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The Effectiveness of Monetary Policy During the Recent Financial Turmoil*

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Abstract

The recent financial crisis has deeply affected money markets. We analyze the effectiveness of monetary policy in the euro area with respect to (i) how much monetary policy expectations are reflected in money market rates, (ii) how much money market rates were disturbed by liquidity and credit risk, and (iii) the impact of extraordinary central bank measures on money markets. We find that market's expectations are less relevant for money market rates up to 12 months after August 2007. At the same time, the ECB's additional liquidity provision through longer-term refinancing operations account for at least a 60 basis point decrease in Euribor rates.

Keywords: Monetary transmission mechanism; Financial Crisis; Monetary policy implementation; European Central Bank; Money market

JEL classification: E43, E52, E58

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1 Introduction

The financial market is key for the transmission of monetary policy. Monetary policy is implemented by controlling the very short end of the yield curve. At the same time signals about future monetary policy and the corresponding expectations are reflected in the shape of the money market yield curve. According to the so called expectations hypothesis, the current structure of money market interest rates contains an implicit path of the expected future short term interest rate, i.e. the policy rate set by the central bank, see e.g. Mankiw and Miron (1986), Campbell and Shiller (1991), and Rudebusch (1995). This path reflects how interest rates will evolve over time and will change if new information about the economic outlook and monetary policy necessitate a revision of the path. Hence, for an effective monetary policy, it is, therefore, crucial that interest rate expectations are in line with the central bank policy intentions and are correctly reflected in the shape of the yield curve.

The financial market crisis starting in August 2007 has deeply affected financial markets around the world. Particularly, the money market was hit dramatically with liquidity drying up and money market rates rising to unusually high levels. For example, the spread between the 3-month Euribor and the 3-month OIS rate rose in October 2008 to about 180 basis points. Central banks stepped in with additional liquidity support and other measures to stabilize money market conditions. In this paper we are, therefore, answering three basic yet crucial questions. First, how effective has monetary policy been during the financial turmoil, i.e. how predictable were money market interest rates in the euro area on the basis of monetary policy expectations. Second, which risk factor contributed predominantly to elevated money market interest rates during the turmoil. And third, what was the impact of the extraordinary central bank measures on euro area money market interest rates?

To provide an answer to these questions we analyze the dynamics of the 3, 6, and 12-month Euribor interest rate during the financial crisis in comparison with the pre-crisis developments. We employ an econometric representation of the expectation hypothesis, controlling for variables representing liquidity and credit risk. The reason why the money market yield curve, and in particular the 3-month Euribor, plays a crucial role for the monetary policy transmission process, stems from the fact that many retail market interest rates are linked closely to the Euribor, see e.g. Mojon (2000), de Bondt et al. (2002), and Sorensen and

Werner (2006). Central bank operations are intended to transmit through the money market yield curve to affect short and long term funding conditions with respect to longer term bond rates, but also the marginal costs of loan funding through which the price of bank loans are influenced.

During the financial turmoil, money market rates along the money market yield curve rose dramatically, particularly in the wake of the Lehman bankruptcy. This has been the result of a corresponding increase in credit risk (see e.g. Taylor and Williams (2009) for the US), a combination of liquidity and credit risk (see e.g. Brunnermeier (2009), Michaud and Uppel (2008), and Sarkar (2009) for the US and Schwarz (2009) for the euro area) or funding liquidity risk (see e.g. Eisenschmidt and Tapking (2009) for the euro area). This raises the question to what extent the monetary policy transmission has been still effective, despite the prevailing liquidity and credit risk factors. Therefore, we will test to what extent monetary policy expectations remain a key determinant of money market interest rates, controlling for credit and liquidity risk in the money market.

The European Central Bank (ECB), but also other central banks have mainly reacted to the financial crisis by increasing significantly the liquidity provision to the banking sector via their refinancing operations. For the ECB, this policy was reflected in an increase in the liquidity provided by the weekly main refinancing operations (MROs), a significant increase of the liquidity provision through its (supplementary) longer term refinancing operations (LTROs) and the provision of dollar liquidity through a swap with the Fed. Therefore, we will also analyze whether the liquidity provision of the ECB affected the development of the 3 month Euribor rate, alleviating the strain on money markets during the financial market turmoil.¹

We contribute to previous empirical literature in various respects: first, we evaluate the effectiveness of monetary policy in the euro area during the recent crisis;² second, we measure the impact of risk associated with liquidity risk and credit risk on Euribor rates until June 2009; third, we provide a complete assessment of ECB's liquidity providing measures during the crisis.

Several conclusions can be drawn from our empirical results. Until mid 2007,

¹For the US, the effect of the liquidity providing facilities and programs has been studied by Taylor and Williams (2009), McAndrews et al. (2008), Christensen et al. (2008), and Wu (2008).

²For the U.S. Carpenter and Demiralp (2009) use ois rates for an empirical analysis of the expectation hypothesis of the term structure.

longer-term interest rates up to 12 months were highly predictable on the basis of market's expectations. Factors related to credit and liquidity risk played only a very minor role for money market rates. During the crisis, the clarity with which monetary policy intentions are reflected in the shape of the yield curve becomes less relevant in size. In addition, the persistence of the Euribor has increased significantly suggesting that the effectiveness of monetary policy has been hindered further. Our results also reveal that liquidity risk was the key driver during the recent financial crisis. This is in line with earlier work, see Eisenschmidt and Tapking (2009). This may explain why the undertaken liquidity providing operations by the ECB were also found to relieve strains in money market interest rates. In fact, the increase in the supplementary liquidity provision accounts for an at least 60 basis points reduction of Euribor rates. The increased importance of the allotted refinancing volumes may also explain the ECB's switch to the fixed rate full allotment policy as of October 2008.

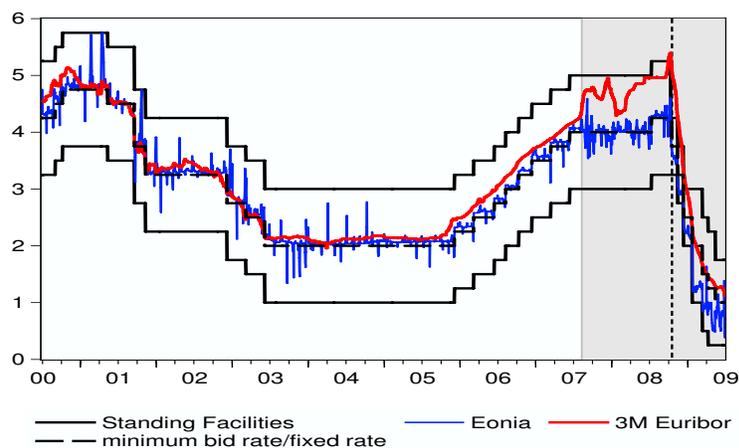
The remainder of the paper is organized as follows. The following section gives a brief overview over the main developments in the euro area money market and the main interventions of the ECB. Section 3 provides a look at the data and presents our model for the dynamics of the 3-month Euribor. Section 4 provides our empirical results and Section 5 concludes.

2 Monetary Policy and the Euro Money Market during the Financial Crisis

Monetary policy in the euro area is implemented by steering the shortest end of the yield curve. In normal times, the euro area overnight rate (Eonia) has been following the ECB's policy rate very closely, see Figure 1.³ At the same time, money market rates along the money market yield curve have been following very closely future expected short term rates. For example, the 3-month Euribor rate has evolved in a close range to the respective 3-month OIS rate (the expected future overnight rate) with an average spread of around 8 basis points in the period prior to the financial crisis, see Figure B.1. The spread stems from a risk premium (as compensation for committing the funds for three month) which rises with the term-to-maturity.

³See European Central Bank (2004) for a description of the ECB's monetary policy implementation. For a detailed analysis of the overnight rate dynamics, please refer to Würtz (2003).

Figure 1: The minimum bid rate, 3-month Euribor and the Eonia



Notes: The shaded area refers to the onset of the financial turmoil as of August 9, 2007. The dashed vertical line represents September 15, 2008 when Lehman filed for bankruptcy.

On August 9, 2007 tensions surrounding assets backed by US sub-prime mortgages started to spill over into money markets around the world, leading to shortages of liquidity in the money market. In the euro area, the Eonia subsequently rose substantially following this increased liquidity demand in the overnight market. Moreover, the combination of heightened uncertainty about counterparties' creditworthiness and evaporating liquidity caused longer-term interest rates in the unsecured segment of the money market increasingly to dry up. In addition, the rising spread between the 3-month Euribor and the Eonia swap rates with the same maturity suggested that interest rate expectations were diverging from money market rates along the yield curve, see Figure B.1. In order to stabilize conditions in the money market, the European Central Bank (ECB) responded to the increased liquidity demand by providing additional liquidity, i. e. the amount of liquidity of the weekly main refinancing operations (MROs) was increased substantially, the longer term refinancing operations (LTROs) were extended in size and frequency and the provision of dollar liquidity (TAFs) were established through a swap with the US Fed.⁴

When Lehman Brothers filed for bankruptcy on September 15, 2008, the crisis intensified further. Banks became more reluctant to engage in interbank

⁴More specifically, the ECB started to allot significant excess liquidity at the beginning of the maintenance period which was then gradually reabsorbed over the remaining weeks of the period by reducing the allotment above the benchmark. This allowed counterparties to meet their strong preferences of "frontloading" liquidity at an early stage in the maintenance period. On average, banks still continued to have a liquidity surplus close to zero at the end of each period, as before August 2007. For further details see e.g. European Central Bank (2009).

money market trading and correspondingly relied on the use of ECB's refinancing operations. The tensions in the money market exacerbated, and the spread between the 3-month Euribor rate and the respective 3-month OIS rate shot up to 180 basis points in September and October 2008, see Figure B.1. On October 15, 2008 the ECB responded with further measures. This included the switch from its variable rate tender format to a fixed rate full allotment policy, hence satisfying the full liquidity demand of the banking sector, in all its regular and supplementary refinancing operations. Additionally, the liquidity provision was extended to operations to up to one year.⁵

Against this background, three questions of crucial importance arise. First, to what extent has the effectiveness of monetary policy, i. e. the clarity with which monetary policy signals are reflected in longer-term money market rates, been affected by the financial crisis? Second, how effective were ECB's measures in reducing the tensions in money market rates? And third, how much of the elevated Euribor rates were caused by risk premia associated with liquidity risk and counterparty risk? This shall be investigated in the following. The changes in the euro money market and in ECB's liquidity policy after August 2007, however, suggest to treat the crisis and pre-crisis period separately.⁶

3 Transmission Mechanism of Monetary Policy

3.1 First look at the data

The textbook view of the monetary transmission mechanism rests on the central bank's ability to steer the overnight interest rate. A rational-expectation mechanism then ensures the reflection of overnight rate movements in longer maturity rates.

As a starting point, we measure this relationship by means of a Granger causality test.⁷ For this purpose, we have collected daily data of 3-month Euribor and Eonia rates covering the period June 27, 2000 until June 30, 2009.⁸

⁵On March 28, 2008 and May 7, 2009 the Governing Council decided to conduct supplementary LTROs with a maturity of six months and one year, respectively. For further details, please refer to the ECB's press release web page.

⁶In the Appendix, we also provide a structural break point test which supports our sample split.

⁷See e. g. Thornton (1992) and Cuthbertson and Bredin (2000), for a similar approach.

⁸Prior to June 2000, the ECB experienced that the rationing of bids in its fixed rate tender *without* full allotment led to an escalating overbidding problem, i.e. banks increasingly exaggerated their bid volumes to circumvent the rationing, see Nautz and Oechsler (2006). In June 2000, the ECB stopped banks' overbidding by switching to a

This leaves us with 1851 observations for the tranquil period, 307 and 171 observations for the period until and after October 2008, respectively.

The results are presented in Table 1. Before August 2007, there is strong evidence for Granger causality between the Eonia and the 3-month Euribor. In the period until October 2008, this relationship vanishes completely. The test cannot reject its null, that the Eonia does not Granger cause the Euribor and vice versa.⁹ In the aftermath of the Lehman bankruptcy, when the developments intensified and the ECB switched to a fixed rate full allotment policy, the 3-month Euribor and the Eonia again Granger cause each other.

Table 1: Granger Causality Test

	Jun 27, 2000 - Aug 8, 2007	Aug 9, 2007 - Oct 14, 2008	Oct 15, 2008 - Jun 30, 2009
	<i>H₀ : 3M Euribor does not Granger cause Eonia</i>		
<i>F</i> -statistic	29.48	0.29	7.43
<i>p</i> -value	0.00	0.92	0.00
	<i>H₀ : Eonia does not Granger cause 3M Euribor</i>		
<i>F</i> -statistic	8.54	0.48	2.34
<i>p</i> -value	0.00	0.80	0.04

The results for the pre-crisis period show that short-term and longer-term interest rates mutually affect each other, see e. g. Estrella and Mishkin (1998) and Ordóñez et al. (2008). As regards the period between August 2007 and October 2008, the relationship between the Eonia and the Euribor may be disturbed. This may have important implications for the clarity with which monetary policy signals are reflected in the money market yield curve. A lowered degree of interest rate predictability will hinder ECB's ability to influence term money market rates and thereby short-term retail bank loan and deposit rates. The results for the period after the Lehman bankruptcy may, on the hand hand, point to an actual existence of a link between short-term and longer-term interest rates after October 2008. On the other hand, our result may suffer from the shortcomings that apply to general one-step-ahead causality test models as argued by Lütkepohl (1993), Durfour and Renault (1998) and Burda (2001). We will therefore investigate the

price-discriminatory variable rate tender format.

⁹Strictly speaking, a failure of Granger causality does not constitute a rejection of the relationship between the Eonia and the 3-month Euribor, however a failure to confirm it.

3.2 Modeling the 3M Euribor Dynamics

The reason why the money market yield curve, and in particular the 3-month Euribor, plays a crucial role for the monetary policy transmission process, stems from the fact that many retail market interest rates are linked closely to the Euribor, see e. g. Mojon (2000), de Bondt et al. (2002), and Sorensen and Werner (2006). We will therefore analyze the dynamics of the 3-month Euribor interest rate before and during the financial crisis. Following the expectation hypothesis of the term structure of interest rates, current longer-term rates should equal to the average expected overnight rate plus some term premium see e. g. Litterman et al. (1991) and Hamilton and Kim (2002). Therefore, we formulate our model as follows:

$$\begin{aligned}
 \Delta i3_t &= \alpha \Delta ois3_{t-1} + \beta_1 \Delta creditrisk_t + \beta_2 \Delta B_{t-1} \\
 &+ \gamma_1 MRO_t + \gamma_2 LTRO_t + \gamma_3 D_{TAF} \\
 &+ \gamma_4 D_{sLTRO3}^{an} + \gamma_5 D_{sLTRO6}^{an} + \gamma_6 D_{sLTRO12}^{an} + \gamma_7 D_{TAF}^{an} \\
 &+ \sum_{j=1}^5 \varphi_j \Delta r3_{t-j} + \mu + \epsilon_t
 \end{aligned} \tag{1}$$

where Δ denotes the first-difference operator. Our model is expressed in first differences in order to avoid potential issues of non-stationarity.¹⁰ In particular, when analyzing the impact of central bank measures, modeling the Euribor in first differences is the most appropriate approach.¹¹ *ois3* represents the 3M Eonia swap rate, *B* and *credit risk* denote the bid-rate dispersion and the corporate versus government bond yield spread, respectively, while *MRO* and *LTRO* control for the logged outstanding volumes related to the respective refinancing operations.

In order to capture *market's expectations*, most of the formulations of the standard test of the expectation hypothesis theory assume perfect foresight and include average realized overnight rates or forward rates instead. Market expec-

¹⁰Please refer to the Appendix for an analysis of the co-integration properties of the data.

¹¹A level representation would be justified if the liquidity risk premium falls on a day of ECB's operation but reverts to the previous level immediately after the operation. Instead, if the liquidity premium remains at the lower level over many days after an operation, the coefficient of the event cannot be interpreted as a central bank effect and it would likely appear insignificant, see also McAndrews et al. (2008).

tations over the next three months can also be measured by the 3-month Eonia swap rate (*ois3*), see e.g. Busch and Nautz (2010) and Carpenter and Demiralp (2009).¹² The Eonia swap rate, in general, is a derivative market reference rate for the euro area. Interest rate swap transactions with various Euribor maturities serve as a tool to speculate on and hedge against future interest rate movements. Therefore, the 3-month Eonia swap rate is a natural proxy for market's expectations. Hence, we have collected 3-month Eonia swap rates from Reuters covering the period June 2000 until June 2009. Until March 2008, the swap rate was determined at 4:30 p.m. CET. Therefore, we include the first lag of changes in Eonia swap rates to avoid timing issues.¹³ Hence, α measures the immediate adjustment of the 3-month Euribor to changes in the market's expectations about longer-term interest rates. Thus, if monetary policy is effective, i. e. is reflected properly in longer-term interest rate expectations α should be significant and positively signed.

In the expectation hypothesis literature, the *term premium* is usually treated as zero (after differencing) if the assumption holds that it changes only a negligible amount from one day to another. This might be a reasonable assumption in normal times. In a financial crisis, however, as recently seen, the premium may very well change significantly from one day to another. In theory, when all banks face uncertainty of risk at the same time, the premium is high. In such a situation, term loan markets come under stress and term interest rates will increase. To account for rises in the Euribor rates associated with these risks, we will include two measures in order to control for the liquidity risk component and credit risk component. For this purpose, the spread between the *financial corporate bond and government bond yield* from the Datastream database will serve as our credit risk proxy (*creditrisk*) for the period of June 2000 until June 2009. Bonds, in general, are debt securities generating identical cash flows in all states of the world. Government bonds are backed by the full faith and credit of the fiscal authority. A financial corporate bond, however, normally bears a default risk and hence carries higher interest rates than a government bond. The spread is therefore a natural proxy for credit risk.

Following Eisenschmidt et al. (2009), we use the *change in MRO's (aggregate)*

¹²In particular, Busch and Nautz (2010) show that spreads between Euribor and Eonia swap rates up to 12 month are stationary, i. e. $d \leq 0.5$

¹³The Euribor is determined at 11 a.m. CET. After March 3, 2008 the Eonia swap rate is, however, announced at 11:00 a.m. CET. For this period, the contemporaneous Eonia swap rate can be included as an explanatory variable.

bid rate dispersion as our liquidity risk proxy (B) for the period until October 2008.¹⁴ This data is based upon true bids of banks in ECB's weekly refinancing operations and publicly not available.¹⁵ If risk premia were of negligible amount, they should play rather a minor role before the crisis. During the crisis, we expect β_1 and β_2 to be significant and positively signed if both risks account for elevated Euribor rates.

As part of its weekly financial statement, the ECB announces its net lending to credit institutions associated with its monetary policy operations. The *outstanding volumes* of MROs and all longer-term refinancing operations are therefore a natural variable with which the effectiveness of ECB's liquidity provision can be evaluated. In normal times, MROs should not affect 3M Euribor rates since the ECB's liquidity management is performed so as to allow banks to fulfill their reserve requirements during the reserve maintenance period which is usually 4 to 5 weeks. One may expect that LTROs should also have no impact on the 3M Euribor since the ECB acts as a price taker and pre-announced the liquidity amount that it deemed appropriate to allot. As Brunnermeier (2009) argues, however, the ECB's collateralized lending enjoys seniority. An increase in the ECB's net lending may therefore make the junior unsecured Euribor lending more risky and hence more expensive.

During the crisis, the effectiveness of ECB's interventions depends upon the key forces driving the crisis. If credit risk were the only driver, the ECB's liquidity providing operations would almost by definition bound to prove ineffective. If, however, liquidity were the dominant risk, then ECB's liquidity provision should be effective, i. e. $\gamma_1 < 0$ and $\gamma_2 < 0$.

To examine the effect of the *US dollar liquidity provision* through a swap with the US Fed, we define a dummy variable as follows.¹⁶ The indicator denoted by D_{TAF} equals 1 on a day with any term auction facility (TAF) operation and zero on other days. In addition, since news releases can cause prices to change in

¹⁴After the ECB's switch to the fixed rate full allotment policy, this data is not available per construction.

¹⁵The aggregate bid rate dispersion refers to the average of all banks' volume weighted variances of their individual bids. It is determined when the main refinancing operation auction results are announced at 11.25 a. m. CET. The Euribor, however, is fixed at 11 a. m. CET. Therefore, the bid rate dispersion enters our regression with one lag in order to avoid timing issues.

¹⁶Taylor and Williams (2009) and McAndrews et al. (2008) apply a similar technique for the federal funds and US Libor market.

an efficient market we also control for the announcement of each operation.¹⁷ Hence, D_{sLTRO}^{an} and D_{TAF}^{an} indicate the collection of the announcement dates of supplementary LTROs and TAFs, respectively.¹⁸ If the undertaken measures have been effective in reducing elevated money market rates, the expected signs of the coefficients are negative.

4 Empirical Results

Table 2 summarizes the estimation results we obtained for the adjustment equation of the 3M Euribor before and during the financial crisis.¹⁹

Table 2: The adjustment equation of the 3-m Euribor

Variable	Coefficient	Sample	
		pre-crisis	crisis
<i>Market's Expectations</i>	α	0.681*** (6.29)	0.094** (2.44)
<i>Corporate vs. Government Bond spread</i>	β_1	0.001* (1.69)	0.001 (1.42)
<i>Bid Rate Dispersion</i>	β_2	0.364 (0.80)	2.087*** (4.79)
<i>Out. vol. related to MROs</i>	γ_1	0.001 (0.80)	-0.015*** (2.93)
<i>Out. vol. related to LTROs</i>	γ_2	0.001 (1.18)	-0.018** (2.45)
<i>Term Auction Facility</i>	γ_3		-0.001 (0.78)
<i>Ann. of 3M sLTROs</i>	γ_4		-0.004** (2.04)
<i>Ann. of 6M sLTROs</i>	γ_5		0.004 (1.10)
<i>Ann. of 12M sLTROs</i>	γ_6		0.001 (0.39)
<i>Ann. of TAFs</i>	γ_7		-0.001 (0.22)
<i>Persistence</i>	$\sum_{j=1}^5 \varphi_j$	0.036 (0.64)	0.683*** (11.61)
R^2		0.50	0.66
<i>Obs.</i>		1851	478

Notes: The table refers to Equation (1). ***, **, * indicate significance at the 1%, 5%, 10% level. Absolute t -statistics are computed according to Newey and West (1987). The term auction facility (TAF) is included as a dummy variable that equals 1 on a day with any TAF operation and zero on other days. The dummy variables to account for announcement effects are defined analogously. The pre-crisis sample runs from June 27 2000 to August 8 2007, and the crisis sample ends in 30 June 2009.

In normal times, monetary policy expectations as measured by the 3-month

¹⁷Regular MROs and LTROs are announced in an annual indicative calendar three months before the year for which they are valid. Therefore, we will only control for announcement effects related to supplementary refinancing operations during the crisis period.

¹⁸On February 1, 2008 the ECB announced that it would not participate in the February US dollar liquidity providing operations. Therefore, we define $D_{TAF}^{an} = -1$ for that special date since this announcement might have reduced the anticipated supply of liquidity in the TAFs and thereby have put an upward pressure on money market rates.

¹⁹Please refer to the Appendix for the adjustment equation of the 6-month and 12-month Euribor.

Eonia swap rate had a major and plausible impact on the 3-month Euribor. Thus, changes in longer-term interest rate expectations translated immediately to money market rates ensuring a expectations to be in line with monetary policy intentions. When market participants were expecting an increase of ECB's key policy rate by 25 basis points, the 3-month Euribor would adjust immediately by roughly 17 basis points. As regards our risk term, both the liquidity and credit risk proxy, as measured by the bid rate dispersion in ECB's MROs and the corporate versus government bond yield spread, respectively, appear to be of no or just a minor role for the change in Euribor rates. This may support the literature's view that risk premia may change only to a negligible amount. Also in line with our expectations are the results obtained for the liquidity provision in ECB's MROs and LTROs.

During the crisis, the adjustment of the Euribor rate to changes in the Eonia swap rate becomes less relevant in size and significance. This implies that after mid 2007, money market rates have a lower predictability on the basis of monetary policy expectations. In addition, the persistence of the Euribor has increased significantly. As Busch and Nautz (2010) argue, if money market rates are too persistent the lasting impact of shocks can impede the transparency of policy signals and the central bank's impact on money market rates along the yield curve. In fact, unclear policy signals about future interest rate decisions should lead to larger forecast errors and more persistent money market rates. This suggests that the effectiveness of monetary policy have been hindered further during the crisis.

With respect to our credit risk measure, we find the estimated coefficient for the corporate versus government bond yield spread to be insignificant, however plausibly signed. The plausible and highly significant result obtained for the change in the bid rate dispersion indicates that liquidity risk may have been the driving factor of elevated money market rates until October 2008.²⁰ This finding is also supported by our results obtained for our liquidity providing measures. The ECB's increase in net lending to credit institutions in its MROs and LTROs are found to have reduced the Euribor significantly and in a plausible way. An increase of the outstanding volume in MROs and LTROs by one percent decreases the Euribor by roughly 2 basis points. Following European Central Bank (2009),

²⁰Recall that the bid rate dispersion is a variable referring to the dispersion in ECB's price-discriminatory multi unit MROs. With the switch to the fixed rate full allotment policy, there is no dispersion by construction.

the share of supplementary LTROs has increased from 33 % of total refinancing volume before the crisis to 67% during the crisis. According to our results, this would imply an overall reduction of the Euribor of roughly 60 basis points. The impact of the liquidity providing measures is even greater during the period after October 2009, when the ECB switched to the fixed rate full allotment policy. Until October 2008, the outstanding volumes in LTROs, for instance, moved in the range between 150 and 450 €billions. After October 2008, we observe the range to be between 300 and 730 €billions. Additionally, the announcement of supplementary 12-month LTROs contributed to a reduction of 3-month Euribor rates. Table 2 shows also that the US dollar provision had no impact on Euribor rates, neither the actual operations nor its announcements.

5 Conclusion

In this paper we have analyzed the effectiveness of monetary policy before and during the financial crisis with respect to how well monetary policy expectations are reflected in the money market yield curve, how much money market interest rates were disturbed by liquidity and credit risk factors and how much the additional liquidity measures by the ECB have affected money market interest rates of 3, 6 and 12 month maturity.

We found that while during the financial market crisis, money market rates were heavily influenced by liquidity risk in the market, the reflection of monetary policy expectations in money market interest rates declined substantially. At the same time, however, we find that the additional liquidity support of the ECB has proven to be effective in affecting money market interest rates.

We conclude that while before the crisis, monetary policy operations have been neutral with respect to the monetary policy stance, i.e. they have not affected interest rates at longer maturities, in the financial crisis, money market interest rates at 3, 6, and 12 month maturity were very well affected by the liquidity measures of the ECB.

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A Euro Money Market Reference Rates

In the unsecured segment of the euro money market, the European overnight index average (Eonia), the European interbank offered rate (Euribor) and the Eonia swap rate (OIS) serve as the main instrument for benchmarking short-term rates and are used as the basis for settlement of interest rate contracts on many of the world's major futures and options exchanges.

The *Eonia* is an *effective* overnight reference rate published by the European Central Bank (ECB) at around 6.45 p. m. and 7.00 p. m. CET. The Eonia reflects the volume-weighted average interest rate of actual lending transactions carried out by a panel of approximately 50 banks in a given day. This market serves as an alternative source of refinancing to borrowing through ECB's open market operations. The ECB implements its monetary policy by steering the Eonia and thereby signalling its monetary policy stance. It is therefore of crucial importance that the Eonia closely follows the ECB's key policy rate, i. e. the minimum bid rate in its weekly main refinancing operations (MROs). The predictability of money market rates on the basis of monetary policy expectations, i. e. the clarity with which monetary policy signals are reflected in the money market yield curve, is a clear indicator for the effectiveness of monetary policy. This is important because expected short-term money market rates affect longer-term rates which are viewed to be fundamental for the transmission of monetary policy into prices and the real economy.

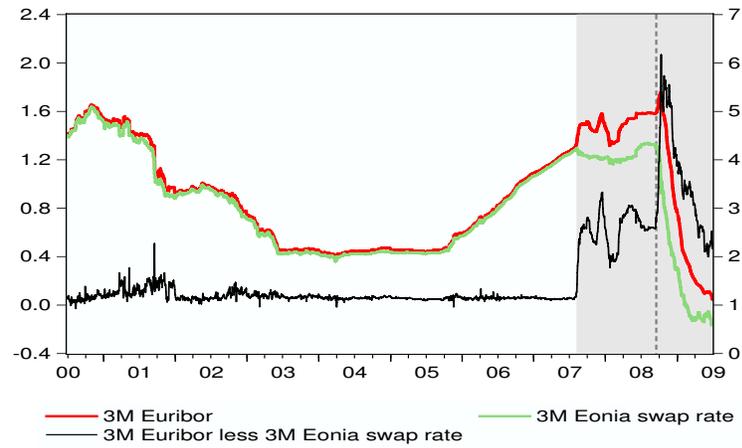
The *Euribor* is an *indicative* interest rate published by the European Banking Federation (EBF) at 11.00 a. m. CET. It reflects self-reported borrowing rates of a known selection of panel banks over a range of maturities. Contributors are asked to quote those rates at which, to the best of their knowledge, euro interbank term deposits are being offered within the euro area by one prime bank to another at 11 a. m. CET. Over-the-counter (OTC) transactions are determined on a bilateral basis and therefore notoriously hard to obtain. Thus, the Euribor fixing is considered to be the best (available) proxy for actual interbank money market transactions in the unsecured segment. It serves as the main instrument for benchmarking short-term rates and is used as the basis for settlement of interest rate contracts on many of the world's major futures and options exchanges, e. g. for setting mortgage rates in countries such as Spain.

The *Eonia swap* rate is another *indicative* reference rate that captures the evaluation of a representative panel of banks of what they believe is the mid market rate of EONIA Swap quotations between prime banks in a given day. This index is announced around 11.00 a. m. CET on a daily basis.²¹ In a swap contract, two parties agree to exchange a fixed rate (the swap rate) against a daily floating rate (Eonia) for a pre-agreed period of time. The Eonia swap rate therefore mirrors expected future Eonia rates over the investment horizon and with it the expected future policy rates. This is why the Eonia swap rate serves as the basis for the Eonia swap forward rate agreements (FRAs) and Eonia Swap Index futures. It is therefore a natural proxy for market's expectations of the future path of interest rates.

²¹Until March 2008, the publication date was 4:30 p. m. CET.

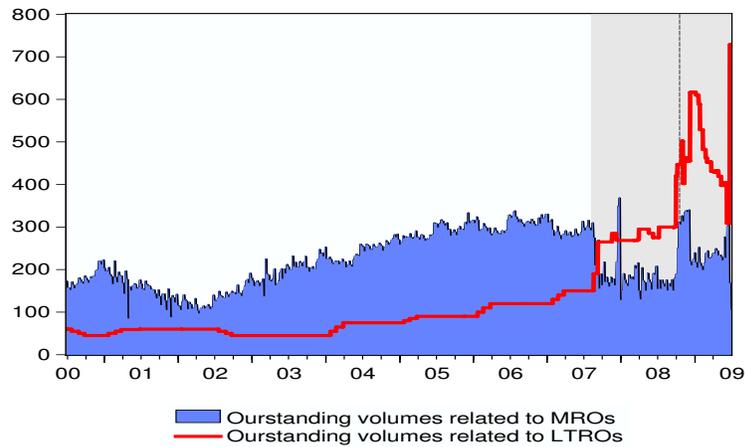
B Figures

Figure B.1: The 3-month Euribor, the 3-month Eonia swap rate and their spread



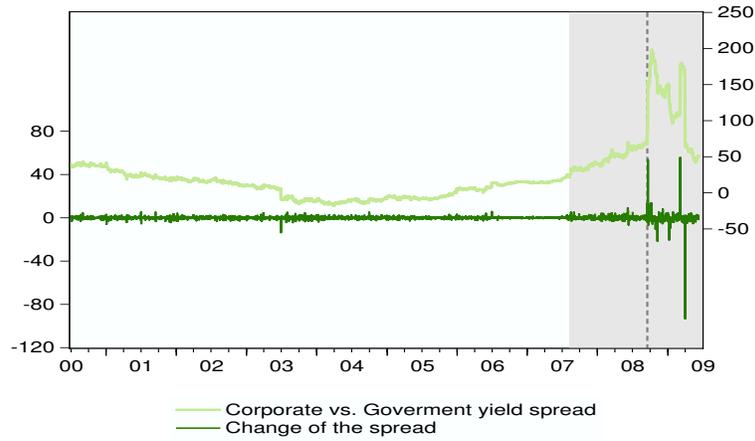
Notes: The shaded area refers to the period after August 9, 2007 and the dashed vertical line refers to the Lehman bankruptcy on August 15, 2008.

Figure B.2: The outstanding volumes related to MROs and LTROs (in billion euros)



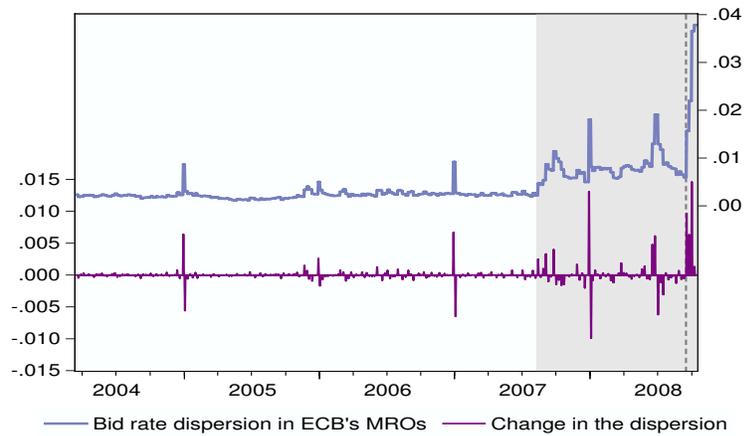
Notes: For details, please refer to Figure B.1.

Figure B.3: Financial corporate bond yield and government bond yield, and the spread (AA rating class)



Notes: For details, please refer to Figure B.1

Figure B.4: The ECB's MRO Bid Rate Dispersion



Notes: The aggregate bid rate dispersion refers to the average of all banks' volume weighted variances of their individual bids. For further details, please refer to Figure B.1.

C.1 6-month Euribor Dynamics

$$\begin{aligned}
\Delta i6_t &= \alpha \Delta ois6_{t-1} + \beta_1 \Delta creditrisk_t + \beta_2 \Delta B_{t-1} \\
&+ \gamma_1 MRO_t + \gamma_2 LTRO_t + \gamma_3 D_{TAF} \\
&+ \gamma_4 D_{sLTRO3}^{an} + \gamma_5 D_{sLTRO6}^{an} + \gamma_6 D_{sLTRO12}^{an} + \gamma_7 D_{TAF}^{an} \\
&+ \sum_{j=1}^5 \varphi_j \Delta r3_{t-j} + \mu + \epsilon_t
\end{aligned} \tag{2}$$

Table C.1: The adjustment equation of the 6-month Euribor

Variable	Coefficient	Sample	
		pre-crisis	crisis
<i>Market's Expectations</i>	α	0.510*** (8.51)	0.124** (2.08)
<i>Corporate vs. Government Bond spread</i>	β_1	0.001 (0.98)	0.001 (1.48)
<i>Bid Rate Dispersion</i>	β_2	0.308 (0.79)	0.766 (1.57)
<i>Out. vol. related to MROs</i>	γ_1	0.002 (1.08)	-0.013*** (2.59)
<i>Out. vol. related to LTROs</i>	γ_2	0.003** (2.22)	-0.014* (1.65)
<i>Term Auction Facility</i>	γ_3		-0.002 (0.99)
<i>Ann. of 3M sLTROs</i>	γ_4		-0.008 (1.56)
<i>Ann. of 6M sLTROs</i>	γ_5		0.003 (0.75)
<i>Ann. of 12M sLTROs</i>	γ_6		0.001 (0.74)
<i>Ann. of TAFs</i>	γ_7		0.001 (0.24)
<i>Persistence</i>	$\sum_{j=1}^5 \varphi_j$	0.026 (0.55)	0.616*** (6.89)
R^2		0.50	0.58
<i>Obs.</i>		1851	478

For details, please refer to Table 2.

$$\begin{aligned}
 \Delta i12_t &= \alpha \Delta ois12_{t-1} + \beta_1 \Delta creditrisk_t + \beta_2 \Delta B_{t-1} \\
 &+ \gamma_1 MRO_t + \gamma_2 LTRO_t + \gamma_3 D_{TAF} \\
 &+ \gamma_4 D_{sLTRO3}^{an} + \gamma_5 D_{sLTRO6}^{an} + \gamma_6 D_{sLTRO12}^{an} + \gamma_7 D_{TAF}^{an} \\
 &+ \sum_{j=1}^5 \varphi_j \Delta r3_{t-j} + \mu + \epsilon_t
 \end{aligned} \tag{3}$$

Table C.2: The adjustment equation of the 12-month Euribor

Variable	Coefficient	Sample	
		pre-crisis	crisis
<i>Market's Expectations</i>	α	0.538*** (8.46)	0.150** (2.43)
<i>Corporate vs. Government Bond spread</i>	β_1	0.001 (1.31)	0.001 (1.52)
<i>Bid Rate Dispersion</i>	β_2	-0.174 (0.28)	1.101** (2.43)
<i>Out. vol. related to MROs</i>	γ_1	0.001 (0.42)	-0.015** (2.48)
<i>Out. vol. related to LTROs</i>	γ_2	0.004** (2.54)	-0.015* (1.71)
<i>Term Auction Facility</i>	γ_3		-0.005* (1.86)
<i>Ann. of 3M sLTROs</i>	γ_4		-0.009 (1.25)
<i>Ann. of 6M sLTROs</i>	γ_5		0.003 (0.74)
<i>Ann. of 12M sLTROs</i>	γ_6		-0.008*** (5.08)
<i>Ann. of TAFs</i>	γ_7		0.001 (0.11)
<i>Persistence</i>	$\sum_{j=1}^5 \varphi_j$	-0.113** (2.41)	0.479*** (4.80)
R^2		0.44	0.46
<i>Obs.</i>		1851	478

Notes: For details, please refer to Table 2.

C.3 (Co-)integration properties of the data

Co-integration, in general, means that over the long run the short-term and long-term interest rates move in tandem with each other. The results from the co-integration analysis presented in Table C.3 refer to our full sample ranging from June 2000 until June 2009 and are in line with Campbell and Shiller (1987). They reveal that the Eonia and the Euribor rate have a unit root, i. e. are $I(1)$, and should be treated as non-stationary variables. As a consequence, an error-correction type representation proves to be the natural starting point for analyzing the Euribor dynamics.

Table C.3: Unit-Root Tests

Variable	ADF Test	Variable	ADF Test	Variable	ADF Test
i	-0.737	Δi	-25.137***	$\Delta ois3$	-9.851***
$i3$	-0.500	$\Delta i3$	-11.542***	$i3 - i$	-5.208***

Notes: *** denote the significance at 1 % critical value. The t-statistic of Augmented Dickey-Fuller (ADF) tests with a constant in the test equation and lag length according to the Schwarz Information Criterion. All results are robust against variation of the lag length or the deterministics in the equation.

C.4 Structural breakpoint test

C.4.1 Chow's breakpoint test

H_0 : No (structural) breaks at specified breakpoints		
Test Date	F -statistic	Log likelihood ratio
8/09/2007	89.33***	827.24***

Notes: ***, **, * indicates significance at the 1%, 5%, 10% level. The F -statistic is based on the comparison of the restricted and unrestricted sum of squared residuals. The log likelihood ratio statistic compares the restricted and unrestricted maximum of the (Gaussian) log likelihood function.

C.4.2 Quandt-Andrews unknown breakpoint test

Date	Maximum LR F -Statistic	p -value
08/06/2007	90.49	0.0000

Notes: The distribution of the maximum F -statistic is non-standard and follows Andrews (1993), and (approximate asymptotic) probabilities were calculated using Hansen (1997) method. For this matter we allowed a symmetric "trimming" of 5%.