

The anchoring of money market expectations in a corridor system implementation framework^{*}

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November 2008

Abstract

This paper aims at exploring one of the dimensions of monetary implementation in which some operational discretion of the central bank exists and appears relevant for overall performance of the operational framework. Specifically, we analyse the relationship, within each maintenance period, between the ECB's money market operations and the anchoring of market participants' expectations of the spread between the level of the overnight rate which will prevail at the end of the maintenance period and the minimum bid rate (MBR) prevailing in the same maintenance period. As pointed out by theoretical literature (Pérez-Quirós and Mendizábal (2006)), the anchoring of money market expectations of the prevailing value of the overnight rate at the end of a maintenance period is central for the smooth functioning of the inter-bank money market. Our results show a significant decline in the volatility of the above defined expected spread in early 2005, coinciding with the beginning of a practice of quasi-systematic fine tuning operations on the last day of the maintenance period. We also obtain that the volatility of expectations increased significantly from November 2005 onwards, coinciding with the beginning of a sequence of increases in key ECB interest rates and a "loose liquidity policy" of the ECB in every Main Refinancing Operation (MRO). Although the analysis of causality of effects is somewhat masked by the overlap of the relevant regimes considered, we conclude tentatively that the ECB's liquidity policy was overall effective at reducing volatility in expectations (lower jump intensity). After this date, the effects on the volatility of money market expectations from the series of increases in key ECB interest rates appears to dominate the smoothing effect of the liquidity policy.

^{*} We are grateful to Vincent Brousseau for elaborating the data. Financial support from the Spanish Ministry of Education and Science through the grants SEJ 2005-09372 (León) and SEJ 2006-05051/ECON (Benito) are gratefully acknowledged. The views expressed in the paper are solely those of the authors and do not necessarily reflect those of the European Central Bank.

^{*} The Monetary Policy Stance Division of the European Central Bank provided very kind hospitality when this paper was written.

1. Introduction

Recent years have witnessed increased interest in the optimal design of a monetary policy operational framework, with an increased tendency across central banks to adopt *corridor systems* for monetary policy implementation. Although the specification of frameworks varies in practice across central banks, corridor systems comprise some common elements as key features for monetary implementation. These include so-called standing facilities, which mark the upper and lower limits of the corridor for very short term money market rates and a number of instruments in the form of open market operations which aim at steering the overnight rate in the inter-bank money market usually close to the centre of the corridor. In order to ensure the demand for central bank money, corridor systems usually include a minimum reserve requirement for banks. In addition, to aim at insulating the implementation of the decisions on the part of monetary authorities about the appropriate level for monetary policy instruments from market speculation about the future evolution of monetary policy, corridor systems usually structure liquidity management action in so-called maintenance periods. They represent a commitment by the central bank to implement a certain level of the policy rate over a pre-specified period of time and to not change the level of policy rates over the course of the maintenance period.

Since the onset of financial turmoil in the Summer of 2007, when money markets suffered serious disruption in particular for tenures beyond one week, the operational framework of some major central banks was subject to unprecedented stress test. The observation of the experience of the various central banks in deploying the instruments within their operational frameworks to address money markets disruptions reveals that even central banks with broadly similar operational frameworks took different paths in dealing with disruption and also performed differently as regards the objective of ensuring the smooth functioning of the money market. A useful distinction may therefore be drawn between the design of the operational framework and the room of manoeuvre or scope for discretion within the context of the instruments in the framework - and thus also the best possible use of the scope for discretion.

While the need to distinguish between the design of the operational framework and best use of discrete action within the boundaries of the framework became particularly manifest over the turmoil period, the experience with corridor systems in regular circumstances had

already revealed the considerable scope for discretion for the central bank's management of liquidity and the importance of the approach taken in the management of liquidity for overall performance. Accordingly, reflecting the existence of a margin for discretion in the use of the operational framework, as central banks adopt a new corridor-type framework, they usually undergo a process of learning as they get experience – and sometimes experiment – with the set of instruments and possibilities provided by the framework.

This paper aims at exploring one of the dimensions of monetary implementation in which central bank's operational discretion exists and is relevant for overall performance of the operational framework. Specifically, we analyse the relationship, within each maintenance period, between the ECB's money market operations and the anchoring of market participants' expectations of the level of the overnight rate which will prevail at the end of the maintenance period. As pointed out by the theoretical literature (Pérez-Quirós and Mendizábal (2006)), the anchoring of market expectations of the prevailing value of the overnight rate at the end of a maintenance period is central for the smooth functioning of the money market. As the maintenance period is limited in time, market expectations of the prevailing level of the overnight market at the end of the maintenance period serves, through the backward induction of expectations, to determine the expectation of the overnight rate in real time in each day of the maintenance period, which in turn is a key element for price determinacy in the overnight market. Theoretical models of the operational framework stress in addition the importance of the alignment of the expectations held in this respect both by market participants at large and the monetary authority.

Against this background, we aim to address the following main questions. First, are expectations of the level of the overnight rate prevailing at the maintenance period well-anchored, as the theoretical literature suggests they should be? Second, do those market expectations react – and if so how – to information releases coming out throughout the maintenance period? Third, how have both the anchoring of those expectations and the effect of news releases changed over various observable regimes and, if so, how?

To address these questions, we start from a measure of market expectations of the level of the overnight inter-bank interest rate prevailing in the last week of the maintenance period.

This measure is observed at daily frequency, in all business days in all weeks except the last one of the given maintenance period. The measure of expectations is based on financial instruments and is akin to measures used in the market and central banks to anticipate the level of the overnight rate's fixing (EONIA) in the last days of the maintenance period. Specifically, we focus on the spread between the measure of expectations and the ECB's minimum bid rate of the main refinancing operation (MRO) (which defines the centre of the Eurosystem's corridor for money market rates). To obtain the spread, we take the difference, at a given day, between the implied 1-week EONIA swap¹ forward rate (for the last week of each maintenance period) and the prevailing level of the minimum bid rate in the same maintenance period (which by construction is a constant in a given maintenance period).

We then analyse whether, in each maintenance period, the volatility of the measured expected spread is affected by certain intra maintenance period information releases. Specifically, we are interested in the impact on the volatility of the expected spread from two information releases which occur in different days within each maintenance period: first, on the day previous to the allotment of the last MRO of each maintenance period, the publication by the ECB of the ECB's forecast of the so-called autonomous factors and the ECB's benchmark allotment amount at that MRO. Second, on the following day (i.e. on the allotment day itself), the release by the ECB of the update of the same information as in the previous day. This permits to assess the information content of the ECB releases for the formation of expectations at the end of the maintenance period.

As anticipated above, we also analyse how the volatility of expectations, both as regards their unconditional level and their reaction to news releases, change over distinct observable regimes. Two regimes are considered. First, the more active liquidity policy by the ECB, aimed at reducing money market spikes in the last days of the maintenance period (specifically, the question is how expectations react to the more frequent fine tuning operations (FTOs) on the last day of the maintenance period and the more frequent

¹ EONIA swap is an agreement between two parties to exchange a set of variable daily payments at the EONIA rate with a set of payments at a fixed rate over an agreed period of time. The interest rate of the fixed leg of this swap is referred to as the EONIA swap rate and it reflects the expected average level of the EONIA over the maturity of the swap collected. It involves no payment of nominal amount.

liquidity allotment above the benchmark in most of the MROs).² Second, the fact that since December 2005 the ECB starts a series of increases in interest rates which were expected to be continued by market participants over our sample period. By looking over different regimes at the volatility of expectations and its relation to news releases we aim at understanding better first, the effectiveness of central bank action at underpinning expectations of the spread and, second, the extent to which the intended insulation of market developments in a given maintenance period from market effects of expectations in changes in the policy rates in future maintenance periods is achieved.

In order to address the above questions, we model the change in the expected spread (Δs_t) using a jump-diffusion process with ARCH structure as in Das (2002) or Benito, León and Nave (2007). We concentrate on the jump-side of the dynamics equation to better understand the empirical evidence of a high jump probability during specific days. The variables of our study are used to determine the reason why these jumps occur and affect the market expectations for the last week of the maintenance period.

Our results show a significant change in the volatility of the expected spread from November 2005 onwards, when the market expectations for the last week of the maintenance period became more instable. This increase in volatility coincides with the beginning of a sequence of increases in key ECB interest rates, but also largely overlaps with the beginning of a loose liquidity policy, i.e. allotment above the benchmark in every MRO, and in this respect the identification of effects is difficult.

We find that on the announcement day the intensity of the jump is similar to the rest of the days, with the jump intensity being stronger on the allotment and settlement days between March 2004 and February 2005. From this last date and with frequent FTOs the jump

² The ECB has carried out these especial liquidity measures during the past years largely to address two specific developments in the money market. First, the expected increase of errors in autonomous factor forecasts -and therefore in volatility in the money market- due to the increase in the number of days between the last MRO and the end of the reserve maintenance period. In the new framework, the last MRO of the maintenance period is always allotted one week before the end of the reserve maintenance period, that is, a longer period than in the previous framework. Therefore, this could lead to greater volatility in money market interest rates at the end of the maintenance period. Decker and Valla (2005), Durré and Nardelli (2007) and Jardet and LeFol (2007) are some of the authors that deal with this subject. The ECB has been addressing this problem from November 2004 by conducting FTOs on the last day of each RMP on a more regular basis, as can be seen in Figure 1. Second, the observed widening of the spread between the EONIA rate and the MBR from summer 2004, slowly but steadily through 2005, which the ECB has been addressing from October 2005 by allotting above the benchmark in all MROs with the exception of the final operation in a RMP, and from spring 2006 in the final MRO as well (see Figure 2). Some studies that try to understand the reason of this widening of the spread, and more specifically the effects of the liquidity measures over the spread are Linzert and Schmidt (2007), Hirsch et al. (2007), Hassler and Nautz (2007) and Välimäki (2007).

intensity becomes very low. Therefore we consider that the FTOs are effective in reducing the jump intensity, but only in the period before November 2005. After this date, the ECB started to increase its key interest rates. The instability coming from this is stronger than the smoothing effect of the FTOs. With regard to the loose liquidity policy, we can conclude that, even if it could help to reduce the realized implied, it has not worked for the implied spread. The expectations on the last week of the maintenance period become more volatile from November 2005. The changes in the operational framework is supposedly aimed mostly at removing expectations of interest rate changes during any particular maintenance period, given that changes in the ECB's key interest rates will only apply to the forthcoming reserve maintenance period and that liquidity conditions will no longer spill over from one reserve maintenance period to the next. However, our results show the possibility that the increases in the implied spread volatility and in jump intensity are related to changes in market expectations about future levels of key ECB interest rates.

The remainder of the paper is organised as follows. Section 2 describes the data definitions. Section 3 explains the ARCH-Poisson-Gaussian model implemented. In Section 4 a structural change test is carried out in order to ensure that a structural change happened from November 2005. Section 5 presents the main results and Section 6 provides concluding remarks.

2. Data

Our data consists of a daily series of average implied spread at a given day for the time span of the last MRO of its period. The implied spread (s_t) is computed as the difference between the implied 1-week EONIA swap forward rate τ days ahead (f_t^τ) and the minimum bid rate (r_t^*):

$$s_t = f_t^\tau - r_t^*$$

For each maintenance period we have data from (and including) the second day until (and including) the settlement day of the last MRO of the maintenance period. The following days until the end of the maintenance period (i.e. the last week) have no data, and nor does the first day of the next maintenance period. The reason is because our data, along the maintenance period, are forward rates over the last week. So we remove the data

for this week (see Figure 4). To sum up 654 data: 836 working days less 182 end maintenance period days.

The implied 1-week EONIA swap forward as extracted from the OIS curve. The daily interest rate data that are employed in this study consist of deposit and swap rates from Reuters³. The data are unsmoothed, but have been filtered for mispriced quotes according to the algorithm developed by Brousseau⁴. The data was interpolated as in Brousseau (2002) to yield curve with a maturity grid of 1-week, covering maturities from the overnight rate up to 2 months. This data has been used, for instance, by Brand et al. (2006) and Coffinet and Gouteron (2007).

In Table 1 we show the unit root test for the 1-week EONIA swap forward rate, the implied spread and its first difference. We are interesting in the dynamic of the change, therefore -even when the implied spread seems stationary- we model the change. Moreover, modelling the change, we avoid a possible undetected unit root, which could not be detected by Dickey Fuller test because this test is, in this setting, too restrictive⁵

In Figure 5 we show the graphic of the change in the implied spread. As commented above, we observe a structural change from November 2005. During this month two important events happened. First, from 11th October 2005 the ECB started with the loose liquidity policy in MROs. Second, on 18th November 2005 the ECB's president pre-announced the increase of key interest rates. We choose 10th November 2005 as starting point of the structural change because it is our first data after one month of allotment above the benchmark⁶. We consider the market needs some weeks to assume the loose liquidity policy as regular. Moreover, we can observe in Figure 5 that graphically the starting point of the changes in the series is very close to the 10th. In Section 4 we carry out a test in order to corroborate the existence of structural change in November 2005.

³ Three 1-day deposits (overnight, tomorrow next and spot next) and six OIS (1-week, 2-weeks, 3-weeks, 1-month, 2-months)

⁴ See The Spectrum of Euro-Dollar (page 69) by Vicent Brousseau in G. Teyssière and A.P. Kirman (2007)

⁵ See Hassler and Nautz (2007) and Cassola and Morana (2007). Motivated by a recently observed upward trend in the EONIA spread, these authors apply fractional integration techniques to examine its changing persistence. Their results show that the EONIA spread is an I(0) process under the old framework but fractionally integrated with long run memory after the introduction of the new operational framework. The order of fractional integration d is a more general measure for persistence of a time series.

⁶ There were four first consecutive allotments above the benchmark (11th, 18th and 25th October 2005). Then there was not loose liquidity policy on the 2nd November. However on 8th November the ECB restarted allotting above the benchmark.

Some descriptive statistics, before and after November 2005, for the 1-week EONIA swap forward rate, the implied spread and its first difference are shown in Table 2. At first sight the three series seem more volatile from November 2005. The standard deviation increases on the second period, especially for the forward rate. The standard deviation of the change in the implied spread doubles its value for the second period. The unit-root test shows clear stationarity just for the series of change in the implied spread.

3. ARCH-Poisson-Gaussian model

A Poisson-Gaussian process with ARCH volatility is selected for the dynamics of the change in the implied spread (Δs_t) as in Benito et al. (2007). Here, we will concentrate more on modelling the jump probability as a function of several liquidity variables. This process appears to be suitable for the empirical characteristics of the series under study. The jump model captures the peaks observed in the series and is also very appropriate for dealing with the high level of leptokurtosis that the change in the implied spread series shows in Table 2. Additionally, empirical evidence shows that jump models diminish the possible nonlinearity of the conditional mean of the series. It is widely accepted that these series have a high level of conditional heteroskedasticity in the variance. An ARCH (1) specification for volatility captures the clustering effect and the high persistence intrinsic to Δs_t .

3.1 The model

The model for the change in the implied spread shows the following discrete version from its jump-diffusion continuous specification:

$$\Delta s_t = \mu_t + \sigma_t \Delta z_t + J_t \Delta n_t \quad (1)$$

where μ_t is the conditional mean when there is no jump; Δz_t is an independent standard normal variable; J_t is the jump size that is also assumed normally and independently distributed with a mean denoted as θ and variance ψ^2 . We assume that Δz_t and J_t are also independent. The variable Δn_t is a Poisson process with mean λ_t as the time-varying intensity parameter for the number of jumps which occur in the interval from $t-1$ to t ,

specifically $(t-1, t]$, and Δn_t is also independent of the other two random variables. We approach the Poisson process with a Bernoulli distribution – see Das (2002) or Benito, León, Nave (2007) – with probability λ_t when there is a jump, that is $P(\Delta n_t = 1 | \Phi_{t-1}) = \lambda_t$, and so a probability $1 - \lambda_t$ when there is no jump. This means that in a given interval either only one jumps occurs or no jumps occur, which seems reasonable for daily data. We specify the conditional variance σ_t^2 with an ARCH (1) feature so as to limit the number of parameters to estimate. Finally, it is important to mention that μ_t, σ_t, θ and λ_t are measurable with respect to the information set Φ_{t-1} .

3.2 Likelihood function and conditional moments

The hypothesis underlying equation (1) implies that the distribution of Δs_t , conditioned to the most recent information set, denoted as Φ_{t-1} , and to j jumps, is normally distributed as

$$f(\Delta s_t | \Delta n_t = j, \Phi_{t-1}) = \frac{1}{\sqrt{2\pi(\sigma_t^2 + j\psi^2)}} \exp\left(-\frac{(\Delta s_t - \mu_t - j\theta)^2}{2(\sigma_t^2 + j\psi^2)}\right) \quad (2)$$

where, for our purposes, j takes either value 0 or 1. The conditional density function of Δs_t is obtained from

$$f(\Delta s_t | \Phi_{t-1}) = (1 - \lambda_t) \times f(\Delta s_t | \Delta n_t = 0, \Phi_{t-1}) + \lambda_t \times f(\Delta s_t | \Delta n_t = 1, \Phi_{t-1}) \quad (3)$$

and its log-likelihood, denoted as L , is calculated as $\sum_{t=1}^T \ln f(\Delta s_t | \Phi_{t-1})$ where T indicates the size of the sample. The conditional mean of Δs_t is

$$E_{t-1}(\Delta s_t) = \mu_t + \lambda_t \theta \quad (4)$$

where $E_{t-1}(\cdot)$ indicates the expectation conditioned to the information set Φ_{t-1} ⁷, while the conditional variance is obtained as

⁷ Note that, despite of the notation, the information set may contain events that occur between time $t-1$ and time t

$$V_{t-1}(\Delta s_t) = \sigma_t^2 + \sigma_{t,J}^2 \quad (5)$$

where $V_{t-1}(\cdot)$ indicates the variance conditioned to the information set Φ_{t-1} . It can be seen that this conditioned variance contains two components. A first component defined as

$$\sigma_{t,J}^2 = \lambda_t [\psi^2 + (1 - \lambda_t)\theta^2] \quad (6)$$

is associated with the innovation of the jumps and secondly, σ_t^2 is modelled with the following ARCH (1) structure:

$$\sigma_t^2 = \omega_0 + \omega_1 [\Delta s_{t-1} - E_{t-2}(\Delta s_{t-1})]^2 \quad (7)$$

where it can be seen that $\omega_0, \omega_1 > 0$. Observe that equation (7) includes the effects of both innovations – normal innovations and innovations due to jumps – in the square of its past innovations.

And finally, according to the Akaike and Schwarz information criterions the behaviour of the conditional mean when there is no jump, is guided by an AR (1) process. Therefore we model μ_t as follows:

$$\mu_t = \alpha_1(\Delta s_{t-1}) \quad (8)$$

3.3 The jump probability

Since λ_t is a probability, and hence it must be bounded between 0 and 1, we model it as $\lambda_t = \exp(u_t) / [1 + \exp(u_t)]$ where u_t will depend on different variables paying attention to the period under analysis.

For the period between March 2004 and November 2005, we are interested in finding how the implied spread reacted to the more frequent FTOs on the last day of the maintenance period and also to the announcement and allotment days of the last MRO. The analysis of the FTOs makes sense in this first period because we can distinguish two subperiods: one without frequent FTOs and another with frequent FTOs, i.e., before and after February 2005. As in Hirsch et al. (2007), we consider that, even when FTOs on the last day of the RMP were conducted from November 2004, the market participants assumed them as more or less regular operations from February 2005.

The specification of u_t for the first period is as follows:

$$u_t = \delta_0 + \delta_1 * D_t^{FTO} + \delta_2 * D_t^{ann+allot} + \delta_3 * D_t^{FTO} * D_t^{ann+allot}$$

where

$$\begin{aligned} D_t^{FTO} &= 1 && \text{from 9th February 2005} \\ D_t^{ann+allot} &= 1 && \text{on the announcement and allotment day of the last MRO} \end{aligned}$$

Therefore, for this first period we have four probabilities:

(1) The probability of a jump occurs before February 2005 -when there were no frequent FTOs- and on days other than the announcement and allotment days of the last MROs:

$$P_1(No_FTO \ \& \ No_ann+allot) = \frac{e^{\delta_0}}{1 + e^{\delta_0}}$$

(2) The arrival probability of a jump after February 2005 -when there were frequent FTOs- and on days other than the announcement and allotment days of the last MROs. Note that δ_1 denotes the incremental jump intensity (either positive or negative) over δ_0 :

$$P_2(FTO \ \& \ No_ann+allot) = \frac{e^{\delta_0 + \delta_1}}{1 + e^{\delta_0 + \delta_1}}$$

(3) The probability of a jump occurs before February 2005 -when there were no frequent FTOs- and on the announcement and allotment days of the last MRO. Now δ_2 denotes the incremental jump intensity (either positive or negative) over δ_0 :

$$P_3(No_FTO \ \& \ L_ann+allot) = \frac{e^{\delta_0 + \delta_2}}{1 + e^{\delta_0 + \delta_2}}$$

(4) The arrival probability of a jump after February 2005 -period with frequent FTOs- and on the announcement and allotment days of the last MROs:

$$P_4(FTO \ \& \ L_ann + allot) = \frac{e^{\delta_0 + \delta_1 + \delta_2 + \delta_3}}{1 + e^{\delta_0 + \delta_1 + \delta_2 + \delta_3}}$$

For the second period, i.e., after November 2005 we will just distinguish between the arrival probability of a jump on the announcement and allotment day of the last MRO and the rest of the days. Along this second period three events coincide: the FTOs, the loose liquidity policy and the sequence of increase on ECB key interest rates. Therefore, it is very difficult to distinguish which of these events the jumps come from. The specification of u_t for the second period is:

$$u_t = \delta_0 + \delta_1 * D_t^{L_ann+allot}$$

where

$$D_t^{L_ann+allot} = 1 \quad \text{on the ann. and allot. day of the last MRO}$$

Therefore now we will have two probabilities:

- (1) The probability of a jump occurs on days other than the announcement and allotment days of the last MROs:

$$P_5(No_ann + allot) = \frac{e^{\delta_0}}{1 + e^{\delta_0}}$$

- (2) The probability of a jump occurs on the announcement and allotment days of the last MROs:

$$P_6(ann + allot) = \frac{e^{\delta_0 + \delta_1}}{1 + e^{\delta_0 + \delta_1}}$$

4. Structural change test

In order to ensure that a structural change happened from November 2005, we apply a new version of the previous model including a dummy variable for the second period and for each parameter. It implies that we have to estimate double the number of parameters. With

the goal of simplifying the estimation procedure, we specify λ as constant, but with a different value for each period.

In expression (1) we will now have the following specification for the conditional mean when there is no jump:

$$\mu_t = \alpha_1 \Delta s_{t-1} + \alpha_{1,After} \Delta s_{t-1} D_t^{After}$$

where

$$D_t^{After} = 1 \quad \text{from November 2005.}$$

The new parameter, $\alpha_{1,After}$, represents the increase or decrease over the level of α_1 for the period after November 2005.

Accordingly, the specification for the conditional variance is:

$$\sigma_t^2 = \omega_0 + \omega_{0,After} D_t^{After} + \omega_1 \varepsilon_{t-1}^2 + \omega_{1,After} \varepsilon_{t-1}^2 D_t^{After} \quad \text{where} \quad \varepsilon_{t-1} = \Delta s_{t-1} - E_{t-2}(\Delta s_{t-1})$$

Where the parameters $\omega_{0,After}$ and $\omega_{1,After}$ also represent the increase or decrease over the level of ω_0 and ω_1 for the period after November 2005 respectively.

The jump size will now be specified as $J_t \sim N(\theta_t, \psi_t^2)$, where $\theta_t = \theta + \theta_{After} D_t^{After}$ and $\psi_t = \psi + \psi_{After} D_t^{After}$. The two new parameters, θ_{After} and ψ_{After} , are again increments or decrements over θ and ψ respectively.

And finally the jump intensity is modelled as $u_t = \delta_0 + \delta_{0,After} D_t^{After}$, where the arrival intensity of a jump before November 2005 is obtained as

$$P_1(\text{before November 2005}) = \frac{e^{\delta_0}}{1 + e^{\delta_0}},$$

and for the period after November 2005 this probability is

$$P_{1,After}(\text{after November 2005}) = \frac{e^{\delta_0 + \delta_{0,After}}}{1 + e^{\delta_0 + \delta_{0,After}}}$$

In order to corroborate that a structural change exists, at least one of the new parameters, i.e., $\alpha_{1,After}$, $\omega_{0,After}$, $\omega_{1,After}$, θ_{After} , ψ_{After} or $\delta_{0,After}$ has to be significant. The results of this study are shown in Table 3. Most of the increases or decreases for the second period are significant; therefore we conclude that a structural change exists from November 2005.

5. Empirical results

In this section, the results obtained from applying the model developed in Section 3 are discussed and Table 4 shows the results obtained by this Poisson-Gaussian model with ARCH variance for the two periods under analysis. Remember that there is different specification of the jump intensity in each period.

The results in Table 4 confirm what Figure 5 shows, i.e., there is an increase of the volatility of the changes in the implied spread from November 2005. The market expectations for the last week of the maintenance period became more instable. Looking at Panel A, we can see that the magnitude of ω_1 -the sensitivity of the variance to the previous errors- increases from 0.2571 (2.4627) to 0.4709 (3.2659), being also more significant in the second period. The volatility of the jump component, ψ , is also higher and more significant after November 2005, moving from 0.0186 (2.5481) to 0.0582 (7.1396). This increase in volatility coincides with the beginning of a sequence of increase in key ECB interest rates, but also with the beginning of a loose liquidity policy in every MRO.

In Panel A, we also observe that there is not a significant input from the jump mean, θ , to the total conditional mean –equation (4)- either before or after November 2005. Therefore it will depend exclusively on the conditional mean when there is no jump, μ_t , which has been modelled as an AR(1) process. For the first period, α_1 is negative and significant, therefore there is a reversion process. After November 2005, α_1 shows a lower and not significant value, which involves a total conditional mean close to zero, i.e., the implied spread shows more evidence of a martingale behaviour for the second period.

Focusing now on the jump intensity specification (Panel B), our initial objective was whether and how the change in the implied spread reacts to the information coming throughout the maintenance period, specifically the publication of the forecast of the

autonomous factor and benchmark on the announcement day of the last MRO of each maintenance period and its update on the following day (allotment day). In Panel B1 we show the results of the probability of a jump on the announcement and allotment days of the last MRO versus the rest of the days. We also wanted to know whether and how the expectations react to the new liquidity policy. Specifically, how they react to the more frequent FTOs on the last day of the maintenance period and the more frequent liquidity allotment above the benchmark in most of the MROs. These are the reasons for the three columns in Panel B.

In Panel B1 we have the following results: the probability of a jump occurring between March 2004 and February 2005 -the period without frequent FTOs- is high both on the announcement and allotment days of the last MRO and on the rest of the days. However we can observe an important reduction of the probability of a jump from the introduction of frequent FTOs⁸ from February 2005 to November 2005. Specifically, from 0.5901 (2.4736) to 8.97e-002 (1.734) on the announcement and allotment days of the last MRO, and from 0.4511 (1.841) to 0.0819 (1.859) on the rest of the days. We must keep in mind that we are modelling the average implied spread, at a given day, for the time span of the last MRO of its period. This means that the conclusions have to be relative to market expectations. Therefore, the market expectations, at a given day for the last week of the maintenance period, are sensitive to more frequent FTOs, reducing its jump intensity

For the second period, i.e. from November 2005 to June 2007, there is an increase in the jump intensity for both groups of days, the announcement and allotment days and the rest of the days. It seems that frequent FTOs do not reduce the jump intensity as they did before. From November 2005, the ECB starts to allot above the benchmark in every MRO, which is supposed to help to reduce the width of the EONIA spread. However, it seems that any of these two measures -frequent FTOs and loose liquidity- can reduce instability, on the implied spread, coming from the sequence of increases in key ECB interest rates.

Because we find it strange that after November 2005 the jump intensity is higher on days other than the announcement and allotment days of the last MROs -column three of Panel B1- we carry out a second analysis in order to know the arrival probability of a jump on the settlement day of the last MRO. The results are shown in Panel B2. For the period without frequent FTOs, the jump intensity on the settlement day is very high, and as

⁸ Remember we always refer to the FTOs on the last day of each reserve maintenance period.

happened in Panel B1, it also decreases when the ECB started to conduct FTOs on a more regular basis. In the same way the probabilities increase from November 2005.

In a third study -Panel B3- we are interested in finding the different jump intensities between three groups of days: the allotment day of the last MRO, the settlement day of the last MRO and the rest of the days. While in Panel B4 we also want to know the specific jump intensity for the announcement day of the last MRO. The results show that for this announcement day the intensity of the jump is similar to the rest of the days. Therefore, we concentrate more on Panel B3, which shows that the allotment and settlement day experience a high level of jump probability before the introduction of the FTOs from February 2005. And, as on the rest of the Panels B, the conduct of FTOs decreases the jump intensity, which again increases from November 2005, except for the allotment day. This last result is somewhat peculiar: What could be the reason for a bigger jump on the settlement day than on the allotment day? On the allotment day -usually a Tuesday- the counterparties already know the results of the MRO at 11.15 a.m ECB time (CET). These results are announced publicly by means of wire services. In addition, national central banks may announced the allotment result directly to counterparties without access to wire services⁹.

6. Conclusion

The initial objective of this paper was to know whether and how the market expectations react to the information coming throughout the maintenance period, specifically the publication of the forecast of the autonomous factor and benchmark on the announcement day of the last MRO of each maintenance period and its update on the following day (allotment day). We also wanted to know whether and how the expectations react to the new liquidity policy. Specifically, how they react to the more frequent FTOs on the last day of the maintenance period and the more frequent liquidity allotment above the benchmark in most of the MROs.

The results show a significant change in the implied spread from November 2005 onwards. The market expectations for the last week of the maintenance period became more instable. This increase in volatility coincides with the beginning of a sequence of

⁹ The implementation of Monetary Policy in the Euro Area. General documentation on Eurosystem monetary policy instruments and procedures. ECB September 2006.

increases in key ECB interest rates, but also with the beginning of a loose liquidity policy in every MRO.

We find that on the announcement day the intensity of the jump is similar to the rest of the days, with the jump intensity being stronger on the allotment and settlement days between March 2004 and February 2005. From this last date and with frequent FTOs the jump intensity becomes very low. Therefore we consider that the FTOs are effective in reducing the jump intensity, but only in the period before November 2005. After this date, the ECB started to increase its key interest rates. The instability coming from this is stronger than the smoothing effect of the FTOs. With regard to the loose liquidity policy, we can conclude that, even if it could help to reduce the realized implied, it has not worked for the implied spread. The expectations on the last week of the maintenance period become more volatile from November 2005. The changes in the operational framework is supposedly aimed mostly at removing expectations of interest rate changes during any particular maintenance period, given that changes in the ECB's key interest rates will only apply to the forthcoming reserve maintenance period and that liquidity conditions will no longer spill over from one reserve maintenance period to the next. However, our results show the possibility that the increases in the implied spread volatility and in jump intensity are related to changes in market expectations about future levels of key ECB interest rates.

And finally, we find a peculiar result from November 2005. The jump intensity is higher on the settlement day than on the allotment day of the last MRO. The counterparties know the results of the auction from 11.15 a.m on the allotment day. What could be the reason of a higher jump in the next day, i.e. settlement day?

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Table 1
Unit-Root Test

1-week EONIA swap forward rate τ days ahead	Implied spread	Change in implied spread
f_t^τ	$(f_t^\tau - r_t^*)$ where $r_t^* = \text{MBR}$	Δs_t
0.890	-7.203 (**)	-17.501 (**)

t-statistics of Augmented Dickey-Fuller (ADF) tests for the series of 1-week EONIA swap forward rate, implied spread and its first difference over the period from March 2004 to July 2007. t-statistics with constant and lag length according to the Schwarz Information Criterion (SIC). The 5% (1%) critical value is -2.869 (-3.449), significance is denoted by * (**). All test results are robust if constant in ADF test is not included.

Table 2
Descriptive statistics

	1-week EONIA swap forward rate τ days ahead		Implied spread		Change in implied spread	
	f_t^τ		$(f_t^\tau - r_t^*)$ where $r_t^* = \text{MBR}$		Δs_t	
	from March 2004 to Nov. 2005	from Nov. 2005 to June 2007	from March 2004 to Nov. 2005	from Nov. 2005 to June 2007	from March 2004 to Nov. 2005	from Nov. 2005 to June 2007
Mean	2.056	3.014	0.059	0.073	3.52e-05	-0.0002
Median	2.064	3.021	0.064	0.070	0.000	-0.001
Std. dev.	0.020	0.547	0.020	0.035	0.012	0.025
Kurtosis	3.238	1.608	3.254	6.303	18.568	9.203
ADF	-3.058 *	-1.080	-3.062*	-6.661**	-15.860**	-13.985**

ADF denotes t-statistics of Augmented Dickey-Fuller tests with constant and lag length according to the Schwarz Information Criterion (SIC). The 5% (1%) critical value is -2.869 (-3.449), significance is denoted by * (**). Only the test results for the series of change in implied spread are robust if constant in ADF test is not included.

Table 3
Structural Change

Daily data of implied spread covering the period March, 12 2004 to June, 6 2007. The ARCH-Poisson-Gaussian process for the change in the implied spread is specified as follows:

$$\Delta s_t = \mu_t + \sigma_t \Delta z_t + J_t \Delta n_t \quad \Delta z_t \sim N(0,1); \quad J_t \sim N(\theta_t, \psi_t); \quad \Delta n_t, \Delta z_t \text{ and } J_t \text{ are independent;}$$

$$\mu_t = \alpha_1 \Delta s_{t-1} + \alpha_{1,After} \Delta s_{t-1} D_t^{After}; \quad \theta_t = \theta + \theta_{After} D_t^{After} \text{ and } \psi_t = \psi + \psi_{After} D_t^{After}$$

$$\sigma_t^2 = \omega_0 + \omega_{0,After} D_t^{After} + \omega_1 \varepsilon_{t-1}^2 + \omega_{1,After} \varepsilon_{t-1}^2 D_t^{After}; \text{ where } \varepsilon_{t-1} = \Delta s_{t-1} - E_{t-2}(\Delta s_{t-1})$$

Parameters	Estimations
ω_0	2.07-e005 (1.6871)
$\omega_{0,after}$ (increment)	7.11-e005 (2.5482)
ω_1	0.2514 (2.4827)
$\omega_{1,after}$ (increment)	0.1923 (4.5721)
α_1	-0.2034 (-4.8964)
$\alpha_{1,after}$ (increment)	0.1897 (1.7349)
θ	0.0002 (0.0982)
θ_{after} (increment)	0.0003 (1.0032)
ψ	0.0186 (2.5841)
ψ_{after} (increment)	0.0832 (5.8257)
P_1 (Before Nov.05)	0.6531 (3.214)
$P_{1,after}$ (After Nov.05) (increment)	-0.0947 (2.948)
Log-L Func	1250.28
SIC	1218.56

The jump intensity is model as $u_t = \delta_0 + \delta_{0,After} D_t^{After}$, where the arrival intensity of a jump before November 2005 is obtained as P_1 (Before November 2005) = $e^{\delta_0} / (1 + e^{\delta_0})$, and after $P_{1,After}$ (After November 2005) = $e^{\delta_0 + \delta_1} / (1 + e^{\delta_0 + \delta_1})$

Table 4**ARCH-Poisson-Gaussian process**

Daily data of implied spread covering the period March, 12 2004 to June, 6 2007. The ARCH-Poisson-Gaussian process for the change in the implied spread is specified as follows:

$$\Delta s_t = \mu_t + \sigma_t \Delta z_t + J_t \Delta n_t \quad \Delta z_t \sim N(0,1); \quad J_t \sim N(\theta, \psi^2);$$

$$\mu_t = \alpha_1 (\Delta s_{t-1}); \quad \sigma_t^2 = \omega_0 + \omega_1 [\Delta s_{t-1} - E_{t-2}(\Delta s_{t-1})]^2; \quad \Delta n_t, \Delta z_t \text{ and } J_t \text{ are independent;}$$

Parameters	Before Nov. 05 343 data	After Nov. 05 310 data
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PANEL A

ω_0	2.09e-005 (1.8884)	9.96e-005 (3.8797)
ω_1	0.2571 (2.4627)	0.4709 (3.2659)
α_1	-0.2059 (-4.9964)	-0.01280 (-1.0560)
θ	0.0002 (0.1002)	0.0005 (0.0703)
ψ	0.0186 (2.5481)	0.0582 (7.1396)

PANEL B

Probabilities of jump	No FTOs 12 Mar. 04– 9 Feb. 05	FTOs 10 Feb.05 –9 Nov.05	FTOs + Loose + Interv. 10 Nov 05 – 6 June 07
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PANEL B1

Ann + Allot (last MRO)	0.5901 (2.4136)	8.97e-002 (1.734)	0.2485 (2.7428)
Rest of the days	0.4511 (1.8341)	0.0819 (1.859)	0.4549 (3.0880)

PANEL B2

Sett. day (last MRO)	0.9534 (3.2283)	0.0821 (1.8566)	0.5873 (3.1907)
Rest of the days	0.2740 (1.7822)	0.0519 (1.9227)	0.1784 (2.7328)

PANEL B3

Allot. day (last MRO)	0.9751 (2.9231)	0.0202 (1.7591)	0.0001 (1.7351)
Sett. day (last MRO)	0.9334 (3.2173)	0.0826 (1.8363)	0.5892 (3.2154)
Rest of the days	0.2231 (1.8941)	0.0312 (1.8223)	0.2059 (2.7907)

PANEL B4

Ann. day (last MRO)	0.2244 (1.6827)	0.0311 (1.8364)	0.2103 (2.5831)
Allot. day (last MRO)	0.9770 (2.9211)	0.0222 (1.7591)	0.0002 (1.7321)
Sett. day (last MRO)	0.9438 (3.2385)	0.0829 (1.8363)	0.5892 (3.2133)
Rest of the days	0.2259 (1.9037)	0.0316 (1.8425)	0.2070 (2.7968)

Ann., Allot. and Sett. stand for announcement, allotment and settlement day of the last MRO respectively. Loose stands for loose liquidity policy, i.e., the period with allotment above benchmark in MROs. Interv. stands for the period of increases in ECB key interest rate.

Figure 1

FTOs on the last day of the maintenance period from March 2004 to June 2007 in billion Euros

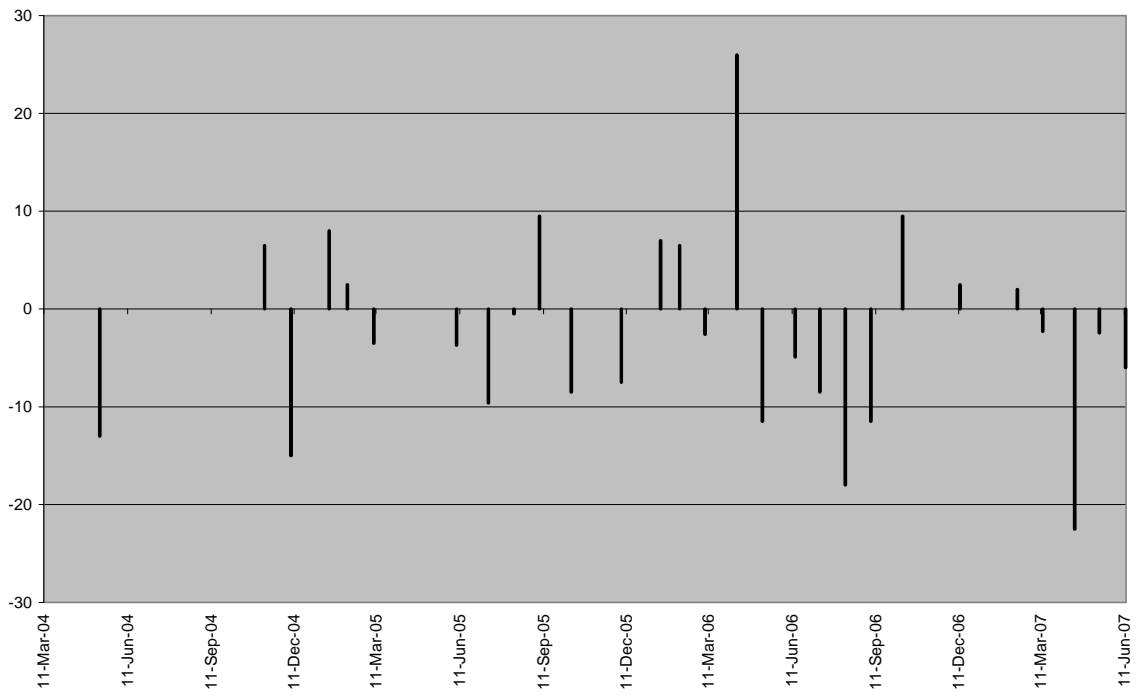


Figure 2.

Allotted amounts above the benchmark in the MROs from March 2004 to June 2007 in billion Euros

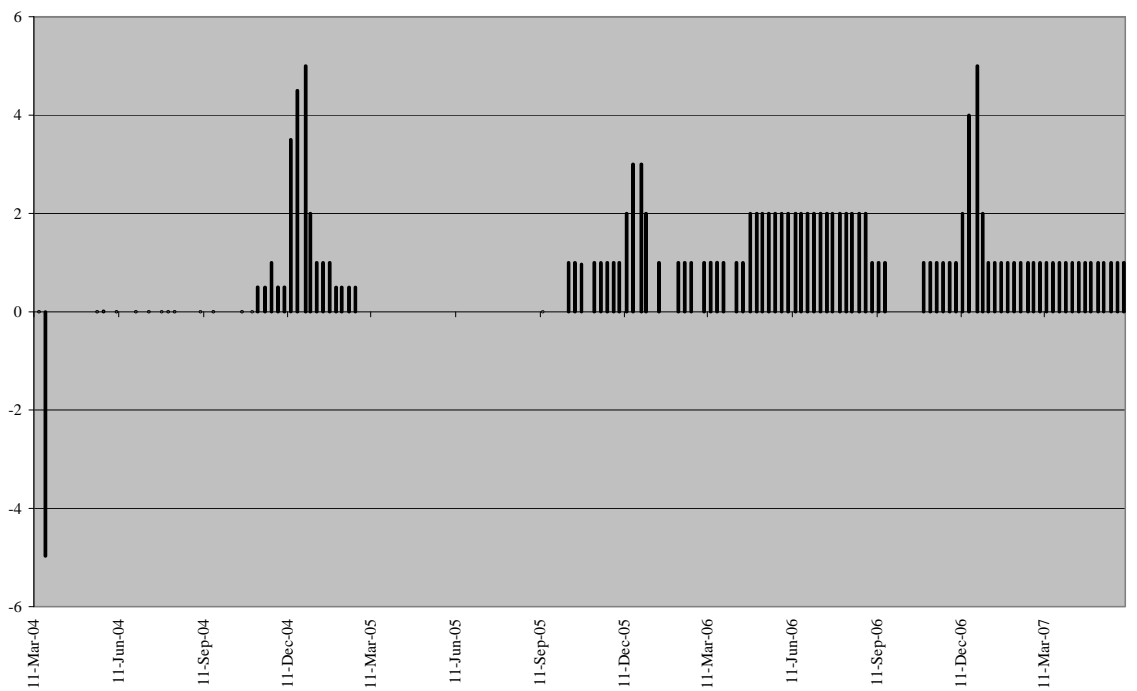


Figure 3
EONIA rate and MBR from March 2004 to June 2007

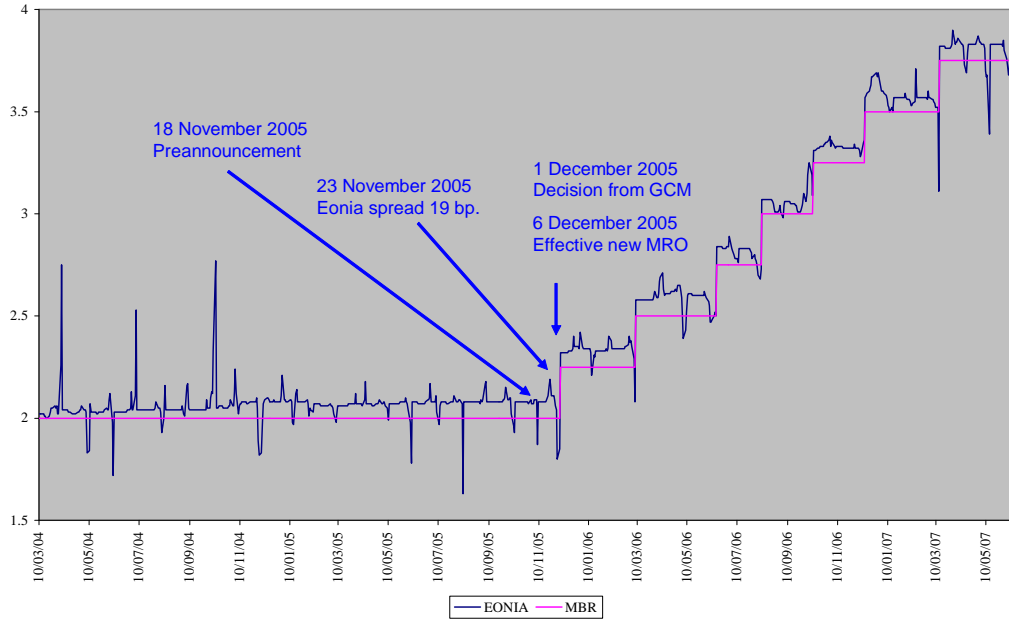
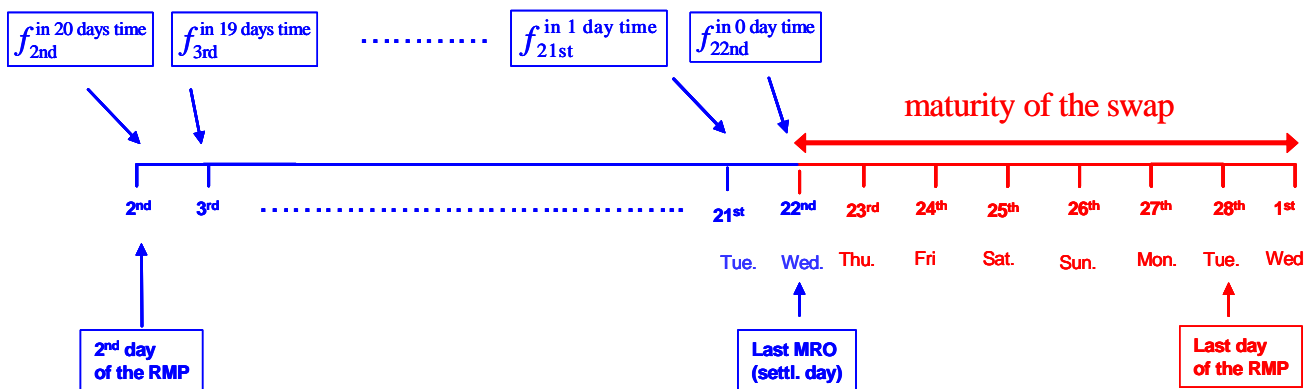
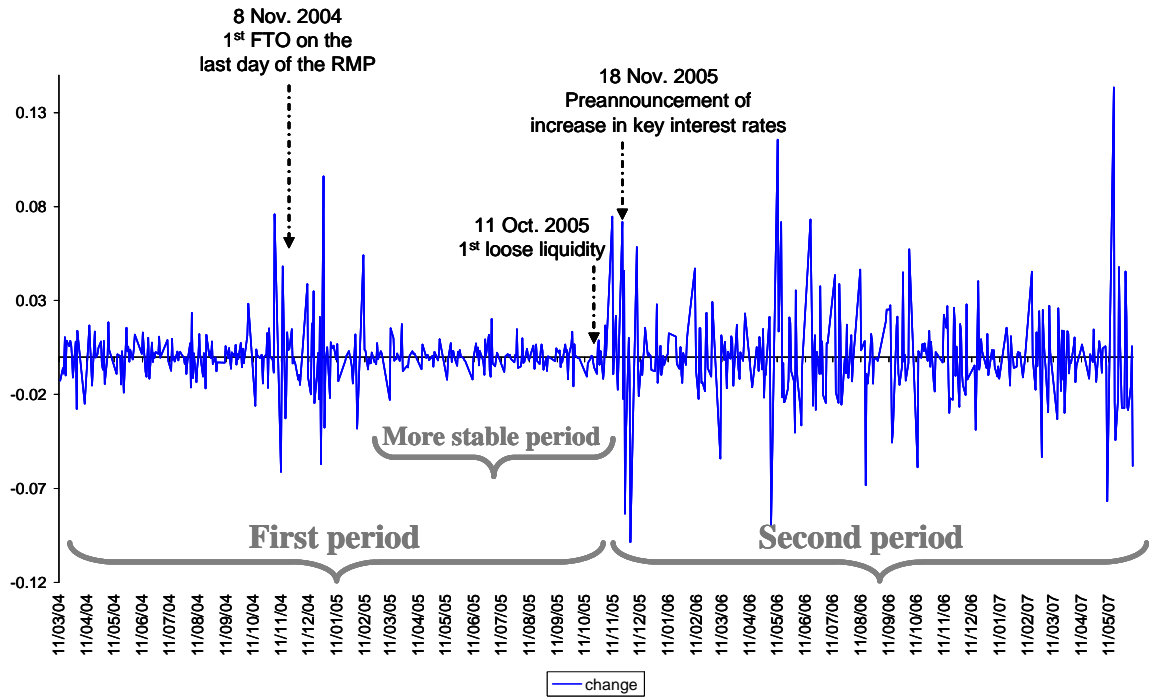


Figure 4
Implied 1-week EONIA swap forward rate



f_t^{τ} is the implied 1-week EONIA swap forward rate τ days head. Each of these forward rates represents the expected average level of the EONIA rate over the last week of the maintenance period (over the maturity of the swap)

Figure 5
Change in the implied spread



Evolution of the change in the implied spread from 11 March 2004 to 6 June 2007