual heteroskedastic effects. However, in contrast with the evidence presented in Table 5, the dummy variable MONDAY does not appear significant. On the other hand, the point estimate of the coefficient of the end-of-period dummy MP turns out to be smaller as compared to that reported in Table 5.

The results of the estimation of the conditional volatility for 1-month, 3-month, and 12-month maturities are presented in Table 10. In all cases, as in the case when the mean model is estimated without splitting the sample (Table 6), our preferred model is an EGARCH(1,3) process, which, according to the diagnosis tests we use, does not show any sign of misspecification. The point estimates of parameters are also very similar. As regards volatility transmission, qualitative results are unchanged. In particular, the evidence suggests that the volatility of the EONIA is transmitted for all days except the last two of the maintenance period to the 1-month and 3-month maturities but it is not transmitted to the 12-month maturity. However, the size of the parameters that capture volatility transmission is slightly lower, suggesting a slightly lower transmission. Thus, our results seem robust to the specification of the mean model.

9 Conclusions

In this paper we have estimated the conditional volatility of the euro money market rates and have investigated to what extent the volatility of the EONIA is transmitted to longer-term rates, which are more relevant for investment and consumption decisions. We estimate the conditional volatilities using an EGARCH model which allows for volatility spillovers from the EONIA to longer-term rates.

It is found that a significant proportion of the average volatility of the EONIA is attributed to the behaviour of this rate around the end of the maintenance period. In particular, the last 5 days of the maintenance period and, especially the last two, appear to have, on average, a much higher volatility.

As regards the volatility spillovers, the evidence reported in this paper suggests that a significant proportion of the volatility of the EONIA is transmitted to 1-month and 3-month interest rates. This result coincides with the evidence documented in Ayuso et al. (1997) for France, for Spain before EMU and for the UK. By contrast, the abnormal high volatility during the last two days of the maintenance period does not seem to be transmitted to longer-term rates. This latter result contrasts with the evidence reported in Ayuso et al. (1997) for Spain and France before EMU, where it is found that volatility transmission tended to be even higher at the end of maintenance periods.

Our results suggest that the operational framework of the Eurosystem has worked successfully in that the volatility of the overnight rate generated at the end of the maintenance periods was not generally transmitted to longer-term rates. In this regard, the choice of not using fine-tuning operations at the end of these periods has proved a good decision. On the other hand, the fact that short-term interest rate volatility is transmitted to longer-term rates during normal days means that the Eurosystem should worry about this volatility. So far it has been, however, low by international standards. After November 2001 it was further reduced, a move that might be connected with the change in the number of Governing Council meetings in which the monetary policy stance is assessed, in that it contributed to reducing interest rate movement expectations during a maintenance period from affecting very short-term interest rates. It is worth noting in this regard that the recently introduced changes in the monetary policy framework –change in the timing of the start of the reserve maintenance period and the shortening of the maturity of the MROs to one week–, which could not be analysed in this paper due to the lack of sufficient data, mean a new step ahead in the process of preventing changes in interest rate expectations from affecting very short-term money market conditions.

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ADF UNIT ROOT TEST

TABLE 1

	LEVEL	FIRST DIFFERENCE
OFFICIAL RATE	-0.230	-17.559
EONIA	-1.574	-22.821
1-MONTH EURIBOR	0.030	-16.943
3-MONTH EURIBOR	0.020	-14.328
12-MONTH EURIBOR	-0.315	-16.098

3 lags and intercept. 5% (1%) critical value is -2.86 (-3.44).

JOHANSEN COINTEGRATION TEST — TABLE 2

Null hypothesis: cointegration rank r	Eigenvalue	Likelihood ratio	5% critical value	1% critical value
r=0	0.123	293.442	76.070	84.450
r<=1	0.047	131.124	53.120	60.160
r<=2	0.037	71.703	34.910	41.070
r<=3	0.017	25.681	19.960	24.600
r<=4	0.004	4.538	9.240	12.970

3 lags and intercept. L.R. test indicates 4 cointegrating equation(s) at 5% significance level.

CAUSALITY-IN-VARIANCE TESTS TABLE 3

Number of lags	1-month EURIBOR causes EONIA	3-month EURIBOR causes EONIA	12-month EURIBOR causes EONIA
k=5	1.936	3.932	3.564
k=10	10.895	8.725	4.339

This table reports the values of the S statistic proposed by Cheung and Ng (1996) to detect causality in variance. $S=T\ \Sigma_1^k\ r_{uv}(i)^2$ where T is the number of observations and $r(i)^2$ is the squared sample cross-correlation at lag i between u and v. u and v are the squares of standardised innovations of the two interest rates for which causality is tested. These standardised innovations are computed estimating univariate mean and variance models. Under the null of no causality S has a chi-square distribution with k degrees of freedom. The 5% critical values are 11.1 for k=5 and 18.3 for k=10.

THE MEAN EQUATION TABLE 4

	EONIA		1-MONTH EURIBOR		3-MONTH EURIBOR		12-MONTH EURIBOR	
	coefficient	st. error	coefficient	st. error	coefficient	st. error	coefficient	st. error
Intercept	0.008	0.005	-0.001	0.001	-0.001	0.001	-0.001	0.002
$(r_1\text{-}o)_{t-1}$	-0.337	0.028	-0.006	0.006	0.003	0.005	0.005	0.008
$(r_2\text{-}o)_{t-1}$	0.194	0.056	-0.030	0.012	-0.024	0.010	-0.010	0.015
$(r_3\text{-}o)_{t-1}$	-0.008	0.048	0.017	0.010	0.000	0.008	-0.008	0.013
$(r_4\text{-}o)_{t-1}$	-0.029	0.019	0.006	0.004	0.012	0.003	0.012	0.005
$\Delta r_{1,t-1}$	0.027	0.031	0.014	0.006	0.008	0.005	0.010	0.009
$\Delta r_{1,t-2}$	-0.011	0.029	-0.004	0.006	-0.002	0.005	0.003	0.008
$\Delta r_{1,t-3}$	0.010	0.028	0.004	0.006	0.007	0.005	0.002	0.008
$\Delta r_{2,t-1}$	0.042	0.169	0.062	0.035	0.024	0.030	-0.031	0.047
$\Delta r_{2,t-2}$	0.246	0.169	-0.025	0.035	-0.016	0.030	-0.088	0.047
$\Delta r_{2,t-3}$	-0.038	0.161	-0.085	0.033	-0.080	0.028	-0.146	0.045
$\Delta r_{3,t-1}$	0.332	0.233	0.054	0.048	0.022	0.041	0.008	0.065
$\Delta r_{3,t-2}$	-0.057	0.232	0.039	0.048	0.082	0.041	0.146	0.064
$\Delta r_{3,t-3}$	0.067	0.229	0.170	0.047	0.134	0.040	0.198	0.064
$\Delta r_{4,t-1}$	-0.016	0.135	0.037	0.028	0.088	0.024	0.080	0.037
$\Delta r_{4,t-2}$	-0.111	0.135	-0.003	0.028	0.018	0.024	-0.008	0.037
$\Delta r_{4,t-3}$	0.150	0.134	-0.053	0.028	-0.042	0.023	-0.063	0.037
Δo_{t-1}	0.055	0.085	0.181	0.017	0.139	0.015	0.113	0.023
Δo_{t-2}	-0.098	0.087	-0.034	0.018	-0.032	0.015	-0.030	0.024
Δo_{t-3}	0.145	0.088	-0.011	0.018	-0.007	0.015	-0.005	0.024
MP_t	-0.057	0.017	-0.001	0.003	0.000	0.003	-0.003	0.005
MP_{t-1}	0.099	0.017	0.000	0.003	0.000	0.003	0.001	0.005
$MONTH_t$	0.064	0.018	-0.002	0.004	-0.001	0.003	-0.004	0.005
$MONTH_{t-1}$	-0.032	0.018	-0.004	0.004	-0.006	0.003	-0.005	0.005
$HALFYEAR_t$	0.151	0.058	0.005	0.012	0.007	0.010	0.017	0.016
$HALFYEAR_{t-1}$	-0.119	0.058	0.000	0.012	-0.002	0.010	-0.023	0.016
$YEAR_t$	0.264	0.084	0.000	0.017	-0.008	0.015	-0.017	0.023
$YEAR_{t-1}$	-0.166	0.084	-0.004	0.017	-0.002	0.015	-0.007	0.023
$Y20001M_t$	0.040	0.101	0.402	0.021	-0.096	0.018	-0.007	0.028
$Y20003M_t$	0.020	0.100	-0.029	0.021	0.285	0.018	0.017	0.028
Adjusted R^2	0.29		0.38		0.32		0.07	
Q10	1.58		15.90		6.22		4.90	

Heteroskedastic-consistent standard errrors (White (1980)). Q10 stands for the Ljung-Box-Portmanteau statistic for 10th order serial correlation. MP, MONTH, HALFYEAR, YEAR, are dummy variables that take value 1, respectively, on the last day of: the maintenance period, the month, June and December, and the year. Y20001M takes value 1on 29-11-99 and value -1 on 29-12-99. Y20003M takes value 1 on 29-9-99 and value -1 on 29-12-99.

THE CONDITIONAL VOLATILITY OF THE EONIA TABLE 5

	coefficient	standard error
ω0	-2.682	0.186
ω1	0.993	0.082
µ1	0.132	0.079
ω2	-0.539	0.094
µ2	-0.111	0.086
ω3	0.549	0.091
µ3	0.281	0.066
λ1	1.280	0.055
λ2	-1.020	0.078
λ3	0.431	0.047
MONDAYt	-0.486	0.172
THURSDAYt	-0.830	0.216
$MP_{t+4}+MP_{t+3}+MP_{t+2}$	1.079	0.116
MP_{t+1}	1.909	0.189
MP_t	2.666	0.244
$HALFYEAR_t$	2.466	0.439
$HALFYEAR_{t-1}$	-2.071	0.355
$MEETING_t$	0.756	0.208
Q2(10)	3.339	
SIGN	1.583	
POS	-1.342	
NEG	-0.169	

Bollerslev-Wooldridge robust standard errors. MONDAY, THURSDAY, MP AND HALFYEAR are stational dummy variables that take value 1, respectively: on Mondays, on Thursdays, on the last day of the maintenance period, on the last day of the month and on the last day of June and December. MEETING is a dummy variable that takes value 1 on the day of Governing Council meeting in which monetary policy stance is assessed. Q2(10) stands for Ljung-Box-Portmanteau statistic for 10th order serial correlation of standardised squared residuals, and SIGN, POS and NEG stand, respectively, for the sign bias, positive size bias and negative size bias tests proposed by Engle and Ng (1993), under the null they all are distributed as a Student-t.

VOLATILITY TRANSMISSION FROM THE EONIA TABLE 6

	1-MONTH EURIBOR		3-MONTH EURIBOR		12-MONTH EURIBOR	
	coefficient	st. error	coefficient	st. error	coefficient	st. error
ω_0	-0.843	0.348	-0.668	0.313	-0.713	0.295
ω_1	0.484	0.093	0.345	0.092	0.302	0.058
μ_1	-0.098	0.091	-0.088	0.053	0.018	0.033
λ_1	0.251	0.142	-0.021	0.074	0.151	0.102
λ_2	0.195	0.164	0.337	0.053	0.411	0.089
λ_3	0.385	0.083	0.525	0.081	0.350	0.086
$MONDAY_t$					-0.428	0.164
$TUESDAY_t$					-0.589	0.180
WEDNESDAYt	0.898	0.331				
MP_t	-1.419	0.409	-1.708	0.357	-0.755	0.232
$MEETING_{t-1}$	1.892	0.436	1.689	0.361	1.051	0.257
$MONTH_t$	-1.532	0.305			0.649	0.203
$\log(\sigma_{1,t}^2)x(1\text{-}MRO_t)$	0.162	0.045	0.153	0.044	0.004	0.015
$\log(\sigma_{1,t}^2)xMRO_tx(1\text{-}MP_{t+1}\text{-}MP_t)$	0.291	0.051	0.289	0.049	0.005	0.027
$\log(\sigma_{1,t}^2)x(MP_{t+1}+MP_t)$	0.093	0.127	0.019	0.152	-0.077	0.060
Q2(10)	1.935		3.310		5.963	
SIGN	0.176		-0.352		-1.821	
POS	-0.501		-0.041		0.260	
NEG	0.432		0.805		1.010	

Bollerslev-Wooldridge robust standard errors. MONDAY, TUESDAY and WEDNESDAY, MP, MEETING, MONTH and MRO are dummy variables that, respectively, take value 1 on: Mondays, Tuesdays, Wednesdays, the last day of the maintenance period, the day of the Governing Council meeting in which monetary policy stance is assessed, the last day of the month and from the day of the last main refinancing operation to the last day of the maintenance period. σ1,t2 is the conditional variance of the EONIA at period t. Q2(10) stands for Ljung-Box-Portmanteau statistic for 10th order serial correlation of standardised squared resisduals, and SIGN, POS and NEG stand, respectively, for the sign bias, positive size bias and negative size bias tests proposed by Engle and Ng (1993), under the null they all are distributed as a Student-t.

THE CONDITIONAL VOLATILITY OF THE OVERNIGHT RATE TABLE 7

	coefficient	standard error
$\omega 0$	-4.734	0.553
$\omega 1$	0.952	0.118
$\mu 1$	0.015	0.058
$\omega 2$	0.418	0.130
$\mu 2$	0.063	0.075
$\lambda 1$	0.011	0.113
$\lambda 2$	0.540	0.043
$\lambda 3$	-0.148	0.067
$FRIDAY_t$	-0.532	0.192
$(MP_{t+4}+MP_{t+3}+MP_{t+2})x(1-MRO_t)$	0.877	0.322
$(MP_{t+4}+MP_{t+3}+MP_{t+2})xMRO_t$	1.876	0.361
MP_{t+1}	2.334	0.296
MP_t	2.286	0.467
MP_{t-1}	1.521	0.318
$MEETING_{t-1}$	0.765	0.172
Q2(10)	9.208	
SIGN	-0.296	
POS	0.002	
NEG	-0.393	

Bollerslev-Wooldridge robust standard errors. FRIDAY, MP, MEETING and MRO are dummy variables that take value 1, respectively: on Fridays and on the last day of the maintenance period, on the day of Governing Council meeting in which monetary policy stance is assessed, and from the day of the last main refinancing operation to the last day of the maintenance period. Q2(10) stands for Ljung-Box-Portmanteau statistic for 10th order serial correlation of standardised squared residuals, and SIGN, POS and NEG stand, respectively, for the sign bias, positive size bias and negative size bias tests proposed by Engle and Ng (1993), under the null they all are distributed as a Student-t.

VOLATILITY TRANSMISSION FROM THE OVERNIGHT RATE TABLE 8

	1-MONTH EURIBOR		3-MONTH EURIBOR		12-MONTH EURIBOR	
	coefficient	st. error	coefficient	st. error	coefficient	st. error
ω_0	-1.101	0.403	-1.039	0.359	-1.749	0.704
ω_1	0.505	0.095	0.501	0.089	0.254	0.075
μ_1	-0.235	0.076	-0.098	0.067	0.097	0.050
ω2	0.544	0.103	0.052	0.151		
μ2	0.051	0.052	-0.262	0.062		
λ_1	0.148	0.052	-0.177	0.136	0.249	0.107
λ_2	0.077	0.057	0.539	0.070	0.083	0.123
λ_3	0.620	0.045	0.475	0.100	0.387	0.102
$MONDAY_t$					-0.358	0.183
$TUESDAY_t$					-0.683	0.198
$WEDNESDAY_t$	0.709	0.235				
MP_t	-1.338	0.393	-1.378	0.516	-1.235	0.374
$MEETING_{t-1}$	1.668	0.336	1.411	0.380	1.048	0.297
$\log(\sigma_{1,t}^2)x(1-MRO_t-MP_{t-1})$	0.195	0.092	0.138	0.062	0.026	0.034
$\log(\sigma_{1,t}^2)xMRO_tx(1-MP_{t+1}-MP_t)$	0.282	0.112	0.284	0.063	0.078	0.049
$\log(\sigma_{1,t}^2)x(MP_{t+1}+MP_t)$	0.198	0.203	0.015	0.171	-0.015	0.093
$\log(\sigma_{1,t}^2)xMP_{t-1}$	0.028	0.196	0.130	0.139	0.010	0.104
Q2(10)	6.666		3.540		7.184	
SIGN	0.395		0.210		-0.310	
POS	-0.638		-0.065		-0.378	
NEG	-0.032		0.082		0.175	

Bollerslev-Wooldridge robust standard errors. MONDAY, TUESDAY, WEDNESDAY, MP, MEETING and MRO are dummy variables that, respectively, take value 1 on: Mondays, Tuesdays, Wednesdays, the last day of the maintenance period, the day of the Governing Council meeting in which monetary policy stance is assessed, and from the day of the last main refinancing operation to the last day of the maintenance period. σ1,t2 is the conditional variance of the overnight rate at period t. Q2(10) stands for Ljung-Box-Portmanteau statistic for 10th order serial correlation of standardised squared residduals, and SIGN, POS and NEG stand, respectively, for the sign bias, positive size bias and negative size bias tests proposed by Engle and Ng (1993), under the null they all are distributed as a Student-t.

THE CONDITIONAL VOLATILITY OF THE EONIA. MEAN MODEL ESTIMATED BY SUBPERIODS

TABLE 9

	coefficient	standard error
ω0	-2.512	0.162
ω1	0.997	0.078
μ1	0.203	0.066
ω2	-0.819	0.092
μ2	-0.239	0.078
ω3	0.734	0.072
μ3	0.228	0.062
λ1	1.361	0.055
λ2	-1.109	0.083
λ3	0.484	0.047
THURSDAYt	-0.380	0.119
$MP_{t+4}+MP_{t+3}+MP_{t+2}$	1.031	0.130
MP_{t+1}	2.067	0.168
MP_t	2.036	0.255
$HALFYEAR_t$	2.437	0.577
$HALFYEAR_{t-1}$	-2.171	0.394
$MEETING_t$	0.586	0.205
Q2(10)	4.714	
SIGN	0.269	
POS	-0.701	
NEG	0.396	

The sample is split in two periods (4/1/1999 to 7/11/2001 and 8/11/2001 to 6/11/2003) and a different mean model is estimated for each subperiod. Bollerslev-Wooldridge robust standard errors. THURSDAY, MP AND HALFYEAR are stational dummy variables that take value 1, respectively: on Thursdays, on the last day of the maintenance period, on the last day of the month and on the last day of June and December. MEETING is a dummy variable that takes value 1 on the day of Governing Council meeting in which monetary policy stance is assessed. Q2(10) stands for Ljung-Box-Portmanteau statistic for 10th order serial correlation of standardised squared residuals, and SIGN, POS and NEG stand, respectively, for the sign bias, positive size bias and negative size bias tests proposed by Engle and Ng (1993), under the null they all are distributed as a Student-t.

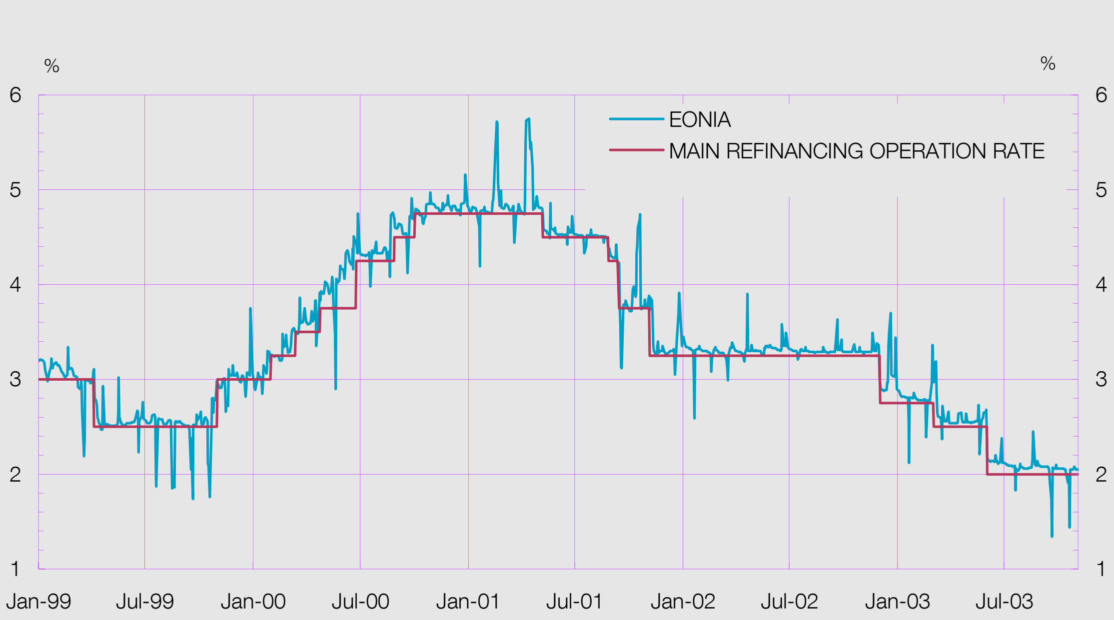
VOLATILITY TRANSMISSION FROM THE EONIA. MEAN MODEL ESTIMATED BY SUBPERIODS

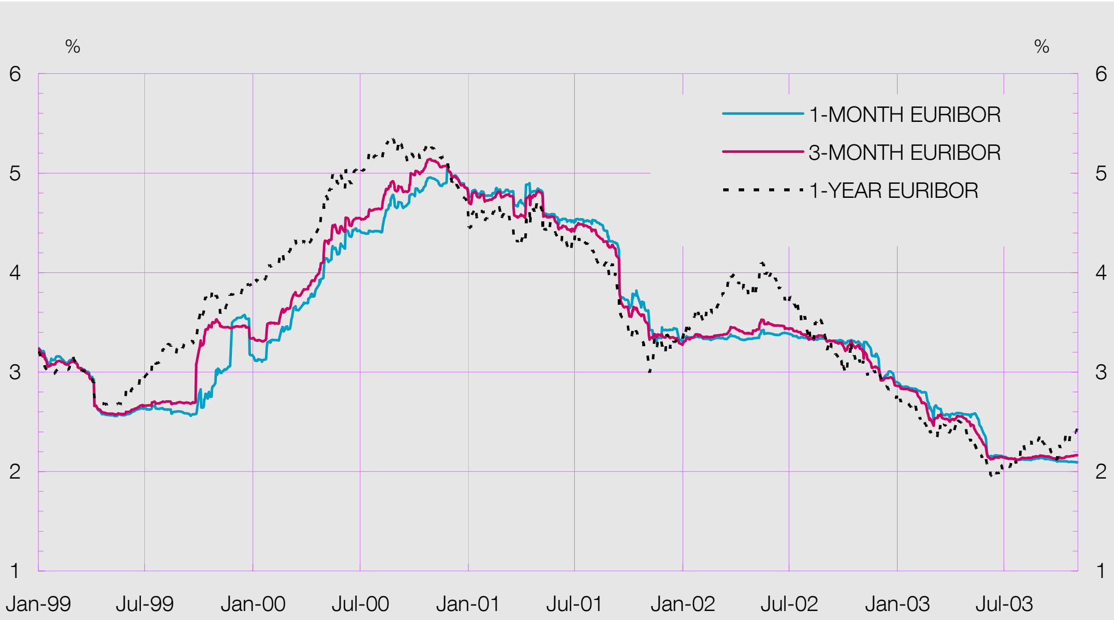
TABLE 10

	1-MONTH EURIBOR		3-MONTH EURIBOR		12-MONTH EURIBOR	
	coefficient	st. error	coefficient	st. error	coefficient	st. error
ω_0	-1.006	0.349	-0.558	0.280	-0.611	0.287
ω_1	0.561	0.092	0.434	0.073	0.275	0.057
μ_1	-0.041	0.076	-0.042	0.050	0.035	0.035
λ_1	0.294	0.128	-0.020	0.081	0.131	0.103
λ_2	0.263	0.090	0.408	0.070	0.388	0.096
λ_3	0.292	0.082	0.500	0.084	0.403	0.095
$MONDAY_t$					-0.424	0.171
$TUESDAY_t$					-0.590	0.180
WEDNESDAYt	1.105	0.306				
MP_t	-1.142	0.398	-1.679	0.352	-0.820	0.236
$MEETING_{t-1}$	1.702	0.407	1.524	0.312	0.959	0.254
$MONTH_t$	-1.519	0.289			0.374	0.221
$\log(\sigma_{1,t}^2)x(1-MRO_t)$	0.126	0.062	0.121	0.050	0.002	0.015
$\log(\sigma_{1,t}^2)xMRO_tx(1-MP_{t+1}-MP_t)$	0.266	0.068	0.221	0.062	0.001	0.027
$\log(\sigma_{1,t}^2)x(MP_{t+1}+MP_t)$	0.098	0.133	-0.061	0.153	-0.075	0.063
Q2(10)	1.920		3.193		6.130	
SIGN	0.169		0.255		-0.758	
POS	-0.306		-0.243		-0.415	
NEG	0.280		0.475		0.850	

The sample is split in two periods (4/1/1999 to 7/11/2001 and 8/11/2001 to 6/11/2003) and a different mean model is estimated for each subperiod. Bollerslev-Wooldridge robust standard errors. MONDAY, TUESDAY and WEDNESDAY, MP, MEETING, MONTH and MRO are dummy variables that, respectively, take value 1 on: Mondays, Tuesdays, Wednesdays, the last day of the maintenance period, the day of the Governing Council meeting in which monetary policy stance is assessed, the last day of the month and from the day of the last main refinancing operation to the last day of the maintenance period. σ1,t2 is the conditional variance of the EONIA at period t. Q2(10) stands for Ljung-Box-Portmanteau statistic for 10th order serial correlation of standardised squared residduals, and SIGN, POS and NEG stand, respectively, for the sign bias, positive size bias and negative size bias tests proposed by Engle and Ng (1993), under the null they all are distributed as a Student-t.

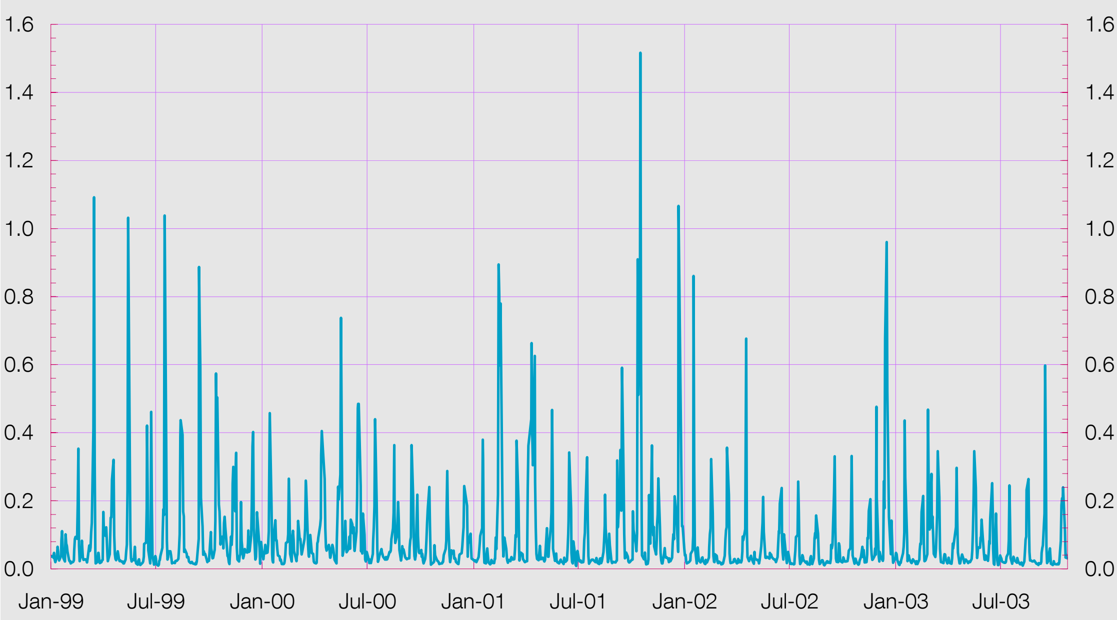
INTEREST RATES CHART 1





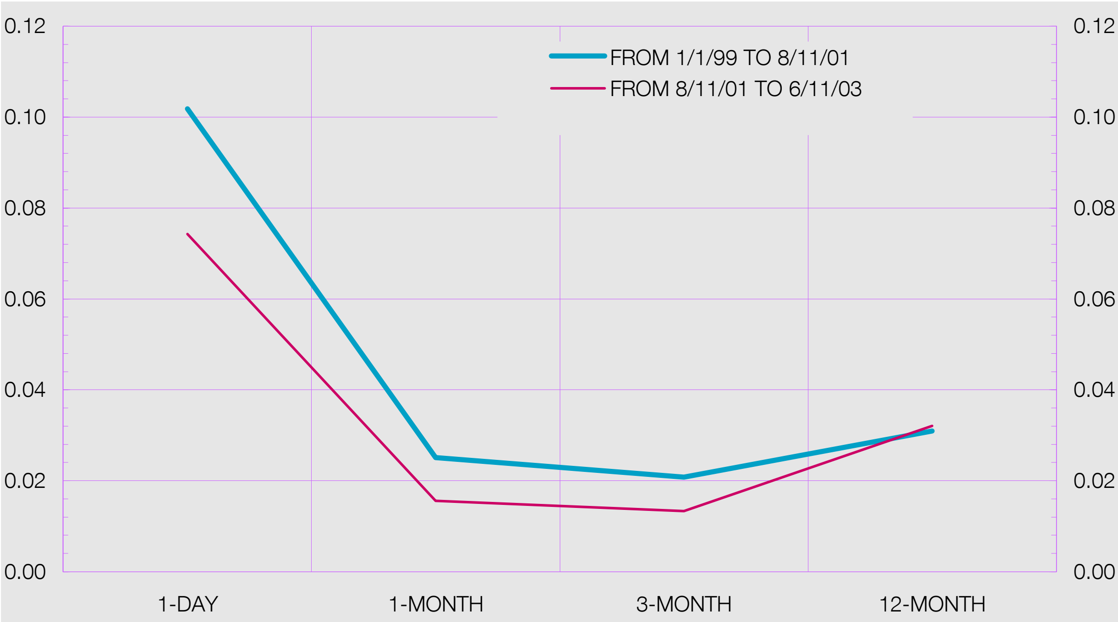
CONDITIONAL STANDARD DEVIATION OF THE EONIA

CHART 2



MEANS OF CONDITIONAL STANDARD DEVIATION FOR MONEY MARKET INTEREST RATES

CHART 3



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