EUROPEAN CENTRAL BANK

EUROSYSTEM

ECB WORKSHOP
ON THE ANALYSIS OF
THE MONEY MARKET

WORKING PAPER SERIES

NO 983 / DECEMBER 2008

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In 2008 all ECB publications feature a motif taken from the €10 banknote.

1 We thank Dieter Nautz, Christian Offermanns, Roger Clews, Matei Demetrescu, Gabriel Pérez Quirós and an anonymous referee for helpful comments and suggestions. We also thank the conference participants at the ECB, the Bundesbank, the EEA and the Verein für Sozialpolitik for further comments. The views of this paper are those of the authors and do not necessarily reflect the views of the European Central Bank.

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ECB WORKSHOP ON THE ANALYSIS OF THE MONEY MARKET

On 14 and 15 November 2007, Alain Durré, Huw Pill and Diego Rodriguez-Palenzuela of the ECB's Monetary Policy Stance Division organised a central bank workshop titled "The Analysis of the Money Market: Role, Challenges and Implications from the Monetary Policy Perspective". This workshop provided an opportunity for participating central bank experts to exchange views and foster debate, also in interaction with international organizations and academic institutions. The first day of the workshop addressed issues related to the macro-perspective of the money market, drawing on the experiences of a large number of countries. The second day adopted a micro-perspective on the money market, looking in particular at trading behaviour in the overnight money market and its implications for the evolution of spreads.

A first version of this paper was presented at this workshop. The papers presented at the time of the workshop did not consider the potential implications of the financial turmoil for the results of the paper, given that the tensions in money markets emerged in August 2007. The published version of these papers represents an update of the original paper, which incorporates the discussion which took place at the workshop and in most cases a discussion on the developments in the money markets since August 2007.

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ISSN 1561-0810 (print)
ISSN 1725-2806 (online)

CONTENTS

Abstract

We employ a time series econometric framework to explore the structural determinants of the spread between the European Overnight Rate and the ECB's Policy Rate (EONIA spread) aiming to explain the widening of the EONIA spread from mid-2004 to mid-2006. In particular, we estimate a model on the EONIA spread since the introduction of the new operational framework in March 2004 until August 2006. We show that the increase in the EONIA spread can for the largest part be explained by the current liquidity deficit. Moreover, tight liquidity conditions as well as an increase in banks' liquidity uncertainty lead to a significant upward pressure on the spread. The ECB's liquidity policy only reduces the spread if a loose policy is conducted during the last week of a maintenance period. Interestingly, interest rate expectations have not been found to have an important influence.

Keywords: Overnight Market Rate (EONIA), Interest Rate Determination, Monetary Policy Implementation, Operational Framework

JEL Classification: E43, E52, C22

Non-technical Summary

The European Central Bank (ECB) implements monetary policy by conducting open market operations to steer the short term interest rates in the interbank market, managing the liquidity situation in the market and signalling the monetary policy stance. In particular, the euro overnight rate, the market interest rate that is most closely linked to the policy rate, is crucial for signalling the policy stance since the overnight rate marks the first step in the monetary policy transmission process. Therefore, it is desirable for the ECB to keep the EONIA in close distance to the policy rate.

The spread between the EONIA and the minimum bid rate (MBR) has widened slowly but steadily since the operational framework was changed in March 2004. The widening has become remarkable in particular since autumn 2005. While a modest spread between the EONIA and the MBR is not of general concern for monetary policy, a large spread could blur the message of the stance of monetary policy. To limit the increase in the spread, the ECB adopted a loose liquidity policy towards the end of the year 2005. The spread decreased somewhat during 2006 while started to increase again towards the end of the year.

This analysis identifies possible driving forces underlying the evolution of the EONIA spread from mid-2004 to mid-2006. In particular, we estimate a model on the spread between the EONIA and the minimum bid rate since the changes to the operational framework in March 2004 until August 2006 (”new” operational framework period). Factors related to the liquidity supply of the ECB and the liquidity needs of the banking sector are of particular interest with regard to the determination of the overnight market interest rate. Uncertainty about liquidity conditions and banks’ expectations on future interest rates may also play a role. More generally, however, the EONIA spread might be affected by the way the ECB implements its monetary policy. In this regard, we perform an estimation from June 2000 to August 2006, a period that also includes the ”old” operational framework period from June 2000 to March 2004, and we allow for different coefficients after March 2004.

Our empirical results provide evidence that the increase of the EONIA spread in the new framework period can for the largest part be explained by a trending liquidity deficit. Moreover, tight liquidity conditions as well as an increase in banks’ uncertainty about the liquidity conditions lead to a significant upward pressure on the EONIA spread. The ECB’s liquidity policy only reduces the spread if a loose policy is conducted during the last week of a maintenance period. Interestingly, policy rate expectations have not been found to have an important influence. Furthermore, our results show that the changes to the framework in March 2004 might be of relevance to the interaction between the explanatory variables and the EONIA spread. In particular, banks reacted less sensitively to the overall liquidity deficit before the changes to the operational framework in March 2004. On the contrary, interest rate expectations play a more important role for the behavior of banks before March 2004.

1 Introduction

The European Central Bank (ECB) implements monetary policy by conducting open market operations to steer the short term interest rates in the interbank market, managing the liquidity situation in the market and signalling the monetary policy stance. In particular, the daily interest rate in the interbank market, the Euro Over Night Index Average (EONIA), the interest rate that is most closely linked to the policy rate, is crucial for signalling the policy stance. Therefore, one purpose of the operational framework of monetary policy implementation is to keep the EONIA in close distance to the policy rate.

The ECB has in general proved successful in steering interest rates using its policy instruments. In particular, the volatility of the interbank overnight rate EONIA has been low on average within the euro area and the spread between the EONIA and the policy rate, i.e. the minimum bid rate in the main refinancing operations (MROs) has also been rather moderate. However, the spread between the EONIA rate and the minimum bid rate (MBR) in the Eurosystem's main refinancing operations (EONIA spread) has steadily widened since the operational framework was changed in March 2004.[1] The widening has become remarkable in particular since autumn 2005. While a modest spread between the EONIA and the MBR is not of general concern for monetary policy, a large spread could blur the message of the stance of monetary policy and, in extreme cases, may inhibit the ECB's ability to steer the overnight rate.

This paper explores the determinants of the EONIA spread that may help to explain the observed widening of the EONIA spread from March 2004 to August 2006. In particular, the focus of the paper is on empirically modelling the spread between the EONIA and the minimum bid rate since the changes to the operational framework in March 2004 until August 2006 ("new" framework period). The analysis aims to identify possible driving forces underlying the evolution of the spread over time and to quantify the impact of specific factors on the observed upward shift. Factors related to the liquidity supply of the ECB and the liquidity needs of the banking sector are of particular interest with regard to the determination of the overnight market interest rate. Uncertainty about liquidity conditions and banks' expectations on future interest rates may also be related to the equilibrium in the overnight market. Besides, we additionally investigate whether the institutional changes as of March 2004 have impacted the EONIA spread. This is done in a supplementary estimation from June 2000 to August 2006, a period which also includes the "old" operational framework period from June 2000 to March 2004.[2]

[1] See ECB (2003).

[2] Since June 2000, the ECB has been conducting its open market operations in a variable rate tender format.

A few other studies have explored the EONIA rate and the link to the operational framework from various perspectives. Pérez Quirós and Rodríguez Mendizábal (2006) point to the importance of the deposit and lending facilities as tools to stabilize the overnight rate within a theoretical model on reserve averaging. Nautz and Offermanns (2007) show that the introduction of variable rate tenders in June 2000 did not lead to a loss of control of the ECB over the EONIA. Würtz (2003) proposes a comprehensive model on the EONIA spread and its volatility. Our paper contributes this literature by presenting a model of structural determinants of the EONIA spread and by quantifying the impact of these underlying driving forces on the increase of the EONIA spread.

Our empirical results provide evidence that the increase of the EONIA spread in the new framework can for the largest part be explained by a trending liquidity deficit. Moreover, tight liquidity conditions as well as an increase in banks' uncertainty about the liquidity conditions lead to a significant upward pressure on the EONIA spread. The ECB's liquidity policy only has a significant impact on the reduction of the spread if a loose policy is conducted during the last week of a maintenance period. Interestingly, policy rate expectations have not been found to have an important influence. Furthermore, our results show that the changes to the framework in March 2004 might be of relevance to the interaction between the explanatory variables and the EONIA spread. In particular, banks reacted less sensitively to the overall liquidity deficit before the changes to the operational framework in March 2004. On the contrary, interest rate expectations clearly play a more important role for the behavior of banks before March 2004.

The remainder of the paper is structured as follows: Section 2 describes the evolution of the EONIA spread during the sample period. Section 3 presents the possible determinants of the EONIA spread and discusses if the changes to the operational framework have influenced the relation between the basic determinants and the EONIA spread. Section 4 presents our empirical model and the results. Section 5 concludes and points to possible implications for monetary policy.

2 The Evolution of the EONIA Spread

With regard to the perspective of signalling the monetary policy stance, the EONIA should move in close distance to the ECB's policy rate, i.e. the minimum bid rate. This section explains how a non-zero EONIA spread can emerge and illustrates the evolution of the EONIA spread during the sample period. The spread between the EONIA rate and the minimum bid rate can be decomposed into the spread between minimum bid rate and the marginal rate[3] of the ECB's Main Refinancing Operations (MROs)[4] and the spread between the marginal rate and the EONIA. A slightly positive spread seems natural, because the marginal rate of the MROs normally lies above the minimum bid rate. Factors that are related to banks' bidding behavior in MROs can influence this component of the EONIA spread. In addition, a positive difference between the EONIA and the marginal rate emerges because open market operations with the ECB are subject to strict collateral requirements whereas the EONIA is calculated from unsecured transactions. Thus, risk premia are reflected in the spread, too. However, an effect into the opposite direction should result from the different maturities of MROs, which have a maturity of one or two weeks, and the overnight rate.

Figure 1 depicts the evolution of the EONIA and the minimum bid rate for the complete sample period from June 2000 to August 2006. As Figure 2 shows in greater detail, the spread has steadily widened since the introduction of the new framework in March 2004. This became particularly visible in autumn 2005. To mitigate the widening of the spread, the ECB started to provide the market with additional liquidity, see Figure 2. Table 1 provides some descriptive statistics of the EONIA spread. The widening of the EONIA spread is more clearly reflected by the median values since—contrary to the means—they are not biased by outliers, which are more pronounced in the old framework period than in the new framework period.[5]

Table 1: Descriptive statistics EONIA spread

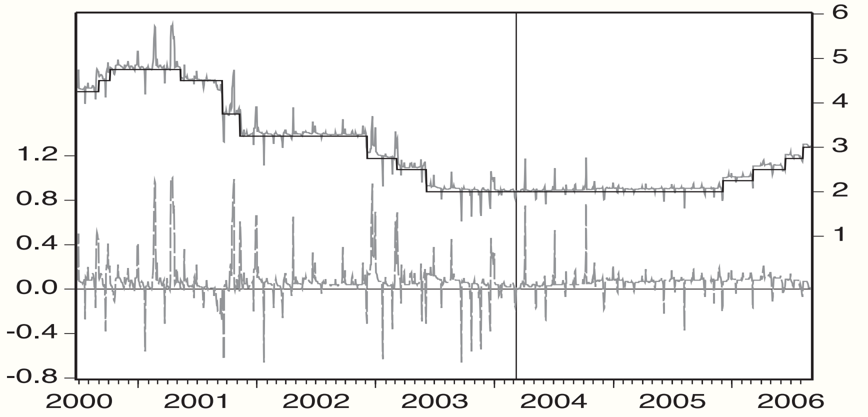
	Time period	Mean	Median
Complete sample	June 2000 to August 2006	7.2 bp	6.0 bp
Old framework	June 2000 to March 2004	7.6 bp	5.0 bp
New framework	March 2004 to August 2006	6.7 bp	8.0 bp
New framework, first part	March 2004 to August 2005	5.7 bp	6.0 bp
New framework, second part	September 2005 to August 2006	7.7 bp	8.0 bp

[3]The marginal rate is the stop-out rate of the tender, i.e. the lowest rate at which a liquidity allotment still takes place.

[4]The ECB uses MROs as a main instrument to regularly provide the banking system with liquidity.

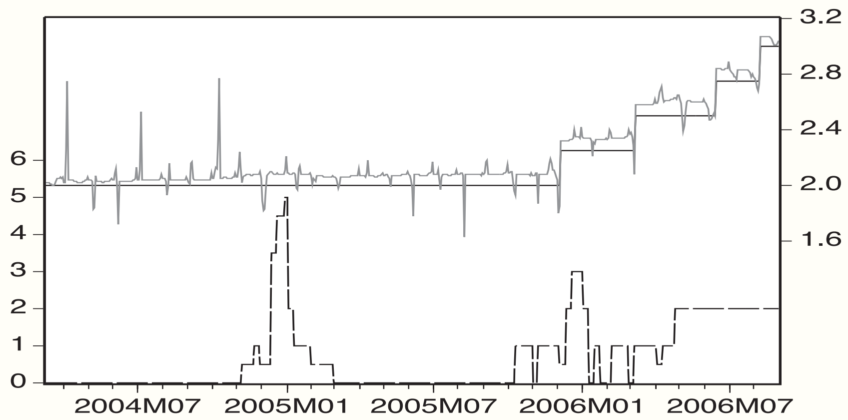
[5]In particular, outliers have been less pronounced since autumn 2005, when the ECB started to conduct fine tuning operations (FTOs) on the last day of the period.

Figure 1: EONIA, minimum bid rate and their spread, complete sample



Notes: Time series: EONIA, MBR (right scale) and their spread (dashed line, left scale). The vertical line corresponds to the introduction of the new framework.

Figure 2: EONIA, minimum bid rate and liquidity policy in the new framework period



Notes: Time series: EONIA, MBR (right scale) and additional liquidity supply by the ECB, measured as actual minus benchmark allotment in EUR bn (left scale).

3 The Determinants of the EONIA Spread: Theoretical Predictions

An obvious candidate for explaining movements in the EONIA spread is the interaction of liquidity supply and demand factors, which determines the liquidity situation in the overnight market. Essentially, the ECB uses tender operations to provide commercial banks with liquidity or to withdraw liquidity from the market. As such, a focal point of our study are MROs as the most important tender operation, including (*i*) the ECB's liquidity supply and (*ii*) refinancing needs of commercial banks, and also (*iii*) variables that are likely to influence liquidity demand of ECB counterparties such as interest rate expectations.

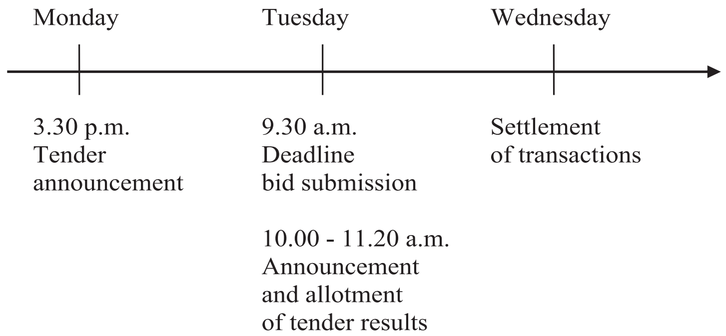
Liquidity supply

To measure liquidity supply in MROs, we define a variable *liquidity policy* as the difference between actual allotment and benchmark allotment. The benchmark allotment is defined as the allotment that ensures a neutral liquidity situation during the period of an MRO (tender period). It seems obvious that a higher than benchmark allotment creates relatively abundant liquidity conditions and therefore should reduce the spread. However, the benchmark allotment takes into account accumulated liquidity imbalances within a maintenance period and thus ”reverses” the liquidity policy of the previous MRO. That means, if liquidity supply was loose in the previous allotment, there is a liquidity imbalance meaning that liquidity supply is higher than what would be compatible with neutral conditions. Thus, the subsequent benchmark allotment is lower compared to a situation with a preceding neutral allotment. In sum, under the currently implemented system of average reserve fulfilment, the liquidity policy in the last MRO of a maintenance period decides about the average liquidity character of all MROs within a maintenance period. This means that only if the actual allotment in the last MRO is higher than the benchmark allotment, liquidity supply in the period has been on average been higher than compatible with neutral liquidity conditions. Consequently, our hypothesis to be examined, is that liquidity policy has a negative effect on the EONIA spread only in the last MRO of a maintenance period.[6]

A further liquidity supply instrument are fine tuning operations (FTOs). They are mainly used to smooth out short-term liquidity fluctuations of large scale. FTOs were only very rarely applied under the old framework. In the new framework period they have been used increasingly in a systematic way to assure banks that there will be no liquidity shortages on the last day of the period. Such a concern might lead banks to keep back reserves in order not to run out of liquidity on the last day. To find out whether this more systematic implementation of FTOs has influenced *banks' expectations about an FTO* and thereby their liquidity management within the period of the new framework, we examine if additional

[6]Results from previous work such as Moschitz (2004), Ejerskov et al. (2003) or Würtz (2003) also suggest that variables related to the ECB's liquidity supply are relevant only in the last week of a maintenance period. Moschitz (2004) divides his variables according to its expected persistence within the period. He finds that liquidity variables that only represent temporary changes do not affect the spread whereas shocks assumed to be permanent do.

Figure 3: Time frame for the operational steps in standard tenders



Notes: Source: ECB, The implementation of monetary policy in the euro area, Sep. 2006.

liquidity supply via an FTO in the previous period mitigates the EONIA spread in the current period.

Liquidity needs

Liquidity needs of counterparties basically arise from two sources: reserve requirements and autonomous factors, see Figure 4.[7] When making the allotment decision in MROs, the ECB takes both reserve requirements and forecasts of autonomous factors into account.

On the basis of autonomous factors forecasts entering the ECB's benchmark allotment, we construct a variable that captures the *cumulated average shocks in autonomous factors* since the preceding MRO.[8] If autonomous factors during a tender period are higher than assumed in the benchmark allotment calculation, the liquidity situation is relatively tight and should lead to pressure on the EONIA spread. The informational content of this variable consists primarily in measuring the degree of unexpected tightening in the market that may be due to liquidity shocks on the one hand or to imprecise forecasts by the ECB on the other hand. Therefore, we examine if higher than forecasted autonomous factors lead to an upward pressure on the EONIA spread.

To measure banks' liquidity needs, we further use the *cumulated average reserve fulfilments* since the beginning of the maintenance period. We take cumulated averages because the reserve averaging mechanism allows banks to smooth their reserve fulfilments within a maintenance period. If past reserve

[7] Autonomous factors include banknotes in circulation, government deposits, net foreign assets or other balance sheet items of the ECB that are neither monetary policy operations nor current account holdings of the ECB's counterparties. As Figure 4 shows, liabilities from autonomous factors are higher than autonomous factors on the asset side, implying a net liquidity deficit of autonomous factors for commercial banks. Whereas reserve requirements are constant for a maintenance period, autonomous factors are out of the control of the ECB and subject to daily variations.

[8] We use cumulated averages because ECB-forecasts refer to average autonomous factors for any day of the tender period, i.e. the relevant information set refers to the allotment Tuesday of an MRO. Cumulating takes into account how conditions have changed since then on average of each day.

Figure 4: Simplified balance sheet of the Eurosystem

Simplified balance sheet of the Eurosystem (1 March 2002)

(EUR billions; references to the corresponding items in the Eurosystem's weekly financial statement are provided in brackets)

Assets		Liabilities	
Autonomous liquidity factors		**Autonomous liquidity factors**	
Net foreign asstes (A1+A2+A3-L7-L8-L9)	387.1	Banknotes in circulation (L1)	285.8
		Government deposits (L5.1)	57.2
		Other autonomous factors (net)	92.1
			435.1
		Current account holdings – covering the minimum reserve system (L2.1)	134.9
Monetary policy instruments		**Monetary policy instruments**	
Main refinancing operations (A5.1)	123.0		
Longer-term refinancing operations (A5.2)	60.0		
Marginal Lending facility (A5.5)	0.0	Deposit facility (L2.2)	0.0
	570.1		570.1

Notes: Source: ECB, Monthly Bulletin May 2002.

fulfilment has been high on average, future reserve pressure in the current maintenance period is low. Thus, we expect a negative sign of this variable on the EONIA spread.[9] Since the changes that were made to the operational framework in March 2004, there have been no more overlaps of maintenance periods. Therefore banks are forced to obtain sufficient liquidity during the maintenance period to fulfil their reserve requirements. This might induce banks to develop specific preferences over the reserve fulfilment path. In particular, if banks face the risk of receiving no liquidity in the last tender of the maintenance period they may find it preferable to front-load the fulfilment of the average reserve requirements. If banks prefer to front-load their reserve requirements instead of fulfilling them smoothly, a positive tender spread may emerge, particularly within the maintenance period.

Bidding in MROs

With regard to liquidity supply in the context of the operational framework, MROs are the main source for liquidity, providing 75 percent of all interbank money. To investigate whether the EONIA is also driven by the outcome of the ECB's MROs, i.e. the marginal rate of the operation, we include several variables related to banks' bidding behavior.

[9] Würtz (2003) includes a similar variable, finding only a negligible effect on the EONIA spread. Moschitz (2004) develops a theoretical model of the intertemporal decision making problem in the supply of and demand for reserves. He concentrates on reserves as crucial liquidity need, pointing to the fact that shocks in autonomous factors directly affect the reserve position as long as the ECB's liquidity supply is given. However, in our context, even given the ECB's liquidity supply, a bank, being confronted to a shock in autonomous factors, may try to cover the additional liquidity needs from the interbank market, i.e. increasing its demand on the market and thus driving the spread upwards. Thus, we model both sources of liquidity needs.

The first variable in this context is the *bid-to-cover ratio*, defined as the ratio between total bid volume and the amount covered. This variable reflects to what degree the demand of banks has been met by the ECB. A high bid-to-cover ratio signals that demand for central bank money has only been satisfied to a low degree by the ECB. Thus, banks have to rely stronger on the interbank market to obtain the necessary liquidity. Prior to March 2004, when liquidity was obtained by overlapping two-week operations, banks always enjoyed a ”liquidity buffer” provided by their allotment in the previous week. Being denied this buffer, concerns about receiving an allotment of desired size in each operation may have risen. Therefore, banks may dislike the uncertainty surrounding their allotment, and consequently bid more aggressively, i.e. placing bids above the expected marginal rate to increase the certainty of their pro-rata allotment. If many banks follow this strategy, an upward trend in the tender spread could become self-sustaining. Therefore, we include the bid-to-cover ratio to test if there is a positive relationship with the EONIA spread and in particular, if its influence is stronger in the new framework period.

Given banks' uncertainty about the actual allotment, the marginal cost of the risk of receiving no liquidity in the tender is likely to increase with the size of banks' desired liquidity. Therefore, bidding at higher rates to secure allotment will likely increase in the bid volume. If the refinancing volume for banks is high, going out empty-handed from an open market operation, i.e. the exposure to the risk of obtaining smaller than expected allotment amounts may be more serious compared to a situation of moderate refinancing needs. In this sense, obtaining lower than expected allotments becomes more costly the larger allotment and bid volumes are. Consequently, banks insure themselves by bidding at higher rates to avoid unexpected rationing.

This hypothesis is formally underpinned by Neyer and Wiemers (2004) or Välimäki (2006). Based on individual banks' cost minimization Välimäki shows that under uncertainty, the expected bid volumes and the probability of bidding at rates above the marginal rate are an increasing function of the individual targeted refinancing volume in the MRO.[10] All in all, his model predicts that higher allotment volumes lead to more aggressive bidding, i.e. bid rates and bid volumes tend to be higher. Similarly, Neyer and Wiemers (2004) show in a model on the overnight interbank market that the EONIA depends positively on total liquidity needs of banks. Their result is driven by increasing marginal costs of banks of refinancing in the interbank market.

Applied to our analysis, this would mean that a higher *aggregate liquidity deficit*[11] of the complete banking sector would induce a more aggressive bidding behavior. Consequently, the marginal rate

[10] This results from the fact that banks are assumed to face convex costs when actual allotment deviates from the desired allotment volume. Such a cost convexity is likely to result from risk aversion, from market frictions or capital adequacy requirements.

[11] The liquidity deficit can be derived from the supply side as the sum of open market operations or from the demand side as net autonomous factors plus reserve requirements, see also Figure 4. Välimäki (2006) shows how allotment uncertainty can lead to an increasing marginal rate of the tender even though the ECB in principle provides banks with sufficient liquidity.

would rise and entail a higher EONIA rate. Since the size of the liquidity deficit has increased steadily since March 2004 and, in addition, the allotment volume has doubled with the introduction of the new operational framework, the trend of the liquidity deficit is a potential candidate that could explain the increase in the EONIA spread.[12] These theoretical considerations are underlined by comments the ECB received in response to a public consultation of banks concerning their attitude towards the changes in the operational framework. Some of the banks expressed concerns about a higher liquidity risk in case bidders receive a zero allotment.[13]

According to Välimäki (2006), the uncertainty of a bank about the bidding behavior of other banks is a necessary condition for banks to bid at rates higher than the minimum bid rate. To approximate this uncertainty, we introduce a variable *liquidity uncertainty*, which is derived as the conditional volatility from cumulated average reserve fulfilment during a maintenance period. In the case of increased uncertainty about the allotment at the marginal rate in particular and aggregate liquidity uncertainty in general, banks may intuitively wish to avoid going out with empty hands from the auction and hence bid at higher rates. Consequently, banks may engage in so-called safety bids, bidding at higher rates to insure against the risk of not obtaining the desired liquidity which in turn translates into higher overnight rates. In this sense a higher EONIA spread reflects a liquidity risk premium that banks are willing to pay if there is uncertainty over their individual allotments from the tender operation. Following this reasoning, we also want to examine if liquidity uncertainty indeed leads to an increase in the EONIA spread.

[12] See Figures 6 and 7 in Appendix A for illustration.

[13] Compare ECB Public Consultation, Summary of comments received on the measures proposed to improve the operational framework for monetary policy, 23 January 2003.

Interest rate expectations

The changes in the operational framework mainly aimed at eliminating the influence of interest rate expectations in determining the EONIA. While there has been ample evidence for the impact of interest rate expectations on the EONIA under the old framework, the evidence for the new framework period seems to be less obvious so far.[14] To shed further light on this issue, we include several variables related to interest rate expectations.

First, the spread between one-week swap rates and the ECB policy rate represents the *within maintenance period rate expectations* commercial banks face when participating in MROs, which have a maturity of one week in the new framework period. High within period rate expectations would increase the willingness to bid at higher rates since refinancing in the interbank market would become relatively costly. As a consequence, we expect a positive relationship between the swap spreads and the EONIA spread.

Also, the uncertainty about the expected value of the auctioned good may be relevant for the auction outcome. In this context, theories of bidding behavior describe the phenomenon of the ”winner's curse”. It originates from the theory about common value auctions where a good of unknown true value is sold. The average of all bids may show a correct valuation, but by the nature of the auction, the winner placed the highest bid and thus turns out to have overvalued the good more than the others. Rational bidders should be aware of this possible overvaluation in advance. If the signals about the true value of the auction are relatively clear bidders feel more comfortable and see less need to adjust their prior estimates. If, however, the signals are diffuse, they will revise their bids downwards. In consequence, a higher uncertainty would strengthen the winner's curse effect, leading to a downward-correction of bids. ECB auctions have a common value character insofar as there exists a liquid and competitive market for central bank funds. A private value component is introduced because banks differ in terms of creditworthiness or size, which influence transaction costs in the interbank market or the access and cost of collateral necessary for MROs. This private value component would dilute the winner's curse effect in ECB auctions.[15] To test for the existence of the winner's curse, we define a variable *interest rate uncertainty*, which is represented by the conditional volatility of the first difference in one-week swap rates, and analyze if it has a diminishing effect on the spread.

In addition, rate expectations of the subsequent period defined as the spread between forward rates one month in one month and the minimum bid rate (*policy rate expectations)* might be one reference

[14] Under the old framework, interest rate expectations exerted particular impact during the so-called underbidding episodes documented for example in Bindseil, Nyborg and Strebulaev (2004). Nautz and Offermanns (2007) explain EONIA dynamics using the EONIA spread as well as the term spread (spread between the 3m EURIBOR and the minimum bid rate). Most interestingly they find the term spread - understood to reflect interest rate expectations - to be a significant contributor to the EONIA dynamics, even under the new framework.

[15] Bindseil, Nyborg and Strebulaev (2004) find no evidence for the winner's curse in ECB main refinancing operations for a one-year period from June 2000 to June 2001. Linzert, Nautz and Bindseil (2007) study bidder behavior in longer-term refinancing operations and show that the winner's curse affects bid volume, bid rates and the participation in the tender.

point for the EONIA. If, for example, banks expect interest rates to be cut in the current maintenance period, it would be more favourable to postpone the fulfilment of the reserves. Neyer (2004) shows on a theoretical basis that an influence of policy rate expectations on bidding behavior used to be immanent under the old framework when interest rate changes were possible within a maintenance period. Their influence should have been eliminated in the new framework period by the non-overlapping MRO-periods and the strict implementation of interest rate changes at the beginning of a maintenance period. So we analyze in particular whether her theoretical result applies, which predicts that there is a positive significance of policy rate expectations in the old framework period and that it vanishes in the new framework period. For the period of the old framework, empirical evidence as from Würtz (2003)[16] supports the relevance of interest rate expectations for the EONIA. Nautz and Offermanns (2008) find that the EONIA rate significantly adjusts to the forward spread except for the last week of a maintenance period in both framework periods.

Finally, the lagged EONIA spread is supposed to represent past interest rate expectations. According to the martingale hypothesis, the interest rate tomorrow should equal today's expected level for tomorrow in the absence of market frictions,[17] i.e. $i_t - E_t(i_{t+1}) = 0$. Otherwise there would exist intertemporal arbitrage possibilities. Since existing evidence suggests that the Martingale hypothesis does not hold for the euro zone[18] and since liquidity conditions are expected to play a role for the EONIA, it is natural to add further variables that contribute to explaining the behavior of banks or to record unforeseen shocks.

[16] Würtz (2003) distinguishes additionally for interest rate cut and hike expectations.
[17] See Hamilton (1996).
[18] See for example Pérez Quirós and Rodríguez Mendizábal (2006), Ejerskov et al. (2003).

Novelties of the new framework

The design of the operational framework governs the outcome of the open market operations and should in principle be reflected in banks' bidding behavior in open market operations and therefore affect the interbank market equilibrium.[19] As a consequence, when identifying the determinants of the spread, it might be important to take changes in the institutional framework into account. These exogenous changes can influence the relationship between the basic determinants and the spread.[20] The three major changes to the operational framework as of March 2004 primarily relate to institutional parameters and to information and transparency issues. The first innovation is that MRO tender periods are reduced from two weeks to one week so that periods no longer overlap. As a consequence, MRO volumes doubled. This might result in banks being more sensitive to variables related to liquidity needs. Second, higher transparency with regard to the publication of autonomous factor forecasts and benchmark allotment might enable banks to make more precise assessments and to react to misalignments of actual versus forecasted liquidity conditions. And third, policy rate changes become effective only with the first MRO of a maintenance period. This should imply that longer-term interest rate expectations become irrelevant.

Table 2 summarizes the theoretical predictions of the explanatory variables on the EONIA spread.

Table 2: Theoretical predictions: Summary

Increase in explanatory variable	Notation	Predicted influence
Liquidity policy	$l(mro_t)$	-
Errors in autonomous factors	$e(af)_{t-1}$	+
Reserve fulfilment	rf_{t-1}	-
Bid-to-cover ratio	$b(mro_t)$	+
Liquidity deficit	ld_t	+
Liquidity uncertainty	$\sigma_{l,t-1}$	+
Within period rate expectations	sws_t	+
Policy rate expectations	fs_t	0 (NFW) / + (OFW)
Lagged policy spread	s_{t-1}	+
Interest rate uncertainty	$\sigma_{i,t}$	-
Expected FTO	$fto(mp_{-1})$	-

Notes: See Table 12 in the Appendix for a detailed description of the variables.

[19] See Eisenschmidt, Hirsch and Linzert (2008) for panel econometric evidence on the determinants of banks' bidding behavior in ECB's MROs. See also Bindseil, Nyborg and Strebulaev (2004), Linzert, Nautz and Breitung (2006) and Linzert, Nautz and Bindseil (2007) for further studies on banks' bidding behavior in central bank auctions.

[20] Hassler and Nautz (2007) confirm the ECB's control over the EONIA during the period of variable rate tenders. But they find that the influence of the ECB on the EONIA has weakened slightly since the introduction of the changes to the operational framework in March 2004.

4 Empirical Model and Results

Our model specification is mainly based on Würtz (2003), who assesses an EGARCH model explaining the spread and its volatility. Since volatility was rather moderate and not an issue of concern during our sample period, we use a more structural approach to model the mean of the EONIA spread. Possible dynamics within a period are incorporated by allowing for a different reaction of the EONIA on the days before and after the last MRO. Würtz (2003) and Pérez Quirós and Rodríguez Mendizábal (2006) found significant outliers of the EONIA at the end of a maintenance period. To avoid dealing with them, we exclude the last day of a maintenance period from the analysis.[21] Non-structural movements such as calendar effects or other outliers are corrected by dummy variables. We estimate a daily model of the spread by OLS as presented in the following equation

$$\begin{aligned} s_t &= const + \alpha_1 s_{t-1} + \alpha_2 sws_t + \alpha_3 fs_t + \alpha_4 l(mro_t) + \alpha_5 l(mro_t)|_{lastMRO} \\ &+ \alpha_6 b(mro_t) + \alpha_7 rf_{t-1} + \alpha_8 e(af)_{t-1} + \alpha_9 ld_t + \alpha_{10}\sigma_{i,t} + \alpha_{11}\sigma_{l,t-1} \\ &+ \alpha_{10} fto(mp_{-1}) + \alpha_{11} fto(mp_{-1})|_{lastMRO} + v(d) + \varepsilon_t. \end{aligned}$$

4.1 Estimation Results

Table 3 presents the estimation results of the for the period of the new framework. To check if the relationship between the explanatory variables and the EONIA spread changed after the changes to the operational framework in March 2004, we further estimated the model for the complete sample period from June 2000 to August 2006, and conducted a Chow test of a structural break in March 2000, see Table 8 in Appendix C. The Chow test significantly rejects the null hypothesis of no structural break with respect to the introduction of the new framework on 10 March 2004.[22] To allow for a possibly different relationship during the new framework period, we re-estimate the model for the complete sample period and interact the explanatory variables with a dummy variable for the new framework period, see Table 4.

From Table 3 it can be seen that *liquidity policy* ($l(mro_t)$) in MROs has a statistically significant impact on the EONIA spread. In accordance with the hypothesis, only a loose allotment in the last MRO ($l(mro_t)|_{LMRO}$) of a maintenance period has the intended effect of reducing the spread. In this sense, an allotment of one billion euro above benchmark in the last MRO decreases the spread by four basis points. In contrary, allotment above benchmark within the maintenance period does not play an im-

[21] See Table 11 in Appendix C for estimation results including end-of-period observations.

[22] Cassola and Morana (2006) investigate the issue of a structural break in money market volatility. These authors do not find a permanent impact of the changes to the framework on the volatility of the EONIA, i.e. their finding implies that the introduction of the new framework has not led to a significant stabilization of the EONIA. Note, however, that the focus of our analysis is on the spread between the EONIA and the ECB's policy rate and not on the volatility of the EONIA. A structural break in the relationship between the EONIA spread and its explanatory variables may emerge even if the volatility of the EONIA does not change permanently.

portant role because it will not necessarily remain constant during the current period. Both results also hold in the case of a liquidity absorbing FTO at the last day of the maintenance period, see Table 11 in Appendix C. A comparable result is found by Moschitz (2004). He shows that an additional supply of reserves of one billion euro reduces the interbank rate by eight basis points, if the change is expected to remain effective until the end of the maintenance period. In our model, this would correspond to the last MRO.[23] According to Table 4, the effects of liquidity policy on the EONIA spread are stable during the complete sample period.

As presumed, tight liquidity conditions at the interbank market as signaled by positive errors in autonomous factor forecasts, high bid-to-cover ratios or low reserve fulfilments exert an upward pressure on the EONIA spread, see Table 3.

Table 3: Benchmark equation new framework period

Dependent variable: s_t = EONIA - MBR					
$const$	-1.153	$l(mro_t)$	0.007	$\sigma_{i,t}$	-8.601
	(-4.64)		(4.00)		(-3.97)
s_{t-1}	0.128	$l(mro_t)\vert_{LMRO}$	-0.038	$\sigma_{l,t-1}$	6.205
	(2.62)		(-5.83)		(2.82)
sws_t	0.214	$b(mro_t)$	0.037	$fto(mp_{-1})$	0.001
	(3.27)		(2.44)		(3.08)
fs_t	0.004	rf_{t-1}	-0.144	$fto(mp_{-1})\vert_{LMRO}$	-0.002
	(0.20)		(-2.40)		(-3.46)
ld_t	0.101	$e(af)_{t-1}$	0.212		
	(5.08)		(3.43)		
R^2	0.59				

Notes: Sample period: 10 March 2004 to 31 August 2006, daily observations. Estimations without last day of maintenance period. HAC consistent t-values in parentheses. More detailed estimation results in Table 7 and explanations of variables in Table 12 in Appendix C.

As the theoretical considerations suggest, the *bid-to-cover ratio* ($b(mro_t)$) has a significantly positive influence on the EONIA spread in the new framework period. This is plausible because a high bid-to-cover ratio reflects the fact that liquidity demand has only been met to a low degree by the ECB.

In the old framework period, the evidence on the bid-to-cover ratio is less clear. As is shown in Table 4, we corrected for the underbidding episodes (d_{ubd} and $b(mro_t) \cdot d_{ubd}$), which occurred in the old framework period. In these cases, interest rate cut expectations led to extreme underbidding in MROs. As a consequence, banks could not cover their liquidity needs in the MRO and the EONIA rate soared in spite of interest rate cut expectations and a low bid-to-cover ratio. Accordingly, these episodes are shown in the estimations with a significantly negative sign. After having separated out these particular

[23] Note, that the equation includes the lagged policy spread as well as the liquidity supply variable. One might assume that liquidity supply reacts to past values of the EONIA spread and that consequently, the lagged spread and the liquidity policy variable are correlated. However, robustness checks show that the estimated coefficients for the liquidity policy variable remain robust, whether the lagged EONIA spread is included or not.

Table 4: Estimation complete sample period with interaction terms during new framework period

Dependent variable: s_t = EONIA - MBR					
$const$	0.136	$l(mro_t)$	0.005	$\sigma_{i,t}$	-0.024
	(0.43)		(1.97)		(-2.30)
d_{nfw}	-1.288	$l(mro_t) \cdot d_{nfw}$	0.001	$\sigma_{i,t} \cdot d_{nfw}$	-9.008
	(-3.17)		(0.38)		(-4.11)
s_{t-1}	0.439	$l(mro_t)\vert_{LMRO}$	-0.039	$\sigma_{l,t-1}$	3.111
	(6.34)		(-5.95)		(0.66)
$s_{t-1} \cdot d_{nfw}$	-0.307	$l(mro_t)\vert_{LMRO} \cdot d_{nfw}$	0.065	$\sigma_{l,t-1} \cdot d_{nfw}$	1.943
	(-3.61)		(0.67)		(0.39)
sws_t	0.144	$b(mro_t)$	0.001	$b(mro_t) \cdot d_{ubd}$	-0.020
	(3.27)		(0.24)		(-4.23)
$sws_t \cdot d_{nfw}$	0.104	$b(mro_t) \cdot d_{nfw}$	0.044	d_{ubd}	0.164
	(1.32)		(2.61)		(5.12)
fs_t	0.071	rf_{t-1}	-0.254		
	(2.73)		(-3.49)		
$fs_t \cdot d_{nfw}$	-0.075	$rf_{t-1} \cdot d_{nfw}$	0.151		
	(-2.29)		(1.59)		
ld_t	0.010	$e(af)_{t-1}$	0.040		
	(0.42)		(0.58)		
$ld_t \cdot d_{nfw}$	0.087	$e(af)_{t-1} \cdot d_{nfw}$	0.128		
	(2.74)		(1.33)		
R^2	0.71				

Notes: Sample period: 27 June 2000 to 31 August 2006, daily observations. Estimations without last day of maintenance period. HAC consistent t-values in parentheses. d_{nfw}: Dummy for new framework period from 10 March 2004 to 31 August 2006, d_{ubd}: Dummy for underbidding episodes. More detailed estimation results in Table 9 and explanations of variables in Table 12 in Appendix C.

underbidding episodes, we do not find any evidence of a significant influence of the bid-to-cover ratio under the old framework. As outlined in Section 3, this may be related to the fact that the overlapping maturity structure of MROs during the old framework period provided more flexibility for banks regarding their refinancing opportunities. In addition, the bid-to-cover ratio may have had a weaker signalling character. Note also, that the bid-to-cover ratio in the old framework period is defined as the average value of the current and previous MRO.

The *average reserve fulfillments* (rf_{t-1}) have a significantly negative impact on the EONIA spread. This supports the presumption that high past reserve holdings reduce the EONIA spread which appears self-evident against the background of high past reserve holdings creating little pressure on the reserves for the remaining days within the period. Table 4 indicates that the influence of average reserve fulfilments has not changed significantly with the introduction of the new framework.

The hypothesis by Välimäki (2006), which predicts that an increasing total *liquidity deficit* (ld_t) exerts pressure on the spread, is supported by the results for the new framework period. This confirms the notion that the risk of receiving no liquidity in the tender is likely to increase as the banks' desired liquidity grows. In fact, the finding is in line with results from analyzing banks' bidding behavior where the aggregate size of allotment has been found to significantly determine the marginal rate of the auction. Interestingly, this variable does not play a significant role under the old framework, see Table 4. The result could be brought in accordance with the model of Välimäki (2006) in the sense that allotment uncertainty as a crucial variable for the tender outcome is the necessary condition for the liquidity deficit being significant. Given the liquidity buffer banks had in the old framework period, allotment uncertainty may have existed but may have played a less important role for the bidding decision of banks. [24]

Uncertainty about the liquidity situation ($\sigma_{l,t-1}$), which is represented by the conditional variance of reserve fulfillment of banks, has both a positive and significant effect on the spread during the new framework period, see Table 3. It appears that in the presence of higher uncertainty about the liquidity situation, banks are willing to pay a risk premium that secures their liquidity provision. This finding is in line with Välimäki's model, which incorporates liquidity uncertainty as a decisive variable for the emergence of a tender spread. However, the estimation for the complete sample period (Table 4) fails to produce significant estimates of this variable.

Our findings concerning *policy rate expectations* (fs_t) underpin the theoretical implications from Neyer (2004). During the new framework period, policy rate expectations apparently do not influence banks' behavior in the tender operations or in the interbank market. In contrast, they have a positive and significant impact on the spread in the sample period for the old framework period. Hence, it appears that the changes to the operational framework had their intended effect, eliminating policy rate expectations from the bidding behavior in the MROs and thus also from the determination of the overnight market rate.

Within period rate expectation (sws_t) as measured by the spread between one-week swap rates and the minimum bid rate are—as expected—positively related to the development of the EONIA spread. This confirms the presumption that interest rate expectations up to the following MRO induce banks to accept higher refinancing costs in the current MRO. Notice, however, that the various interest rate measures used in the empirical analysis are interlinked during the last week of a maintenance period. This makes it difficult to separate the effects into within period rate expectations and policy rate expectations. Therefore, the relevance of interest rate expectations in the overnight market cannot be ruled out completely.

The negative coefficients of *interest rate uncertainty* ($\sigma_{i,t}$), defined as the conditional volatility of the

[24] Note that it is difficult to disentangle the effect related to the change in the explanatory variable itself and the change in the underlying rules of the operational framework. As regards the liquidity deficit, it has increased substantially over the sample period. So, on the one hand, one could argue that at low levels of the liquidity deficit it does not exert any pressure on banks' refinancing, while at higher levels it does. On the other hand, one could also argue that the rule of the new framework to fulfil the reserve requirements by the end of the maintenance period without the liquidity buffer banks were used to under the old framework due to overlapping tender periods contributed to an increased sensitivity towards allotment uncertainty, see Välimäki (2006).

first difference in one-week swap spreads, suggests that the phenomenon of the winner's curse is relevant in both sample periods, i.e. banks bids are increasingly cautious as they are uncertain about the future interest rate. Note, that there was less interest rate uncertainty under the new framework compared to the old framework.

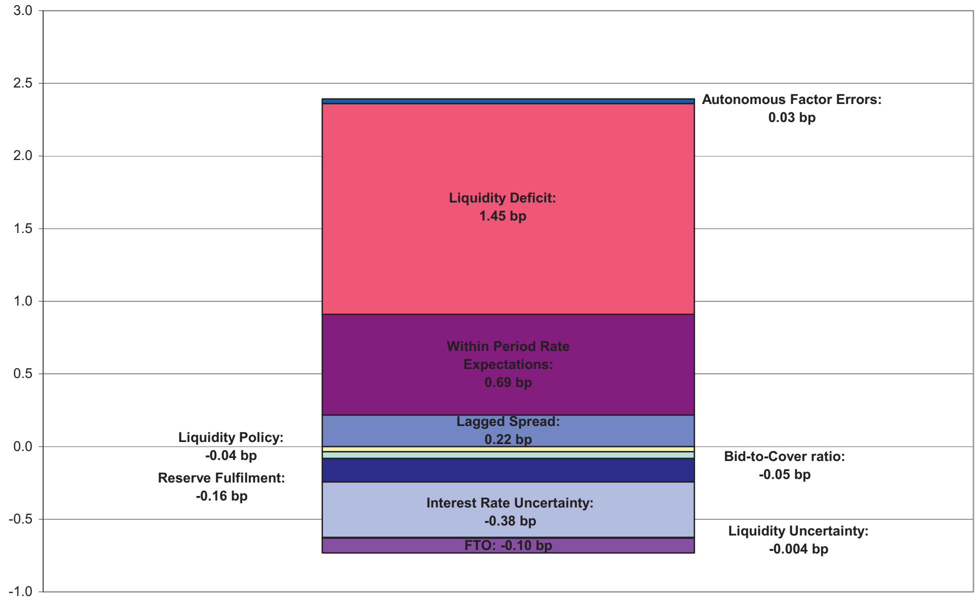
A further interesting insight is provided by the *market's expectations about an FTO* ($fto(mp_{-1})$). This variable illustrates the fine tuning operation of the previous maintenance period. During the course of the new framework period, FTOs took place increasingly systematically on the last day of a maintenance period. Consequently, a bank should take this policy into account for its reserve management. The regression results show that expectations about a liquidity injecting FTO only mitigate pressure on the EONIA during the last week of a maintenance period ($fto(mp_{-1})|_{LMRO}$), see Table 3.

4.2 Economic Significance

In order to get a better understanding of which factors may have contributed to the overall rise of the EONIA spread since the introduction of the new framework, it is useful to quantify the contributions of each variable to the increase in the overall spread. As described in Section 2, a steady widening of the EONIA spread had been observed since March 2004. For ease of illustration, however, we divide the new framework period into two parts and quantify the respective contributions of each variable from the first part to the second part of the new framework period on the widening of the spread of about 2 basis points, see also Table 1. This division is not supposed to suggest a break in the new framework period. It is rather meant to provide a rough assessment about the impact of the variables on the spread in quantitative terms.

As it is apparent from Figure 5, the most important driving force on the EONIA spread is the liquidity deficit. On average, the increase in the liquidity deficit has led to an increase in the EONIA spread by 1.45 basis points. Other relevant variables affect the spread more within the maintenance period. In this model, banks' fulfilment of reserve is shown to play a crucial role. Interestingly, the liquidity policy by the ECB did not play a very significant role in the overall determination of the EONIA spread contributing to a reduction in the EONIA spread of 0.04 basis points. Moreover, errors in the forecasts of autonomous factors affect the EONIA spread significantly. Since the forecast quality of autonomous factors has been relatively similar in both parts of the sample, the quantitative effect is not very strong.

Figure 5: Individual contributions to the widening of the spread in the new framework period



Notes: Quantitative contributions of the determinants to the widening of the spread of 2 bp from March 2004 to August 2005 versus September 2005 to August 2006. Individual contributions are calculated as partial influence of the respective variable on the EONIA spread multiplied by average change of the variable from the first to the second part of the sample.

5 Conclusions

This paper investigated the possible determinants of the spread between the EONIA and the ECB's policy rate from March 2004 to August 2006. The EONIA spread has widened slowly but steadily since the introduction of the changes to the operational framework in March 2004. To limit the increase in the spread, the ECB adopted a loose liquidity policy towards the end of the year 2005. The EONIA spread decreased somewhat during 2006 while increasing again towards the end of the year.

The results from the empirical analysis indicate that a rise in the liquidity deficit induces the EONIA spread to increase significantly. Moreover, tight liquidity conditions as well as an increase in banks' uncertainty about the liquidity conditions exert a significant upward pressure on the spread. ECB's liquidity policy has a significant impact on the reduction of the spread only when a loose policy is conducted in the last MRO of the maintenance period. Policy rate expectations (as measured by the forward rate spread) have not been found to be relevant, while within period rate expectations (as measured by the 1w swap spread) were found to have a significant impact on the spread. Notice, however, that separating the two effects is difficult.

In terms of the historical contribution to the overall increase of the spread, the results demonstrate that the increase in the EONIA spread can largely be explained by the current liquidity deficit. The ECB's loose liquidity policy has contributed to a (small) reduction in the spread. As to the more indirect effects, it may have induced banks to front-load their reserve holdings contributing to a reduction in the spread.

With regard to possible implications for monetary policy implementation it seems crucial to break the upward trend and to reduce the overall liquidity deficit to alleviate pressure on the EONIA spread. Since the increase in the liquidity deficit goes along with an increase in refinancing volumes in MROs, allowing banks to receive liquidity in alternative refinancing such as LTROs might contribute to mitigating the effect of the increasing liquidity deficit.[25] Moreover, in order to further increase the transparency and the clarity of the operational framework it appears to be pivotal to reduce banks' uncertainty about the liquidity situation as much as possible. Finally, the results suggest that the liquidity policy, particularly when conducted in the last operation of the maintenance period, is an effective tool to reduce the EONIA spread. Overall, the results suggest that structural factors related to the design of the central bank's balance sheet and the operational framework can have an impact on the EONIA spread.

Looking ahead, regarding the exploitation of the link between the marginal rate and the EONIA, it seems crucial to further examine bidding behavior in the main refinancing operations that will be key in order to understand the determination of the equilibrium rate in these operations.[26] This would enable us to analyze how bank-specific behavior, for example, the individual use of collateral or strategic bidding by certain banks, spills over into the overnight market.

[25] Note that some counterparties produced this argument during the public consultation on the changes to the operational framework.

[26] See Bindseil, Nyborg and Strebulaev (2004), Linzert, Breitung and Nautz (2006), Linzert, Bindseil and Nautz (2007) and Eisenschmidt, Hirsch and Linzert (2008) for studies on bidding behavior in central bank auctions.

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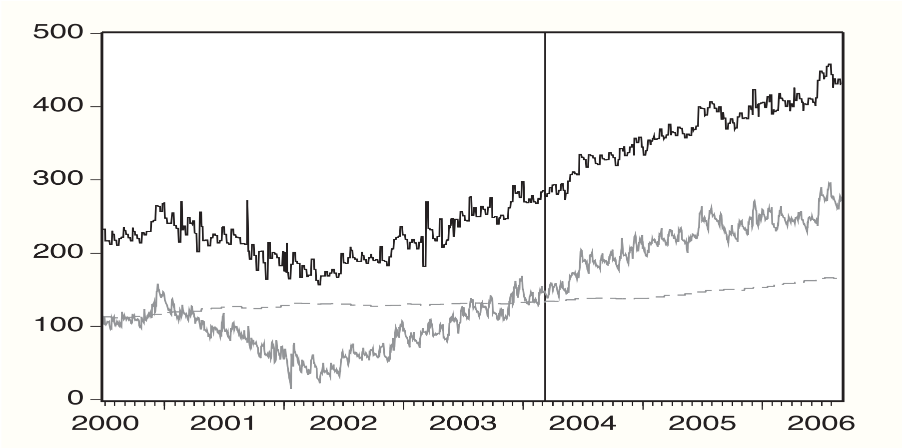
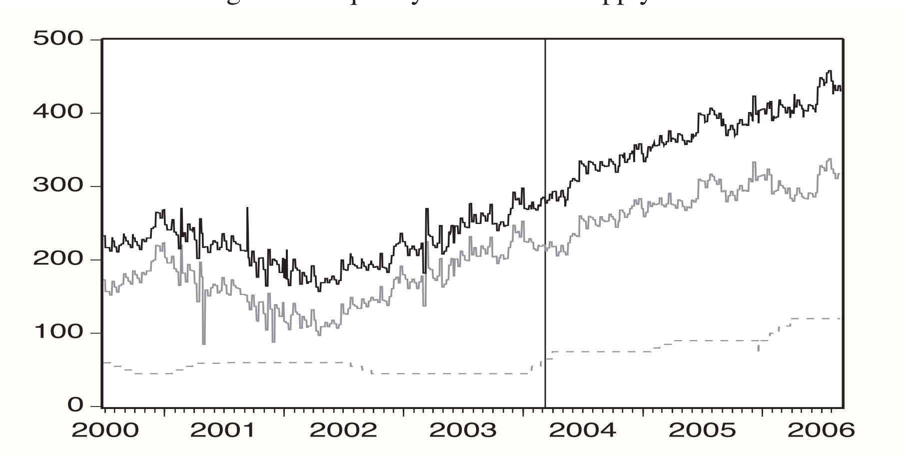
A Liquidity Deficit

Figure 6: Liquidity deficit from demand side



Time series: Liquidity deficit (black line), net autonomous factors (grey line) and reserve requirements (dashed line). The vertical line corresponds to the introduction of the new framework.

Figure 7: Liquidity deficit from supply side



Time series: Liquidity deficit (black line), outstanding MROs (grey line) and outstanding LTROs (dashed line). The vertical line corresponds to the introduction of the new framework.

The liquidity deficit and its components from the demand side, reserve requirements and autonomous factors, are depicted in Figure 6, see also Figure 4 for balance sheet items. The variable is mainly driven by the development of autonomous factors, which have declined before the introduction of the euro as a cash currency in January 2002 and have steadily increased again. Figure 7 shows the composition from the supply side. As it can be seen, MROs account for about 75 percent of all liquidity supply and LTROs for about 25 percent.

B Unit Root Tests

Estimated equation:

$$\Delta S_t = \phi_0 - \rho S_{t-1} + \gamma t + \varepsilon_t.$$

where

$$\rho = 1 - \phi_1$$

Table 5: Results unit root tests, old framework versus new framework

Old framework		New framework, with trend		New framework, without trend	
ϕ_0	0.03***	ϕ_0	0.03***	ϕ_0	0.03***
ϕ_1	0.71***	ϕ_1	0.29***	ϕ_1	0.40***
γ	—	γ	2.66E-05**		

Notes: ***/** indicate significance at the 1%/5%-level. — indicates no significance.

Tables 5 and 6 demonstrate that the importance of the lagged spread has decreased under the new framework compared to the old framework. In addition, a positively significant time trend is found in the new framework period. In summary, the relationship between the spread and previous values has become less close under the new framework compared to the old framework.

Table 6: Results unit root tests, new framework

March 2004 - September 2005				October 2005 - August 2006	
Including a trend		Without trend			
ϕ_0	0.03***	ϕ_0	0.03***	ϕ_0	0.03***
ϕ_1	0.32***	ϕ_1	0.33***	ϕ_1	0.62***
γ	6.11E-05**			γ	—

Notes: ***/** indicate significance at the 1%/5%-level. — indicates no significance.

C Detailed Estimation Results and Robustness Checks

Table 7 shows the detailed estimation results of the benchmark equation during the new framework period. Table 8 presents the results for the complete sample period, without taking account of the changes to the operational framework. A Chow test indicates a structural break of the model in March 2004. Thus, the estimation presented in Table 9 takes possible changes in the estimated coefficients into account by interacting the variables with a dummy variable for the new framework period (d_{nfw}).

To make sure that it might not be a simple time trend (Table 10) that drives the EONIA spread in the new framework period, we add a time trend to the benchmark equation. It proves to be insignificant and therefore supports the specification of the benchmark equation.

Since the aim of our analysis is not to model end-of-period effects, we exclude end-of-period observations from the benchmark equation. Table 11 shows what happens if we alternatively include the very last day of the period as a step dummy. The last day of period is divided into three categories: last day without FTO, with a liquidity absorbing FTO or with a liquidity injecting FTO. Our results remain robust, only the significance of one-week swap spreads can be modelled less clearly. Since adding end-of-period observations does not improve the explanatory content of the estimation, our benchmark equation is confirmed.

Table 7: Detailed estimation results new framework period

Dependent variable: s_t = EONIA - MBR			
$const$	-1.153	d_{eow}	-0.006
	(-4.64)		(-2.28)
s_{t-1}	0.128	d_{eom}	0.023
	(2.62)		(4.57)
sws_t	0.214	d_{eoq}	0.026
	(3.27)		(2.71)
fs_t	0.004	d_{eos}	0.017
	(0.20)		(1.53)
$l(mro_t)$	0.007	d_{eoy}	0.096
	(4.00)		(3.52)
$l(mro_t)\|_{LMRO}$	-0.038	$d_{5Apr2004}$	0.232
	(-5.83)		(50.72)
$b(mro_t)$	0.037	$d_{8Oct2004}$	0.277
	(2.44)		(63.19)
rf_{t-1}	-0.144	$d_{3Dec2004}$	-0.185
	(-2.40)		(-15.21)
ld_t	0.101		
	(5.08)		
$e(af)_{t-1}$	0.212		
	(3.43)		
$\sigma_{i,t}$	-8.601		
	(-3.97)		
$\sigma_{l,t-1}$	6.205		
	(2.82)		
$fto(mp_{-1})$	0.001		
	(3.08)		
$fto(mp_{-1})\|_{LMRO}$	-0.002		
	(-3.46)		
Adjusted R^2	0.59		

Notes: Sample period: 10 March 2004 to 31 August 2006, daily observations. End-of-period observations are excluded from the estimation. HAC consistent t-values in parentheses. Dummy variables for end of week (d_{eow}), end of month (d_{eom}), end of quarter (d_{eoq}), end of semester (d_{eos}), end of year (d_{eoy}) and special outliers of more than three times a standard deviation as presented.

Table 8: Estimation results complete sample period without distinction for the changes to the framework; test for structural break

Dependent variable: s_t = EONIA - MBR			
$const$	0.122	d_{eow}	0.003
	(0.88)		(0.51)
s_{t-1}	0.403	d_{eom}	0.050
	(6.21)		(7.25)
sws_t	0.149	d_{eoq}	0.012
	(3.44)		(0.59)
fs_t	0.071	d_{eos}	0.109
	(3.16)		(2.26)
$l(mro_t)$	0.005	d_{eoy}	-0.066
	(2.43)		(-1.36)
$l(mro_t)\|_{LMRO}$	-0.040	d_{ubd}	0.141
	(-7.05)		(4.77)
$b(mro_t)$	-0.004	$d_{end20000}$	0.218
	(-1.24)		(12.71)
rf_{t-1}	-0.263	$d_{easter2001}$	0.479
	(-3.91)		(11.76)
ld_t	0.013	$d_{20Sep2001}$	-0.481
	(1.30)		(-33.65)
$e(af)_{t-1}$	0.050	$d_{end2001}$	0.319
	(0.81)		(6.74)
$\sigma_{i,t}$	-0.023	$d_{end2002}$	0.406
	(-2.19)		(13.54)
$\sigma_{l,t-1}$	3.35	$d_{end2003}$	-0.275
	(0.81)		(-15.19)
		$d_{5Apr2004}$	0.235
			(59.70)
		$d_{8Oct2004}$	0.249
			(32.71)
		$d_{3Dec2004}$	-0.145
			(-13.15)
Adjusted R^2	0.70		

Chow test for structural break $\mathcal{H}_0$: No break at 10 March 2004			
F-statistic	6.32	p-value	0.00

Notes: Sample period: 27 June 2000 to 31 August 2006, daily observations. End-of-period observations are excluded from the estimation. HAC consistent t-values in parentheses. Dummy variables for end of week (d_{eow}), end of month (d_{eom}), end of quarter (d_{eoq}), end of semester (d_{eos}), end of year (d_{eoy}) and special outliers of more than three times a standard deviation as presented. d_{ubd}: dummy for underbidding episodes.

Table 9: Detailed estimation results, complete sample period with interaction terms during new framework period

Dependent variable: s_t = EONIA - MBR					
$const$	0.136	rf_{t-1}	-0.254	$d_{end2000}$	0.196
	(0.43)		(-3.49)		(9.69)
d_{nfw}	-1.288	$rf_{t-1} \cdot d_{nfw}$	0.151	$d_{easter2001}$	0.470
	(-3.17)		(1.59)		(11.34)
s_{t-1}	0.439	ld_t	0.010	$d_{20Sep2001}$	-0.47
	(6.34)		(0.42)		(-31.43)
$s_{t-1} \cdot d_{nfw}$	-3.61	$ld_t \cdot d_{nfw}$	0.087	$d_{end2001}$	0.300
	(0.00)		(2.74)		(5.95)
sws_t	0.144	$e(af)_{t-1}$	0.040	$d_{end2002}$	0.377
	(3.27)		(0.58)		(11.62)
$sws_t \cdot d_{nfw}$	0.104	$e(af)_{t-1} \cdot d_{nfw}$	0.128	$d_{end2003}$	-0.263
	(1.32)		(1.33)		(-13.02)
fs_t	0.071	$\sigma_{i,t}$	-0.024	$d_{5Apr2004}$	0.236
	(2.73)		(-2.30)		(48.37)
$fs_t \cdot d_{nfw}$	-0.075	$\sigma_{i,t} \cdot d_{nfw}$	-9.008	$d_{8Oct2004}$	0.270
	(-2.29)		(-4.11)		(48.79)
$l(mro_t)$	0.005	$\sigma_{l,t-1}$	3.111	$d_{3Dec2004}$	-0.201
	(1.97)		(0.66)		(-16.65)
$l(mro_t) \cdot d_{nfw}$	0.001	$\sigma_{l,t-1} \cdot d_{nfw}$	1.943	d_{ubd}	0.164
	(0.38)		(0.39)		(5.12)
$l(mro_t)\|_{LMRO}$	-0.039	d_{eow}	0.005		
	(-5.95)		(0.95)		
$l(mro_t)\|_{LMRO} \cdot d_{nfw}$	0.065	d_{eom}	0.050		
	(0.67)		(7.21)		
$b(mro_t)$	0.001	d_{eoq}	0.017		
	(0.24)		(0.84)		
$b(mro_t) \cdot d_{nfw}$	0.044	d_{eos}	0.104		
	(2.61)		(2.17)		
$b(mro_t) \cdot d_{ubd}$	-0.020	d_{eoy}	-0.03		
	(-4.23)		(-0.65)		
Adjusted R^2	0.71				

Notes: Sample period: 27 June 2000 to 31 August 2006, daily observations. End-of-period observations are excluded from the estimation. HAC consistent t-values in parentheses. d_{nfw}: Dummy for new framework period from 10 March 2004 to 31 August 2006. Dummy variables for end of week (d_{eow}), end of month (d_{eom}), end of quarter (d_{eoq}), end of semester (d_{eos}), end of year (d_{eoy}) and special outliers of more than three times a standard deviation as presented. d_{ubd}: dummy for underbidding episodes.

Table 10: Robustness check: Results of the new framework including a time trend

Dependent variable: s_t = EONIA - MBR			
$const$	-1.341	d_{eow}	-0.006
	(-2.10)		(-2.30)
s_{t-1}	0.127	d_{eom}	0.023
	(2.61)		(4.51)
sws_t	0.213	d_{eoq}	0.026
	(3.25)		(2.71)
fs_t	0.007	d_{eos}	0.016
	(0.32)		(1.42)
$l(mro_t)$	0.007	d_{eoy}	0.096
	(4.00)		(3.53)
$l(mro_t)\|_{LMRO}$	-0.037	$d_{5Apr2004}$	0.232
	(-5.84)		(46.52)
$b(mro_t)$	0.037	$d_{8Oct2004}$	0.277
	(2.42)		(64.84)
rf_{t-1}	-0.141	$d_{3Dec2004}$	-0.185
	(-2.32)		(-15.14)
ld_t	0.116	$trend$	1.14E-05
	(2.32)		(-0.33)
$e(af)_{t-1}$	0.216		
	(3.49)		
$\sigma_{i,t}$	-8.588		
	(-3.94)		
$\sigma_{l,t-1}$	5.893		
	(2.89)		
$fto(mp_{-1})$	0.001		
	(3.07)		
$fto(mp_{-1})\|_{LMRO}$	-0.002		
	(-3.46)		
Adjusted R^2	0.59		

Notes: Sample period: 10 March 2004 to 31 August 2006, daily observations. End-of-period observations are excluded from the estimation. HAC consistent t-values in parentheses. Dummy variables for end of week (d_{eow}), end of month (d_{eom}), end of quarter (d_{eoq}), end of semester (d_{eos}), end of year (d_{eoy}) and special outliers of more than three times a standard deviation as presented.

Table 11: Robustness check: Results of the new framework including end-of-period effects

Dependent variable: s_t = EONIA - MBR			
$const$	-1.201	d_{eow}	-0.006
	(-4.79)		(-2.26)
s_{t-1}	0.127	d_{eom}	0.023
	(2.70)		(4.40)
sws_t	0.129	d_{eoq}	0.025
	(1.78)		(2.42))
fs_t	-0.001	d_{eos}	0.017
	(-0.03)		(1.36)
$l(mro_t)$	0.008	d_{eoy}	0.091
	(4.69)		(3.56)
$l(mro_t)\|_{LMRO}$	-0.038	$d_{eop,noFTO}$	0.018
	(-6.49)		(0.32)
$b(mro_t)$	0.045	$d_{eop,labFTO}$	-0.039
	(2.84)		(-1.59)
rf_{t-1}	-0.173	$d_{eop,lprFTO}$	0.031
	(-2.87)		(1.99)
ld_t	0.107	$d_{5Apr2004}$	0.232
	(5.46)		(55.27)
$e(af)_{t-1}$	0.213	$d_{6Apr2004}$	0.675
	(3.31)		(11.76)
$\sigma_{i,t}$	-7.987	$d_{8Jun2004}$	-0.333
	(-3.46)		(-5.81)
$\sigma_{l,t-1}$	5.935	$d_{6Jul2004}$	0.456
	(2.63)		(8.06)
$fto(mp_{-1})$	0.001	$d_{9Aug2004}$	-0.426
	(3.26)		(-17.22)
$fto(mp_{-1})\|_{LMRO}$	-0.002	$d_{8Oct2004}$	0.276
	(-3.46)		(63.24)
		$d_{11Oct2004}$	0.665
			(11.46)
		$d_{3Dec2004}$	-0.187
			(-16.27)
		$d_{7Jun2005}$	-0.271
			(-10.50)
Adjusted R^2	0.78		

Notes: Sample period: 10 March 2004 to 31 August 2006, daily observations. HAC consistent t-values in parentheses. Dummy variables for end of week (d_{eow}), end of month (d_{eom}), end of quarter (d_{eoq}), end of semester (d_{eos}), end of year (d_{eoy}) and special outliers of more than three times a standard deviation as presented. End-of-period dummies include dummies without FTOs ($d_{eop,noFTO}$), with liquidity absorbing FTOs ($d_{eop,labFTO}$) and liquidity providing FTOs ($d_{eop,lprFTO}$).

Table 12: List of variables

Variable	Notation	Construction	Data source
EONIA spread	s	Spread between EONIA and Minimum Bid Rate (MBR)	ECB
Within period rate expectations	sws	Spread bw. one-week swap rates and MBR, EONIA swap rates as mean bw. bid and ask prices, quoted at noon	Reuters
Policy rate expectations	fs	Spread bw. forward rates one month in one month and MBR Forward rates one month in one month = 2*(swap rate(2 months) - swap rates(1 month), quoted at noon	Reuters
Liquidity policy	$l(mro_t)$	Actual minus benchmark allotment of current MRO	ECB
Bid-to-cover ratio	b	Bid-to-cover ratio of current MRO in the new framework, average of the two most recent MROs in the old framework	ECB
Reserve fulfilment	rf	Current account holdings divided by reserve requirements, cumulated average since beginning of period	ECB
Errors in autonomous factors	$e(af)$	Forecast error of realized autonomous factors, cumulated average during an MRO-period, relative to assumptions for benchmark allotment	ECB
Liquidity deficit	ld	Log of sum of all open market operations*	ECB
Interest rate uncertainty	σ_i	Uncertainty about EONIA rate at one-week horizon: GARCH(1,1)-conditional volatility of Δ(one-week swap rates)	Reuters
Liquidity uncertainty	σ_l	GARCH(1,1)-conditional volatility of cumulated average reserve holdings	Reuters
Expectations of an FTO	$fto(mp_{-1})$	Volume of FTO allotment in preceding maintenance period	ECB
Dummies	$v(d)$	Vector of Dummy variables for FTOs, end of maintenance period, calendar effects and extreme outliers	

Notes: *The liquidity deficit, here calculated from the supply side, i.e. from open market operations, equals net autonomous factors and reserve requirements from the demand side, see also Figure 4 for balance sheet items and Figures 6 and 7 for its decomposition over time.

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ISSN 1561-0810
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