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How they respond to recent changes in the operational framework

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Euro money market interest rates dynamics and volatility:

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Résumé

En mars 2004, l'Eurosystème a mis en place différentes modifications de son cadre opérationnel et de sa gestion de la liquidité. L'objectif de cet article est d'étudier les effets de ces changements sur le niveau et la volatilité de l'écart entre l'Eonia et le taux de soumission minimum. Nos résultats montrent que ces changements ont globalement eu un effet positif sur le niveau et la volatilité du spread. La baisse de la volatilité observée après 2004 est largement expliquée par ces modifications.

Classification JEL : E52, E58, E43

Mots clés : Marché monétaire européen, cadre opérationnel, effet de liquidité.

Abstract

At the beginning of 2004, the Eurosystem implemented several modifications of its operational framework and liquidity management aiming at enhancing market efficiency. The purpose of this article is to study the effects of theses changes in the spread between the Eonia and the minimum bid rate. Our results reflect that both the operational changes as well as the new liquidity management are responsible for a significant decrease in the interest rate volatility.

JEL Classification: E52, E58, E43

Keywords: European money market, Eonia, Operational framework, Liquidity effect.

Résumé non technique

En mars 2004, l'Eurosystème a mis en place différentes mesures, modification du cadre opérationnel, allocations de liquidités supérieures au "benchmark" ("loose policy") plus fréquentes, visant à améliorer la stabilité et l'efficacité du marché monétaire européen. L'objectif de cet article est d'étudier l'impact de ces changements sur le spread entre l'Eonia et le taux de soumission minimum, en niveau et en volatilité. Dans un premier temps, l'accent est mis sur les conséquences du changement de cadre opérationnel. Depuis mars 2004, la maturité des opérations principales de refinancement (OPR) a été réduite de deux semaines à une semaine. De plus la période de constitution des réserves débute désormais le jour de réglement de la première OPR suivant le conseil des Gouverneurs au cours duquel sont décidés les taux directeurs. Le risque associé à ce changement est de voir apparaître une plus forte volatilité en fin de période de constitution des réserves, car dans ce nouveau cadre, le délai entre la dernière OPR et le dernier de jour de la période de maintenance (8 jours) est toujours supérieur à celui observé avant 2004. Pour limiter cela, la fréquence d'opérations de réglages fins (FTO[1]) conduites le dernier jour de la période de maintenance, a été augmentée. Dans un second temps, nous cherchons à évaluer les conséquences de la politique de gestion de la liquidité mise en place par la BCE sur la période récente.
Nos conclusions sont les suivantes. Les changements opérés au niveau du cadre opérationnel ont globalement eu un effet positif sur le niveau et la volatilité du spread. La baisse de la volatilité observée après 2004 est largement expliquée par ce changement. Nous estimons bien une hausse de la volatilité le dernier jour de la période de maintenance après 2004. Cependant, cette hausse est bien compensée par la mise en place de façon quasi systématique de FTOs le dernier jour de la période de maintenance. En moyenne, la volatilité enregistrée à la fin de la période de maintenance reste la même. Par ailleurs, nos résultats montrent que la "loose policy" est plus efficace lorsqu'elle est menée à la fin de la période de maintenance, et reduit l'écart entre l'Eonia et le taux de soumission minimal. De plus, la "loose policy" a tendance à engendrer une hausse de la volatilité avant 2004, alors qu'elle n'a aucun effet sur la volatilité après 2004. Ce résultat peut s'expliquer par une meilleure politique de communication de la BCE après 2004, qui rend publique, en plus des révisions de facteurs autonomes, le montant du benchmark pour les OPRs.

[1]Fine-tuning operations.

Non technical summary

At the beginning of 2004, the Eurosystem implemented several measures such as operational framework modifications and more frequent liquidity allotment above the benchmark (loose policy) during its weekly main refinancing operations (MROs) aiming at enhancing market efficiency. The goal of this paper is to study the impact of these changes on the spread between the Eonia and the minimum bid rate (spread), dynamics and volatility. First, we investigate and provide an assessment of the consequences on the spread dynamics of the changes in the operational framework in March 2004. At this date the maturity of the weekly main refinancing operations was shortened from two weeks to one. Furthermore, since then, reserve maintenance periods have started on the settlement day of the main refinancing operation following the Governing Council meeting at which the monthly assessment of the monetary policy stance is pre-scheduled. In the new framework, the last MRO of the maintenance period is always allotted eight days before the end of the reserve maintenance period (RMP), that is, a period longer than in the previous framework. Therefore, this could lead to a greater volatility in money market interest rates at the end of the maintenance period. To avoid this problem, the ECB started to conduct fine-tuning operations (FTO) on a more regular basis. Second, we explicitly take into account liquidity effects. Actually, in the recent period, the ECB began an allotment policy, whereby it allotted above the benchmark more frequently.
The paper reaches the following conclusions. The changes of the operational framework have an overall positive impact on both the level of the spread as well as its volatility. The decrease that can be attributed to the changes is significant and large. As regards the increased number of FTOs implemented at the end of the maintenance period, it has also played its expected role. Because the period between the last MRO and the last day of the RMP in the new framework is now longer, the spread volatility should have drop-up at the end of the period. Our results show that this effects exists but is offset by the FTOs. Our results suggest that the implementation of "loose policy" on last days of the RMP lowers the spread on either framework, but the impact is less pronounced after 2004. Concerning volatility, the "positive" effect of pre-2004 changes does not longer exist. However, this cannot be attributed to the only operational changes. In fact, before 2004, any deviation between the MRO allotment and the benchmark amounts that banks had calculated, could be due to ECB deliberately pursuing a non-neutral liquidity target, or autonomous factors predictions errors. In the new framework, the ECB decided to also publish its calculation of the benchmark in order to avoid misperceptions in the market. Our estimation indicates that this additional

communication by the ECB has well reached its goal given that the volatility remains unchanged when a "loose policy" is conducted.

1 Introduction

Nowadays, most central banks aim at steering a short term interest rate. This operational target is in many cases an overnight interest rate, as it plays crucial role in the financial structure, notably because it anchors the term structure of interest rates.

In the case of the Eurosystem there is no explicit target rate, as the federal fund target rate in the United states. Instead, the ECB provides a signalling rate, that is the minimum bid rate on its main refinancing operations. The reference for the operational overnight rate is the Eonia (Euro OverNight Index Average), which is related to the unsecured segment of the euro money market. Therefore, steering interest rate in the case of the Eurosystem means stabilizing the Eonia around the minimum bid rate.

At the beginning of 2004, the euro money market has experienced important changes aiming at enhancing market efficiency. To do this, the Eurosystem implemented several measures such as operational framework modifications and more frequent liquidity allotment above the benchmark (loose policy) during its weekly main refinancing operations (MROs).

The goal of this paper is to study the impact of this operational changes on the spread between the Eonia and the minimum bid rate, hereafter the Eonia spread, dynamics and volatility. More precisely, we want to know if the observed decrease in the spread volatility is more likely to be explained by the stability of the key policy rates or by the operational and/or the liquidity management changes.

The interest for the money market and even for the European money market is not new. A great deal of research has focused on the features of the overnight interest rate, aiming to explain what drives its level and volatility and what factors make it diverge from the target rate. The empirical literature on the conditional volatility of the overnight rate was initiated by the seminal article by Hamilton (1996). While that paper has a strong focus on testing the martingale hypothesis for the federal fund rate, it also analyses the calendar as well as the reserve maintenance period (RMP) effects on the overnight interest rate volatility in a EGARCH framework. Since then, this specification has been widely used in the literature on interbank rates. See for example, Pérez-Quíros and Rodríguez-Mendizabal (2005) for an application to German and European overnight rates. Gaspar, Pérez-Quíros and Sicilia (2001) use a similar model to analyze the individual rates reported by the banks contained in the Eonia panel. Bartolini, Bertola and Prati (2002) analyze the volatility in daily overnight rates for a whole set of countries, including the euro area. These articles confirm the existence of empirical

regularities in the mean and the volatility of the overnight rate dynamics. Some are usual seasonal patterns known as end of period effects (end of week, end of month, end of quarter...). Other regularities can be associated with the operational framework of monetary policy. More specifically the volatility of the overnight interbank rate tends to be higher at the end of the reserve maintenance period. As regards volatility transmission, conclusions are more heterogeneous. Ayuso and al (1997) estimate the volatility of the money market rates for various European countries before European Monetary Union (EMU). They use an EGARCH model and introduce an estimate of the overnight rate volatility as exogenous variable. Their study leads to the conclusion of a significant volatility transmission from overnight to longer-term money market rates. While this transmission is rejected on UK data (Vila Wetherit (2003)), it is confirmed on post-EMU data at least for shorter maturities (Cassola and Morana (2006), Alonso and Blanco (2005), Durré and Nardelli (2006)).

Another strand of the literature has tried to improve the specification of the mean equation of the overnight rate, distinguishing between short run and long run dynamics, or emphasizing asymmetries and non-linearities. Würtz (2003) estimates a non linear equation for the spread between Eonia and the official rate in order to take into account that the Eonia is bounded by the corridor set by European Central Bank's (ECB) standing facilities. Sarno and Thornton (2003) estimate non-linear error-correction equations for the US Federal Funds rate and the three-month Treasury bill rate. They find that the adjustment of the overnight rate to the Treasury bill is asymmetric. Kuo and Enders (2004) and Clarida and al. (2006) show that non-symmetric error correction is also present in the Japanese and the German term structure. Nautz and Offermanns (2005) investigate the dynamic adjustment of the Eonia to the term spread and the ECB's policy rate. They show that the adjustment of the Eonia is significantly stronger when the policy spread is below average. This result is also present in the study of Ayuso and Repullo (2003). According to these authors, this asymmetry in the Eonia dynamics comes from the fact that the central bank is more averse to let interest rate fall below the target than let them exceed it (asymmetric loss function).

The present paper is in line with previous studies. Indeed, we use the EGARCH specification to model the Eonia spread. However, this paper differs from existing literature in the followings ways.

First, we investigate and provide an assessment of the consequences on the spread dynamics of the changes in the operational framework in March 2004. At this date the maturity of the weekly main refinancing operations (MRO) was shortened from two weeks to one. Furthermore, since then, reserve maintenance periods have started on the settlement day of the main

refinancing operation following the Governing Council meeting at which the monthly assessment of the monetary policy stance is pre-scheduled. The objective of the combined measures was to contribute stabilizing the conditions in which credit institutions bid in the MRO. However, in the new framework, the last MRO of the maintenance period is always allotted eight days before the end of the reserve maintenance period, that is, a period longer than in the previous framework. Therefore, this could lead to a greater volatility in money market interest rates at the end of the maintenance period (see Decker and Valla (2005), Durré and Nardelli (2006)).

Second, we explicitly take into account liquidity effects. On one hand, liquidity appears to be a natural candidate to explain interest rates dynamics as they come from the matching of demands and supplies and thus depends on the liquidity inflows. On the other hand, in the recent period, the ECB began an allotment policy, whereby it allotted above the benchmark more frequently. In fact, as mentioned in Gonzalez-Paramo (2007), "[...] large volume in each MRO have [...] grown four-fold since the beginning of 2004. Half of this increase was caused by the shortening of the MRO maturity [...], while the other half reflects the continued expansion in the liquidity deficit".

The rest of the paper is structured as follows. Section 2 describes the Eurosystem monetary policy framework with a special focus concerning the changes of the operational framework in March 2004. Section 3 presents the data and provides some descriptive statistics and the econometric specification. In section 4, we present empirical results. The last section concludes the paper.

2 Recent changes in the operational framework and liquidity policy in the Eurosystem

2.1 Operational framework

In order to achieve its primary objective, the Eurosystem has a set of monetary instruments and procedures at its disposal. This set forms the operational framework. Its main components are: the open market operations (OMOs), the standing facilities and the minimum reserve requirement.

Open market operations play an important role in steering interest rates, signalling the stance of monetary policy and managing the liquidity situation in the money market. The main refinancing operations (MROs) are the most

important open market operations. Through MROs, the Eurosystem lends funds to its counterparts against collateral with a weekly frequency. This lending normally takes place in the form of a reverse transaction. The Eurosystem may also carry out fine tuning operations (FTOs). The frequency and maturity of such operations are not standardized. They can be liquidity-absorbing or liquidity-providing. They aim at managing the liquidity situation, in particular to smooth the effects on interest rates of unexpected liquidity fluctuations in the money market.

The Eurosystem also offers two standing facilities to its counterparts, the marginal lending facility and the deposit facility. They both have an overnight maturity and are available to counterparts on their own initiative. The corresponding interest rates provide a ceiling and a floor for the overnight rate in the money market. Therefore, by setting the rates on the standing facilities, the Governing Council determines the corridor within which the overnight money market can fluctuate.

Finally, the ECB requires credit institutions to hold deposits on accounts with the national central banks (NCBs), the "minimum" or "required" reserve. On the first hand, the role of reserve requirements is to create a liquidity deficit. On the other hand, the averaging provision on reserve fulfilment[2] tends to stabilize short term interest rates as a result of an intertemporal arbitrage mechanism.

2.2 Changes of the operational framework as of March 2004

The Eurosystem monetary policy framework has experienced periods of tension in the past when pronounced speculation on an imminent interest rate change has affected counterpart's bidding in the main refinancing operations, known as "overbidding" and "underbidding" episodes. Both problems stemmed mainly from the fact that the timing of the reserve maintenance periods was independent of the dates of the Governing Council meetings at which changes in the key ECB rates were decided. Thus changes in the key ECB interest rate could occur within a reserve maintenance period. In addition, the maturity of the weekly MROs (which was two weeks long) was such that the last operation of each reserve maintenance period overlapped with the subsequent reserve maintenance period. As a result, bidding behavior at

[2]This means that compliance with reserve requirements is determined on the basis of the average of the daily balances on the counterpart's reserve accounts over a reserve maintenance period of around one month.

the end of a maintenance period could be affected by expectations of changes in the key ECB interest rates in the next reserve maintenance period.

To respond to this problem, the Governing Council decided in 2003 on two measures, effective as of March 2004:

- Change of the timing of the maintenance period beginning. More precisely, it was decided that maintenance periods would start on the settlement day of the first MRO following the Governing Council meeting at which the monthly assessment of the monetary policy stance was pre-scheduled. This was to ensure that there are no expectations of changes to the key ECB rates occurring during a reserve maintenance period.

- Reduction of the maturity of MROs from two weeks to one week. This aimed at eliminating the spill-over of interest rate speculation from one reserve maintenance period to the next.

The objective of the combined measures was to contribute towards stabilizing the conditions in which credit institutions bid in the MRO and therefore stabilizing money market volatility.

However, it was noted that some risks could be associated with these changes. For instance, as a consequence of the reduction of the MRO maturity, the allotment amounts of MROs would double. Therefore one could expect that some credit institutions could face difficulties to adjust their bids, especially with regard to the collateral requirements. More importantly, as regards money market volatility, it can be stressed that in the new framework, the last MRO of the maintenance period is one week from the end of the reserve maintenance period. Therefore, this could generate large aggregate liquidity imbalances at the end of the maintenance period, leading to greater volatility in money market interest rates.

2.3 The liquidity management by the Eurosystem over the recent period

Being the monopolistic supplier of liquidity, the Eurosystem can steer short-term interest rates. Its aim is to provide the liquidity needed by the banking community, that is, the amount that helps banks to fulfill their reserve requirement (benchmark).

In parallel with the operational framework modifications, the Eurosystem has experienced a significant change in the liquidity management over the recent period.

This change is first materialized by more frequent FTOs at the end of the maintenance period. Actually, as noted above, one risk associated with the new framework is an increase in the likelihood of having large imbalances during the last week of a maintenance period. To avoid this problem, the ECB started to conduct fine-tuning operations on the last day of the maintenance period on a more regular basis. Hence, we observe in our sample 8 FTOs in the old framework. Only 1 out of 8 occurred the last day of the maintenance period. In contrast, in the new framework, 22 out of 23 occurred the last day of the maintenance period. A higher frequency of FTOs, and particularly at the end of the maintenance period, should contribute to reduce the volatility of the Eonia spread. Consequently, in order to provide unbiased assessment of the operational framework change in the volatility of the Eonia spread, we must take into account FTOs.

In addition, the evolution of the Eonia spread under the new operational framework has showed a quite unexplained slight upward trend during the summer 2004 and autumn 2005. In reaction to that, the ECB began an allotment policy, whereby it allotted above the benchmark in all MROs, with the exception of the final operation in a maintenance period. This policy was at first successful in containing spreads. However, in spring 2006, money market spread again showed an increasing trend, and the ECB started to allot above the benchmark in the final MRO as well. As a result, in our sample, the ECB has allotted above the benchmark 320 times in the new framework, against 192 in the old one.

The risk associated with "loose policy" was that it could be misinterpreted by market participants. In 2002, the formula for the benchmark was published. Moreover before 2004, the ECB also provided its forecasts of the average autonomous factors. However, the forecast of the benchmark was left to banks. Therefore when banks observed a deviation between the MRO allotment amount and the benchmark they had calculated, there was uncertainty about the cause of this deviation, that is a deliberate non-neutral policy of the ECB, or simple update of the autonomous factors update. In order to avoids such misunderstanding, the ECB decided to systematically provide after 2004 its forecast of autonomous factors and its calculation of the benchmark allotment amount. This additional communication in the new framework should also contribute towards stabilizing the money market volatility by reducing uncertainty in periods of loose policy.

3 Data description and descriptive statistics

3.1 Interest rate data and variables

The analysis focuses on a key money market rate of the unsecured segment, the Eonia. The Eonia is a volume-weighted average of daily interest rates reported by a panel of approximately 50 banks that have the highest business volume in the unsecured euro money market. It is computed by the ECB and published between 6.45 p.m. and 7.00 p.m.

Whereas the Eonia rates was launched with the adoption of the Euro on the first of January 1999, we choose to start our analysis on June 28, 2000. This date corresponds to the implementation of the current variable rate tender procedure adopted by the ECB for its main refinancing operations. The sample period runs from that date to January 16, 200 (1677 observations).

In this article, we compare the Eonia with the "official" or "target" monetary policy rate. Here, this rate is the minimum bid rate set by the ECB in the variable rate tenders applied in its weekly main refinancing operations.

	Whole Sample				
Variables	Mean	Median	Std	skewness	kurtosis
Eonia : i_t	2.96	2.71	0.97	0.74	2.33
Policy rate : i_t^*	2.89	2.50	0.95	0.73	2.21
spread : $i_t - i_t^*$	0.07	0.06	0.13	1.80	19.5

Table 1 : Descriptive statistics, from June, 28 2000 to January, 16 2007 .

Table 1 shows that, over the whole sample, the overnight rate is on average above the official rate by around 7 *bp*. One factor accounting for this spread is that transactions on the unsecured money market are riskier than transactions with the ECB. In addition, we observe that standard deviations of both rates are quite similar.

As noted above, in March 2004, two modifications have been carried out to hamper the tensions on the money market observed since the year 2000. First, the calendar of the beginning of the reserve period has been modified.

Second, the duration of the main refinancing operation has been shortened from two weeks to one. A first glance at the statistics over the two subsamples, given in table 2, can give some insight concerning the impact of such changes.

	Before institutional change (941 obs.)			After institutional change (736 obs.)		
Variables	Mean	Median	Std	Mean	Median	Std
Eonia i_t	3.44	3.30	1.00	2.35	2.08	0.45
official rate i_t^*	3.36	3.25	0.98	2.29	2.00	0.44
Spread $i_t - i_t^*$	0.07	0.05	0.16	0.07	0.08	0.08

Table 2 : Descriptive statistics from June, 28 2000 to March 9, 2004 (Before institutional change), and from March, 10 2004 to January, 16, 2007 (After institutional change).

We note a decrease in the mean of the Eonia rate by almost 109 basis points between the two sub-samples. However, this more likely reflects the drop in level of the official rate rather than the operational framework changes. In contrast, the mean of the Eonia spread is unchanged before and after 2004. The former result seems to indicate that the policy allotment have been successful in containing the upward trend of the spread experienced in the new framework.

But more important, the standard deviation of the Eonia fell by around 55 *bp* whereas the spread one fell by around 44 *bp*. Because money market volatility might give the market confusing messages about the stance of monetary policy, any change accompanied with a lowering of the volatility seems quite a success.

Finally, these statistics seem to indicate that monetary policy implementation over the recent period has contained the spread between the Eonia and the minimum bid rate, and reduced its volatility. At least three elements may explain this success : the official rate was very stable, the new operational framework is implemented, and liquidity management by ECB. The key question is to determine which of these three elements plays the most important role in explaining the change the Eonia spread.

3.2 Seasonal and microstructure dummies

We construct standard dummies to take into account calendar effects which are end-of-the-week (EOW), end-of-the-month (EOM), end-of-the-quarter (EOQ) and end-of-the-year (EOY). We also introduce other dummies to account for the structure of the money market: main refinancing operation announcement and settlement (MROa and MROs, respectively), monetary policy day (MPD), namely the day on which the monthly stance of monetary policy is decided and announced, first and last days of the reserve maintenance period (RMP), the last week of the RMP, that is all the days between

the last MRO of the maintenance period and the last day before the end of the reserve maintenance. We also take into account in our estimation potential tensions caused by episodes of underbidding (relevant before march 2004), by including a dummy variable equal to one when an underbidding situation occurs.

3.3 Liquidity variable

As previously noted, over the recent period, the amount allotted at MROs has been frequently above the benchmark[3]. When the spread between the allotted amount and the benchmark is positive, the liquidity conditions are targeted to be "loose". In this case, there is an excess of reserves in the market.

In order to take into account the "loose policy" effects on the mean and the volatility in the new framework, we include in our explanatory variables set a dummy variable that is equal to one when a "loose policy" is implemented.

We can expect that short-term interest rates will react very sensitively to changes in the aggregate liquidity supply the last week of the RMP. Actually on the last days of the periods, banks can no longer postpone their fulfilment of reserve requirements and are very sensitive to the liquidity situation. Therefore, the "policy loose" variable is decomposed into a variable measuring the spread during the last MRO of the RMP ("policy loose last") and a second one that provide the spread on the other MROs ("policy loose other").

The recent period is also characterized by more frequent FTO at the end of the maintenance period. In order to take into account this fact, we also include in our estimation a dummy variable that is equal to one when a FTO is implemented the last day of the RMP.

3.4 The econometric specification

The above descriptive statistical analysis induces that the Eonia spread dynamic did change with the institutional modifications in March 2004. The impact on the variance of this variable is clear and gives ground to the GARCH (Generalised autoregressive conditional heteroskedasticity) specification we choose.

This specification has also been used in the recent empirical literature on money market rate dynamics. Initiated by the seminal article by Hamilton

[3]The amount aims at balancing the demand and the supply of liquidity over one week

(1996), and widely used in this literature since, the mean and the conditional volatility of the overnight rate are estimated. The mean equation is assumed to be linear in some explanatory variables that include dummies for the end of periods (week, quarter, month or year), dummies characterizing the features of the operational framework (beginning and end of the reserve maintenance period, announcement or settlement days of MRO, announcement of the key interest rate by ECB and following days...).

The mean equation (1) for $i_t - i_t^*$ is modelled as an autoregressive model with explanatory variables. More precisely, we have:

$$i_t - i_t^* = c + \sum_{k=1}^{p} \phi_k (i_{t-k} - i_{t-k}^*) + \lambda X_t + \sigma_t \nu_t \tag{1}$$

where X_t is a set of explanatory variables that includes dummies variables to take into account the operational framework and end of period effect. v_t is a $i.i.d$ white noise. We assume the innovations v_t to be distributed as a Student-t, with degrees of freedom estimated to match the fat tails and concentration of small rate changes found in the data.

The volatility is assumed to follow an EGARCH (Exponential GARCH, see Nelson (1991)) representation and is related to a set of explanatory variables, V_t , also including dummies. Gaspar and al. (2004), Pérez-Quirós and Rodríguez-Mendizábal (2005), Bartolini and Prati (2004) have estimated this model for the euro overnight rate. These papers principally focus on the martingale hypothesis of the overnight rate. Besides the usual seasonal effect, they emphasize significant effects related to the day of the reserve maintenance period ("institutional effects"). Our specification is in the line with these studies, and we model the conditional variance of the interest rates as an EGARCH process. This specification allows us to deal with possible non-linearities and asymmetric responses of conditional variances to negative and positive shocks. The EGARCH model we estimate is the following:

$$\log(\sigma_t^2) = \omega + \gamma' V_t + \sum_{j=1}^{r} \delta_j \log(\sigma_{t-j}^2) + \sum_{i=1}^{p} \alpha_i |v_{t-i}| + \theta_i v_{t-i} \tag{2}$$

The set of explanatory variables V_t include dummies variables to take into account the operational framework and end of period effect.

Estimates of the parameters are obtained by maximum likelihood estimation (Marquard algorithm).

We perform a two-steps estimation procedure. First, the mean equation is estimated. The number of lags, p is determined by a back-testing procedure, starting with a number of lags equal to 6. Then we check that the

residuals present no remaining autocorrelation by displaying autocorrelations and partial autocorrelations up to 25 lags and computing the Ljung-Box Q-statistics[4]. For all the estimated models, we can not reject the hypothesis $\phi_2 = ... = \phi_n = 0$. We also check that imposing these restrictions lead to white noise residuals. Therefore the mean equation is :

$$i_t - i_t^* = c + \phi_1(i_{t-1} - i_{t-1}^*) + \lambda X_t + \sigma_t \nu_t$$

Second, the volatility equation is estimated. The order of the EGARCH model, that is the number of lags r and p, are chosen in order maximize information criteria (AIC and Schwartz). For each model, we find that imposing $r = 1$ and $p = 1$ provides better results. Therefore we retain an EGARCH(1,1):

$$\log(\sigma_t^2) = \omega + \gamma' V_t + \delta_1 \log(\sigma_{t-1}^2) + \alpha_1 |v_{t-1}| + \theta_1 v_{t-1}$$

Note that in this specification, strict stationarity of $\log \sigma_t^2$ is equivalent to $\delta_1 < 1$.

In order to deal with the March 2004 structural break, we decompose the set of explanatory variables X_t (or V_t) in to sets of variables : the first one gives the values of X_t (or V_t) before the 9th March 2004, and zero after ; the second one gives the values of X_t (or V_t) after the 10th March 2004, and zero before.

Finally, if we denote $I_{bef2004}$ (resp. $I_{aft2004}$) a dummy variable that takes the values one all the days before March, 9th 2004 (all the days after March, 10th 2004) and zero after (before), the econometric specification we estimate is :

$$i_t - i_t^* = c + \phi_1(i_{t-1} - i_{t-1}^*) + \lambda_1 X_t I_{bef2004} + \lambda_2 X_t I_{aft2004} + \sigma_t \nu_t$$

$$\log(\sigma_t^2) = \omega + \gamma_1' V_t I_{bef2004} + \gamma_1' V_t I_{aft2004} + \delta_1 \log(\sigma_{t-1}^2) + \alpha_1 |v_{t-1}| + \theta_1 v_{t-1}$$

4 Empirical results

Tables 2 and 3 in the appendix report the estimates of the mean and volatility equations of the Eonia spread respectively. In what follows we will focus on

[4]results of these tests are no reported here, but are avalaible on request upon authors.

the effects of the operational framework pattern[5].

4.1 Global effects of the operational framework change

In this section, we question whether the lower volatility observed in the new framework is the result of the operational change, the stability of monetary policy rates, or both.

Recall that the rationale for the change was principally to avoid underbidding episodes. First, we note that the coefficient of the "underbidding" dummy is significant in the volatility equation. Underbidding episodes are responsible for increasing the volatility. As no such episodes are present in the new framework, we can conclude that the change was successful in stabilizing the spread. However the downward sloping evolution of the interest rate over the period may also explain part of this stabilization. In fact, the probability to observe a monetary policy interest rate cut was very low. But this fact cannot alone explain the absence of underbidding after 2004. Actually, monetary policy rates have also been very low and stable in the old framework from June 2003 to March 2004, but this was not sufficient to avoid two underbidding episodes during this period.

We include in our estimation a dummy variable that takes the value one for all the days before the March, 9th 2004 and zero after. This variable should capture all the changes that are not due to explanatory variables present in the model. For both the mean and the volatility this variable is not significant. Together with a white noise test of the residuals, this indicates that our set of explanatory variables is sufficient to explain the change.

Therefore, we try to determinate whether the sensibility of the level and the volatility of the spread are significantly different after the 2004 change. For that purpose, we test whether the sum of the coefficient associated with operational framework variables is significantly different before and after 2004.

As regard to the mean equation, the sum of the operational framework coefficient before 2004 is equal to -0.38. After 2004, this sum is equal to -0.08. A Wald test indicates that this difference is significant.

In the volatility equation, the sum of the operational framework coefficients before 2004 is equal to 10.34 (without including "Underbidding"), whereas it equals 5.6 after 2004. A Wald test indicates that the difference

[5]Calendar effects are residually linked to the operational framework, particularly in the new framework in which some operational events occur at more regular periods in the week or the month. This explains why calendar effect could be slightly differents before and after 2004.

is significantly different from zero. Therefore, the change of the operational framework has significantly reduced the volatility of the spread caused by operational patterns. The new operational framework seems to have succeeded in reducing the uncertainty due to monetary policy action, and consequently, has well achieved its goal of stabilizing the Eonia around the minimum bid rate.

In the Following, we try to disentangle why the volatility of the spread is lower in the new framework.

4.2 Monetary policy decision in the new framework

We expect, from the operational framework change, a lower effect of market participants' expectations regarding to the monetary policy rate. First, we note that this goal has been achieved as no more underbidding episode has been experienced since the beginning of the new framework. Another way to address this issue, is to look at how the dynamic of the spread reacts around the days of the monetary policy rates announcement and during the main refinancing operations.

Estimates of the volatility equation indicate that the volatility of the spread significantly increases the day that precedes the monetary policy day before the change. This result probably captures the effects of the market participants' expectation on the volatility before the policy rates are announced. In contrast, after the change, no significant variation of the volatility is detected the day before the monetary policy day. In both subperiods, the volatility increases on the monetary policy days. Finally, before 2004, the rise is immediately reversed the following day. We test whether the sum of the coefficients associated with the monetary policy day[6] is significantly different before and after the change. A Wald test indicates that this difference is not significant. Hence, overall the volatility generated by the monetary policy rates announcement is not significantly different before and after 2004. However, in the new framework this increase is concentrated on one day, whereas it is more diffuse in the old framework, indicating that now the period of uncertainty is reduced.

We also check whether the volatility is significantly lower the days of the main refinancing operations since 2004. For that purpose, we compare the sum of the coefficients associated with the day of the MRO adjudication and settlement before and after 2004. The sum is equal to 0.78 and 0.89 before and after 2004 respectively. A Wald test indicates that this difference is not

[6]The monetary policy day, the day before and the day after.

significant. Therefore we conclude that the volatility observed during main refinancing operations (with no underbidding) is not significantly different in both sub-periods.

4.3 The last days of the reserve maintenance period in the new framework

As previously noted, since 2004, the last MRO of the maintenance period is always allotted eight days before the end of the period. Therefore there could be a higher probability of the accumulation of large aggregate liquidity imbalances at the end of the period, leading to greater volatility in the spread. In this subsection, we try to establish whether this effect is significant.

Our estimates show that the coefficient of the last day of the RMP in the volatility equation is higher in the new framework (3.84 after 2004, 2.87 before). A Wald test indicates that this difference is significant. The week that precedes the end of the period, volatility tends to rise before and after the change. If this rise seems lower since 2004, a Wald test resjects this hypothesis.

Since 2004, more frequent FTOs have been implemented at the end of the maintenance period in order to compensate this eventual rise of the volatility. The dummy variable "FTO the last day of a RMP" is significant and negative after 2004, whereas not significant before 2004. As a result, the more frequent FTOs conducted at the post 2004 end of the maintenance period seem to lower the spread volatility.

Finally, we test whether the combined effects, "FTO at the end of the RMP+last days of the maintenance period", are significantly different before and after 2004. The result of the test shows that this difference is not significant. Therefore the FTOs implemented in the new framework have perfectly compensated the effects expected from a higher probability of more aggregate imbalances at the end of the maintenance period on the volatility of the spread.

4.4 The liquidity policy since 2004

In this section, we analyze the effect of the "loose policy" implemented before and after 2004. "Loose policy" effects should be different whether it is implemented at the beginning or at the end of the maintenance period. For that reason, we include in our estimation one dummy variable that marks

"loose policy" occurring the last week of the maintenance period[7] ("loose policy last") and another one for loose policy occurring any other day ("loose policy other").

As regards the level of the spread (mean equation), we note that the coefficient of the variable "loose policy last" is always significant, and negative. This indicates that allotment policy reduces the spread between the Eonia and the minimum bid rate. The coefficient of the variable "loose policy other" is not significant before 2004, and significant after. Furthermore, it is positive, indicating that when the ECB injects more liquidity than needed in the market at the beginning of the maintenance period, the spread tends to increase. This result is puzzling, as we may expect that more liquidity should lower the Eonia, and then lower the spread. A possible explanation is that when market participants observe a "loose policy" at the beginning of the RMP, they expect that the ECB will probably allot under the benchmark at the end of the period in order to compensate this excess of liquidity and they prefer accumulate liquidity from now on.

As regards the volatility equation, the only significant coefficient concerns the "loose policy last" variable before 2004 (0.83). It means that implementation of a "loose policy" used to increase uncertainty. Another explanation comes from the fact that allotments above the benchmark were rather scarce before 2004, and often conducted in response to underbidding, i.e in a hight volatility period. In addition, before 2004, when credit institution observed a deviation between the MRO allotment amount and the benchmark amount that they had calculated, they didn't known whether the deviation was actually due to the ECB deliberately pursuing a non-neutral liquidity target, or whether the autonomous factors predictions were false. In the new framework, the ECB decided to also publish its calculation of the benchmark in order to avoid misperceptions in the market. Our estimation indicates that this additional communication by the ECB has well reached its goal given that the volatility remains unchanged when a "loose policy" is conducted.

5 Conclusion

The purpose of this paper was to study the effects of the ECB monetary policy framework on the Euro area money market. This paper has provided a model of the EONIA-key policy rate spread dynamics close to the well-documented analysis of the ECB operational framework on the overnight

[7]The last week of the maintenance period includes all the days between the last MRO and the last day of the maintenance period.

unsecured interest rate literature. The advantage of such modelling is to allow for an inspection of the mean and volatility of the spread that includes exogenous variables.

Here, we focus on the particular changes that occurred in March 2004. The objective was to enhance the money market efficiency by stabilizing the short term interest rate around the key policy rate. The measures to achieved that goal are twofold. First, the maturity of the main refinancing operations has been shorten and the first day of the reserve maintenance periods became the settlement day of the main refinancing operation following the Governing Council meeting. Second, the Eurosystem started to perform more fine tuning operations at the end of the maintenance period and to allot regularly above the benchmark during the main refinancing operation settlement.

The paper reaches the following conclusions. The changes of the operational framework have an overall positive impact on both the level of the spread as well as its volatility. The decrease that can be attributed to the changes is significant and large. Of course underbidding became less probable because interest rates are non decreasing since 2004. However, the same apply to the end of 2003 period where two underbidding episodes were reported.

As regards monetary policy decisions, no underbidding episodes have been observed since then. Besides, the spread volatility tends to rise only on monetary policy days and not anymore on the day before. These two-days rises were compensated the following day, however the compensation was only partial.

As regards the increased number of FTOs implemented at the end of the maintenance period, it has also played its expected role. Because the period between the last MRO and the last day of the RMP in the new framework is now longer, the spread volatility should have drop-up at the end of the period. Our results show that this effects exists but is offset by the FTOs.

Finally, the "loose policy" measure seems less convincing eventhough it seems that the ECB continue to increase the use of such practices. Our results suggest that the implementation of "loose policy" on last days of the RMP lowers the spread on either framework, but the impact is less pronounced after 2004. On other days, it even enlarges the spread in the new scheme. Concerning volatility, the "positive" effect of pre-2004 changes does no longer exists. However, this cannot be attributed to the only operational changes. In fact, before 2004, any deviation between the MRO allotment and the benchmark amounts that they had calculated, could be due to ECB deliberately pursuing a non-neutral liquidity target, or autonomous factors predictions errors. In the new framework, the ECB decided to also publish its calculation of the benchmark in order to avoid misperceptions in the mar-

ket. This study allows for a better understanding of the impact of the 2004 changes as a all. It pointed out that the very low and stable level of short term interest rate are in favour of the new operational framework. One way to test the robustness of these results is to run the same estimation in a similar decreasing interest rate period. Another way to adress this issue is to analyse the impact of bull/bear market anticipations.

Appendix

Name	Variable
Eonia :	i_t
Official Rate	i_t^*
ΔEonia :	$\Delta i_t = i_t - i_{t-1}$
Spread	$i_t - i_t^*$

Table 1 : Variable description summary

Mean equation		
Variables	Coefficients	
Constant	0.016***	
	(0.004)	
Before march 2004	-0.003	
	(0.007)	
$i_{t-1} - i^*_{t-1}$	0.622***	
	(0.053)	
	Before 2004	After 2004
Last day of the week	0.01	-0.005
	(0.011)	(0.003)
Two last days preceding the end of the month	0.055	0.001
	(0.006)	(0.002)
End of the month	0.050***	0.020***
	(0.011)	*(0.005)*
Two days preceding the end of the quarter	0.007	0.016
	(0.010)	*(0.010)*
End of the quarter	0.140***	0.040***
	(0.046)	*(0.015)*
Two days preceding the last day of the year	0.003	-0.004
	(0.026)	*(0.014)*
End of the year	0.043	0.021
	(0.061)	*(0.023)*

Table 2 : Mean equation.
standard deviation are indicated in the brackets.
(*),(**),(***) mean significant at the 10%, 5% and 1% levels respectively

Mean equation (continued)		
Day of MRO adjudication	0.008	0.001
	(0.010)	(0.002)
Day of MRO settlement	-0.004	0.002
	(0.012)	(0.007)
Last week of the RMP	0.030	0.030
	(0.023)	(0.024)
Last day of the RMP	-0.070	0.121
	(0.043)	(0.078)
FTO the last day of RMP	-0.349***	-0.152*
	(0.042)	(0.082)
Two first days of the RMP	0.042**	0.011
	(0.020)	(0.014)
Monetary policy day	0.032	-0.059
	(0.019)	(0.033)
Two days following the monetary	0.010	-0.031
policy day	(0.011)	(0.034)
Underbidding	0.100	
	(0.092)	
Loose policy last week of the RMP	-0.163***	-0.029*
	(0.044)	(0.017)
Loose policy other days of the RMP	0.011	0.018***
	(0.008)	(0.006)

Table 2 (continued) : Mean equation.
standard deviation are indicated in brackets.
(*),(**),(***) mean significant at the 10%, 5% and 1% levels respectively.

Volatility equation		
Variables	Coefficients	
Constant	-3.430***	
	(0.274)	
Before march 2004	0,283	
	(0.193)	
$\|\nu_{t-1}\|$	0.839***	
	(0.059)	
ν_{t-1}	0.122***	
	(0.038)	
$log(\sigma^2_{t-1})$	0.707***	
	(0.023)	
	Before 2004	After 2004
Last day of the week	0.571***	0.158
	(0.205)	(0.294)
Two last days preceding the end of the month	-0.663***	0.046
	(0.209)	(0.279)
End of the month	1.966***	1.048***
	(0.329)	*(0.500)*
Two days preceding the end of the quarter	0.249	0.462
	(0.434)	*(0.450)*
End of the quarter	2.087***	-0.078***
	(0.808)	*(0.913)*
Two days preceding the last day of the year	0.242	-0.041
	(1.440)	*(0.839)*
End of the year	0.163	1.041
	(1.576)	*(1.313)*

Table 3 : Volatility equation.
standard deviation are indicated in brackets.
(*),(**),(***) mean significant at the 10%, 5% and 1% levels respectively

Volatility equation (continued)		
Day of MRO adjudication	0.303*	0.119
	(0.179)	(0.260)
Day of MRO settlement	0.486**	0.787***
	(0.193)	(0.254)
Last week of the RMP	1.726***	1.429***
	(0.167)	(0.293)
Last day of the RMP	-2.879***	3.842
	(0.324)	(0.606)
FTO the last day of RMP	0.728	-1.100*
	(1.427)	(0.617)
Two first days of the RMP	-0.245	-0.897***
	(0.191)	(0.193)
One day before the monetary	0.517**	0.282
policy day	(0.230)	(0.501)
Monetary policy day	1.785	1.403***
	(0.275)	(0.384)
Two days following the monetary	-1.159	-0,180
policy day	(0.276)	(0,488)
Underbidding	2.592***	
	(0.471)	
Loose policy last week of the RMP	0,835***	-0.202
	(0.224)	(0.169)
Loose policy last week of the RMP	-0.083	0.2143
	(0.103)	(0.112)

Table 3 (continued) : Volatility equation.
standard deviation are indicated in brackets.
(*),(**),(***) mean significant at the 10%, 5% and 1 % levels respectively

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