DEUTSCHE
BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 14/2012

The effectiveness of monetary policy in steering money market rates during the financial crisis

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ISBN 978-3–86558–819–7 (Printversion)
ISBN 978-3–86558–820–3 (Internetversion)

Abstract

The financial crisis has deeply affected money markets and thus, potentially, the proper functioning of the interest rate channel of monetary policy transmission. Therefore, we analyze the effectiveness of monetary policy in steering euro area money market rates looking at, first, the predictability of money market rates on the basis of monetary policy expectations, and second the impact of extraordinary central bank measures on money market rates. We find that during the crisis money market rates up to 12 months still respond to revisions in the expected path of future rates, even though to a lesser extent than before August 2007. We attribute part of the loss in monetary policy effectiveness to money market rates being driven by higher liquidity premia and increased uncertainty about future interest rates. Our results also indicate that the ECB's non-standard monetary policy measures as of October 2008 were effective in addressing the disruptions in the euro area money market. In fact, our estimates suggest that non-standard monetary policy measures helped to lower Euribor rates by more than 80 basis points. These findings show that central banks have effective tools at hand to conduct monetary policy in times of crises.

Keywords: Monetary transmission mechanism; Non-standard monetary policy measures; European Central Bank; Interbank money market

JEL classification: E43, E52, E58

Non-technical Summary

The financial crisis starting in August 2007 has deeply affected financial markets around the world. In particular, money markets contracted substantially leading to severe disruptions in banks' short-term funding. Interest rates in the unsecured segment of the money market rose to unprecedented levels leading to a tightening of credit standards for both businesses and households. This has not only challenged the ability of central banks to effectively steer term money market rates via the setting of policy rates but also seriously impaired the transmission of monetary policy. Hence, central banks around the world have responded by substantial policy rate cuts and engaged in a series of non-standard monetary policy measures to alleviate the funding conditions in the money market.

This paper studies the effectiveness of the European Central Bank's monetary policy in steering short term money market rates during the crisis. Towards this aim, it explores the predictability of money market rates via the traditional policy rate expectations channel as well as the impact of the ECB's crisis-related (non-standard) monetary policy measures on term money market rates. We provide new evidence on the drivers of euro area money market rates, i.e. the 3-month, 6-month and 12-month Euribor rate, respectively. In particular, we investigate the effect of three factors: (i) changes of monetary policy expectations attributed to changes in the policy rate, (ii) liquidity risk and credit risk factors as well as interest rate uncertainty and (iii) the ECB's non-standard monetary policy measures during the crisis.

Overall, our results document a loss in the effectiveness of standard monetary policy during the crisis compared to the pre-crisis period. In fact, while before the crisis Euribor rates significantly respond to revisions of market expectations for all maturities under consideration, this relationship - though still statistically and economically significant - becomes weaker between August 2007 and October 2008 and further weakens in the period post October 2008. We find that changes in euro area money market rates were driven by elevated liquidity premia and become more persistent during the crisis. The

loss in policy effectiveness during the crisis, was to some extent compensated by the use of non-standard monetary policy. Indeed, our results provide strong evidence that the ECB's crisis-related monetary policy measures were highly effective in reducing Euribor rates and the uncertainty around the prevailing term money market rates. Our estimates suggest that the significant increase in the outstanding amounts associated with open market operations as of October 2008 caused Euribor rates to decline by more than 80 basis points.

Nicht-technische Zusammenfassung

Die seit August 2007 andauernde Finanzkrise hat die Finanzmärkte auf der ganzen Welt geprägt. Insbesondere sind Geldmärkte betroffen, auf denen die Zinssätze für unbesicherte Liquiditätstransaktionen auf bislang nie da gewesene Niveaus gestiegen sind. Dies hat zu einer erheblichen Beeinträchtigung von kurzfristigen Refinanzierungsmöglichkeiten der Banken geführt. Als Konsequenz ergeben sich daraus schärfere Kreditanforderungen für Unternehmen und Haushalte. Das erschwert aber nicht nur die Fähigkeit einer Zentralbank, die Geldmarktzinssätze mittels ihres Schlüsselzinsatzes zu steuern, sondern behindert zudem den monetären Transmissionskanal. Um die Finanzierungsbedingungen auf den Geldmärkten zu erleichtern, haben sich daher Zentralbanken auf der ganzen Welt zu starken Zinssenkungen entschieden und eine Reihe von unkonventionellen geldpolitischen Maßnahmen eingeführt.

Das vorliegende Papier untersucht die Effektivität der Geldpolitik des Eurosystems, kurzfristige Geldmarktsätze zu steuern. Dabei liegt der Fokus der Studie sowohl auf der Vorhersehbarkeit von Geldmarktzinssätzen auf Basis des traditionellen Zinskanals als auch auf dem Einfluss von unkonventionellen geldpolitischen Maßnahmen auf Geldmarktsätze. Unsere Analysen beschränken sich auf den drei-, sechs- und zwölfmonatigen Euribor und liefern neue Erkenntnis über die Effekte der folgenden drei Faktoren: (i) Veränderungen in den Erwartungen über die zukünftige Geldpolitik, (ii) Liquiditäts- und Kreditrisiko sowie Zinsunsicherheit und (iii) die krisenbedingten unkonventionellen geldpolitische Maßnahmen.

Relativ zur Vorkrisenperiode deuten unsere Ergebnisse für die Krise insgesamt auf eine Abnahme der Effektivität gewöhnlicher geldpolitischer Instrumente hin. Während wir vor der Krise für alle betrachteten Laufzeiten eine signifikante Reaktion auf Änderungen in den Markterwartungen finden, nimmt diese Beziehung -wenngleich sie statistisch und öknomisch signifikant bleibt- in der Periode von August 2007 bis Oktober 2008 ab und wird danach noch schwächer. Wir finden zudem, dass Veränderungen der Geldmarktsätze während der Krise durch erhöhte Liquiditätsprämien getrieben wurden und eine höhere Persistenz aufwiesen. Der Verlust der geldpolitischen Effektivität seit Anbeginn der Krise konnte aber teilweise durch die Anwendung unkonventioneller Geldpolitik kompensiert werden. Genauer gesagt zeigen unsere empirischen Befunde sehr deutlich, dass krisenbedingte geldpolitische Maßnahmen sich als besonders effektiv erwiesen haben, Euriborsätze und die Unsicherheit hinsichtlich künftiger Geldmarktsätze zu reduzieren. Die jeweiligen Schätzungen legen nahe, dass die Erhöhung der mit Offenmarktgeschäften assoziierten ausstehenden Beträge seit Oktober 2008 zu einer Reduktion der Euriborsätze um mindestens 80 Basispunkten geführt hat.

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1 Introduction

Since August 2007, financial markets around the world are severely impaired. In particular, money markets have contracted substantially with unsecured money market rates rising to unprecedented levels. This has caused serious disruptions in banks' short-term funding leading to a tightening of credit standards for both businesses and households. This has not only challenged the ability of central banks to effectively steer term money market rates via the setting of policy rates but also seriously impaired the transmission of monetary policy. Hence, central banks around the world have responded by substantial policy rate cuts and engaged in a series of non-standard monetary policy measures to alleviate the funding conditions in the money market.

This paper studies the effectiveness of the European Central Bank's monetary policy in steering short term money market rates during the crisis. Towards this aim, it explores the predictability of money market rates via the traditional policy rate expectations channel as well as the impact of the ECB's crisis-related (non-standard) monetary policy measures on term money market rates. For the U. S. a series of recent contributions have studied the impairment of money markets in the crisis, investigated the determinants and sources of elevated money market rates and, particularly, analyzed the effectiveness of the Fed's non-standard measures.[1] Empirical evidence for the euro area is rather scarce, see Cecioni et al. (2011). We provide new evidence on the drivers of euro area money market rates, i.e. the 3-month, 6-month and 12-month Euribor rate, respectively.

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[1]For instance, D'Amico and King (2010), Gagnon et al. (2011), and Swanson (2011) study the effectiveness of the Federal Reserve's (Fed) first and second quantitative programs, respectively. McAndrews et al. (2008), Christensen et al. (2009), Taylor and Williams (2009), and Wu (2011) assess the impact of Fed's term auction facility on the U.S. money market.

In particular, we investigate the effect of three factors: (i) changes of monetary policy expectations attributed to changes in the policy rate, (ii) liquidity risk and credit risk factors as well as interest rate uncertainty and (iii) the ECB's non-standard monetary policy measures during the crisis.

First, according to the expectations hypothesis, the term structure of money market rates should contain an implicit path of the expected future short term interest rate, i.e. the policy rate set by the central bank (e.g. Campbell and Shiller, 1991, and Rudebusch ,1995). This path reflects how interest rates will change if new information about the economic outlook and monetary policy necessitates a revision of the path. Hence, for effectively steering money market rates, interest rate expectations are required to be in line with the central bank policy intentions and the dispersion of market expectations should be kept at the lowest level possible. To study the effectiveness of standard monetary policy, we investigate how policy rate expectations have driven the dynamics of the Euribor rates before and during the financial crisis. We follow the framework of Kuttner (2001) and analyze changes in Euribor rates as a response to revisions to the expected path of future interest rates as proxied by changes in the correspondingly dated overnight-indexed swap (OIS) rates.

Second, the surge of money market rates since August 2007 has often been attributed to a corresponding rise in risk premia, see e. g. McAndrews et al. (2008), Christensen et al. (2009), Taylor and Williams (2009), Schwarz (2010), and Wu (2011). We provide evidence on the importance of liquidity and credit risk for the dynamics of money market rates in the euro area. In this context, we also look at how money market rates are affected by the uncertainty *around* the expected path of future interest rates as measured by implied volatility on Euribor futures, a factor that has not yet been accounted for in existing approaches.

Third, the ECB, like other major central banks around the world, has engaged in a set of non-standard monetary policy measures. The significant liquidity provision to financial institutions has expanded the ECB's balance sheet and has substituted for interbank intermediation. We analyze the impact of non-standard measures on term money market rates using the outstanding volumes associated with ECB's open market operations. This approach differs from existing literature in that it does not use binary variables to study the effectiveness of crisis-related monetary policy measures in reducing interest rates (e. g. McAndrews et al., 2008 and Taylor and Williams, 2009). The impact of ECB's crisis-related monetary policy measures has so far been largely confined to its effect on macroeconomic and financial aggregates, see e. g. Lenza et al. (2010), Fahr et al. (2011), Giannone et al. (2011), and Giannone et al. (2012). The quantification of the impact of non-standard measures on macro variables is usually based on underlying assumptions on changes in money market spreads implicitly attributed to the effect of non-standard measures. In providing the actual evidence on the effect of non-standard measures on money market rates, we add to the very scarce empirical literature on the financial market impact of non-standard measures for the euro area.

Overall, our results document a loss in the effectiveness of standard monetary policy during the crisis compared to the pre-crisis period. In fact, while before the crisis Euribor rates significantly respond to revisions of market expectations for all maturities under consideration, this relationship - though still statistically and economically significant - becomes weaker between August 2007 and October 2008 and further weakens in the period post October 2008. We find that changes in euro area money market rates were driven by elevated liquidity premia and become more persistent during the crisis. The loss in policy effectiveness during the crisis, was to some extent compensated by the use of non-standard monetary policy. Indeed, our results provide strong evidence that the ECB's crisis-related monetary policy measures were highly effective in reducing Euribor rates and the uncertainty around the prevailing term money market rates. Our estimates suggest that the significant increase in the outstanding amounts associated with open market operations as of October 2008 caused Euribor rates to decline by more than 80 basis points.

The remainder of the paper is organized as follows. The next section briefly elaborates on the importance of interbank money markets for the monetary transmission process. Variables that might determine the dynamics of Euribor rates are presented in

Section 3. We present our empirical model in Section 4 and our results in Section 5. Section 6 concludes.

2 Money Market Rates, Monetary Transmission, and the Expectations Hypothesis

The ECB sets its policy rate - and in normal times provides liquidity according to the implied liquidity needs of the financial sector - to steer short term money market rates. As central bank actions anchor economic agents' expectations about the future path of longer-term interest rates, the monetary policy stance is subsequently transmitted through the money market yield curve ultimately affecting other segments of broader financial markets (Woodford, 2003).[2] The euro interbank offered rate (Euribor) is the standard reference rate for the unsecured money market, which also serves as the benchmark for the pricing of fixed-income securities throughout the economy and determines short-term retail bank interest rates as well as mortgage rates (e.g. Sorensen and Werner, 2006). In this regard, the interbank money market plays a crucial role for credit market conditions and longer-term interest rates and, hence, for the effectiveness of monetary policy and its transmission to the overall economy.

In economic theory, the specific relationship between longer-term money market rates and the expected path of future interest rates relies upon the expectations hypothesis of the term structure. Its weak form postulates the equality between current longer-term rates and the average expected overnight rate plus a constant maturity specific risk premium, see e.g. Litterman et al. (1991) and Hamilton and Kim (2002).[3] In a first-difference representation of the respective longer-term interest rate, R, of maturity k, the relationship can be written as:

$$\Delta R_t(k) \quad = \quad \alpha \left(\frac{1}{k} \sum\nolimits_{j=0}^{k-1} \Delta E_t(r_{t+j}) \right) \tag{1}$$

[2]For a detailed discussion of the transmission channels see e. g. Mishkin (1995). Boivin et al. (2010) review the core channels of policy transmission and provide new insights on how the transmission mechanism might have evolved in recent decades.

[3]We consider the weak form of the expectations hypothesis or the liquidity premium and preferred habitat theory, respectively, to be the relevant form. The strong view without a premium conflicts with the fact that yield curves normally slope up, which would imply that short-term rates are expected to trend upwards indefinitely.

where Δ and E_t denote the first-difference and expectations operator, respectively, at time t. The advantage of expressing this relationship in first differences is twofold. First, it relaxes the assumption of perfect foresight (Mankiw and Miron, 1986, and Campbell and Shiller, 1991) and second, it allows to measure the effects of changes in expectations, i. e. the surprise element of monetary policy (Kuttner, 2001).[4] The latter is particularly important for our purpose of analysing the response of Euribor rate changes to market's revisions to the expected path of future interest rates. In Equation (1) α captures the relationship between the change in the current longer-term rate of maturity k and changes in the average expected overnight rate over the same horizon, i. e. $\frac{1}{k}\sum_{j=0}^{k-1}\Delta E_t(r_{t+j})$.[5]

The expectations hypothesis requires a theoretical one-to-one relationship for it to hold, i. e. $\alpha = 1$. However, the related empirical literature on this relationship provides markedly mixed results, frequently pointing to a rejection of the theoretical value (see e. g. Campbell and Shiller, 1991), albeit estimates of α are typically positive and significantly different from zero. The rejection of the theoretical value is often attributed to a specific cause, e. g. (i) time-varying risk premium, (ii) irrational expectations, (iii) the overreaction of long-term interest rates to expected changes in the short-term rate, see e. g. Thornton (2006) and the references therein. Recent papers suggest that the magnitude of the estimate of α is not a reliable indication of the validity of the expectations hypothesis, see e. g. Thornton (2006). Moreover, Kuttner (2001) argues that changes in current longer-term rates on the day of a policy rate change announcement reflect changes in the average expected overnight rates over the maturity of the contract. Therefore, the impact of a one-day surprise may be less than one-for-one.[6] Furthermore, Demiralp and Jorda (2004) show that many one-day policy steps have to do with the timing of the action rather than with their ultimate size.

In this paper, we will look at the expectations hypothesis relationship in the context

[4]This specification also avoids potential issues of non-stationarity associated with interest rates. Unit root tests are provided in the Appendix.

[5]Given the maturity horizon of our interest rate, we can neglect the Jensen's inequality term.

[6]Demiralp (2008) provides empirical evidence on this for the 3M Treasury Bill rate.

of the euro area money market yield curve. In particular, we are interested to what degree euro area money market rate changes are determined by the revisions of market's expectation for the future levels of interest rates, which we attribute to an effective transmission of monetary policy signals.

3 Determinants for Euribor Rates: Variables and Predictions

For our analysis, we use daily data of the three-month (3M), six-month (6M), and twelve-month maturities of the Euribor rate. The Euribor rate 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 publicly-known selection of banks over a range of maturities. Banks in the Euribor panel 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. Our sample covers the period from 10 March 2004 through 31 December 2009.[7] In the following we will discuss the key determinants of the Euribor rate.

3.1 Market's Expectations

An indicator that represents market's expectations of future monetary policy is the overnight indexed swap (OIS) curve. In the euro area, the OIS rate is the main instrument used by market participants to take positions on expected central bank actions. It reflects the average short-term rate that economic agents expect to prevail over the next k days. Hence, *changes* in euro area OIS rates suggest *revisions* in expectations of future overnight rates over the course of the correspondingly dated Euribor rate. In Equation (1), the term $\frac{1}{k}\sum_{j=0}^{k-1}\Delta E_t(r_{t+j})$ is substituted by $\Delta OIS_t(k)$ measures monetary policy expectations, using the respective OIS rate. If revisions to the expected path

[7]As of March 2004, the Eurosystem changed its operation framework. Prior to March 2004, the reserve maintenance period was not aligned with the setting of the policy rate. This had caused short term volatility to money market rates when banks expected interest rates to fall and refrained from bidding in the ECB's open market operations prior to the rate cut.

of future rates affect Euribor rates, α should have a positive sign.[8]

The OIS rate does not give any indication about the *uncertainty* of the market's expectations about future policy rates. Uncertainty may arise when misperceptions about future monetary policy decisions arise, see e. g. Nautz and Schmidt (2010). In particular in an environment of market distress, uncertainty about the course of future monetary policy may prevail. Hence, we control for the uncertainty associated with expected path of future interest rates by using implied volatility of Euribor futures as they are traded at the London International Financial Futures Exchange (LIFFE).[9] Contracts on interest rate futures rely upon the volatility of the underlying asset, i.e. on the Euribor rate in our case. In the futures market, even tiny moves are tradable. This implies a very sensitive measure of uncertainty. The volatility of Euribor futures is, in turn, closely linked to the volatility of Euribor rates given the linear relationship between these two series at final settlement, i. e. $F_t(k) = 100 - R_t(k)$ where $F_t(k)$ denotes the Euribor futures contract. If the market is uncertain regarding the expected path of future rates, the Euribor rates should respond positively to changes in implied volatility on Euribor futures.

3.2 Risk Measures

Rising money market rates since August 2007 were attributed to a corresponding rise in risk premia. A number of studies have analyzed how such risk premia can be decomposed into different sources of risk (e. g. McAndrews et al. (2008), Michaud and Upper (2008), Brunnermeier (2009), Christensen et al. (2009), Eisenschmidt and Tapking (2009), Taylor and Williams (2009) Schwarz (2010), Wu (2011)).

With regard to measuring liquidity risk, following Schwarz (2010), we use the spread between the Kreditanstalt für Wiederaufbau (KfW) and German federal government bonds to account for (market) liquidity premia present in the German government bond market. The KfW agency and German federal government bonds have the identical

[8]Since March 2008, the announcement of OIS rates has changed from 4:30 p. m. CET to 11 a. m. CET. In line with the fixing of the Euribor, the definition of $\Delta OIS_t(k)$ is adjusted accordingly.

[9]These contracts account for over 90% of euro-denominated short-term interest rate trades with an average daily volume of roughly 1,000,000 contracts.

credit profile as they are backed by the German fiscal authority.[10] In that sense, there is no credit risk attached. However, KfW agency bonds are less liquid than their federal government counterparts.[11] The spread between these bonds, therefore, captures the investors' demanded premium for present and expected transaction costs and for the risk of liquidity deterioration. In contrast to the unsecured segment of the money market, the sovereign debt market traditionally represents an environment in which there is negligible counterparty risk reflected in transaction prices that are agreed upon before the identity of the counterparty is even known.[12] Assuming that our liquidity measure is proportional to the liquidity premium in the money market, higher values of the KfW-government bond spread should hence lead to an increase in Euribor rates.

With regard to measuring credit risk, we compute the median CDS spread of Euribor panel banks using the Markit Group database. A CDS, in general, isolates per construction the credit risk component from other potential risks, such as interest rate risk and foreign exchange risk as investors buy pure credit risk, see Byström (2005) and Taylor and Williams (2009). High values of the median CDS spread are therefore an indication of high credit risk in the euro area financial sector. Assuming, therefore, that financial sector credit risk considerations affected interbank money market trading, higher CDS spreads of Euribor panel banks should be associated with higher Euribor rates.

3.3 Central Bank Measures

High money market spreads can be of serious concern for monetary policy when putting the clarity with which monetary policy intentions are reflected in the shape of the yield curve at risk. As a response to the tensions surrounding the money market after August 2007, the ECB reacted by increasing its liquidity provision towards euro area credit institutions. Until October 2008, the ECB provided additional liquidity via its main refinancing operations (MROs), additional fine tuning daily liquidity injections (FTOs)

[10] In fact, the German fiscal authority explicitly guarantees all KfW's current and future obligations, see www.kfw.de/en for details.

[11] Even though they are less liquid, the bonds are traded sufficiently enough to allow high frequency observations.

[12] While this may not be the case for all euro area government bond markets, especially since 2010, this is certainly true for German government bond prices also during the crisis.

and extended the size of its liquidity provision towards more longer term refinancing operations (LTROs).[13] After October 2008, the ECB's balance sheet grew considerably in size due to (i) the provision of unlimited liquidity at a fixed rate and (ii) a further extension of longer term refinancing facilities towards longer maturities.[14] If the additional liquidity provision helps to alleviate funding strains in the money market, this should lead to a corresponding decline in Euribor rates.[15]

As part of its weekly financial statement, the ECB announces its net lending associated with its monetary policy operations to credit institutions. Hence, the *outstanding volumes* associated with open market operations are therefore a natural variable to account for overall liquidity supply over the full set of maturities (1W, 3M, 6M, 12M) of the ECB's open market operations. Furthermore, the *announcement* of each (non-standard) operation may affect Euribor rates.[16] If the announcement had a relieving impact on the money market rates, Euribor rates are expected to decline on the day of the announcement.

4 Modeling the Euribor Dynamics

Using the relationship between interest rates as postulated by the expectations hypothesis, we specify the following model for the Euribor rate:

$$\begin{aligned} \Delta R_t(k) &= \sum_{i=1}^{3} \alpha_{1,i} D_{t,i} \Delta OIS_t(k) + \sum_{i=1}^{3} \alpha_{2,i} D_{t,i} \Delta IV_t(F) \\ &+ \sum_{i=1}^{3} \beta_{1,i} D_{t,i} \Delta CDS_t + \sum_{i=1}^{3} \beta_{2,i} D_{t,i} \Delta (KfW - bund)_t \\ &+ \sum_{i=1}^{3} \gamma_i D_{t,i} \Delta ln(OMOs_t) + \gamma_4 D^{an}_{nsOMO\ 3M} + \gamma_5 D^{an}_{nsOMO\ 6M} \\ &+ \gamma_6 D^{an}_{nsOMO\ 12M} + \sum_{i=1}^{3} \varphi_i D_{t,i} \Delta R_{t-1}(k) + \epsilon_t \end{aligned} \tag{2}$$

[13] However, overall liquidity provision was kept unchanged as excess liquidity was neutralized through liquidity absorbing operations at the end of a reserve maintenance period

[14] For a full list of undertaken measures see European Central Bank (2010).

[15] Note that prior to the crisis, the Eurosystem's open market operations were conducted according to the liquidity needs of the banking sector, steering the euro area's overnight rate (EONIA) to be close to the policy rate. Moreover, the LTROs were conducted as variable rate tenders with a pre-announced volume, so as to implement this operation fully neutral with respect to the ECB's monetary policy stance.

[16] Standard open market operations are announced in an annual indicative calendar three months before the year for which they are valid. Therefore, we will consider announcement effects related to non-standard refinancing operations during the crisis period.

where ΔR refers to the first-difference of the daily Euribor rates with a maturity of three, six, and twelve months (k={3M, 6M, 12M}). OIS captures the correspondingly dated OIS rate. IV refers to the implied volatility of the 3M Euribor futures (F). $OMOs$ captures the outstanding volumes associated with both the MROs and LTROs.[17] D^{an}_{nsOMO} is a binary variable that equals 1 on days when a non-standard open market operation is announced (as opposed to executed) and zero otherwise. The AR(1)-term (φ) controls for the persistence in changes in Euribor rates.[18]

Taking into account potential different Euribor dynamics before and during the financial crisis, we define a dummy variable (D_1) that equals 1 for the period of March 10 2004 through August 8, 2007. Moreover, also during the financial crisis, Euribor dynamics may have been different before and after the default of Lehman Brothers that had intensified significantly the turmoil in the markets. Accordingly, we define two further binary variables to account for the period August 9 2007 until October 14 2008 (D_2) and October 15 2008 through December 31, 2009 (D_3).

5 The Effectiveness of Monetary Policy: Empirical Results

5.1 Steering Euribor Rates: Monetary Policy Expectations and Uncertainty

The results obtained for the 3M, 6M, and 12M Euribor rate are presented in Table 1, 2, and 3, respectively. Before August 2007, the estimated coefficient of the OIS rate ($\hat{\alpha}_{1,1}$) indicates for all three Euribor maturities a highly significant response of the Euribor rate to revisions in monetary policy expectations. For example, a revision of market expectations by 25 basis points (the size of the typical policy rate change) will cause - according to our results - the 3M, 6M and 12M Euribor rate to rise within a day by 6.75, 5.82 and 7.72 basis points, respectively. For the period after August 2007, our

[17]Note that the outstanding volumes associated with the Eurosystem's open market operations are announced around 9:30 a. m. and hence known to the banks prior to the Euribor fixing.

[18]According to Hassler and Nautz (2008) and Busch and Nautz (2010) controllability of money market rates requires sufficiently low persistence in changes in longer-term money market rates. If money market rates are too persistent, the lasting impact of shocks can impede the transparency of policy signals and the central bank's influence on money market rates along the yield curve. Also the Schwarz information criterium suggests the inclusion of this term.

results still indicate a significant response of Euribor rates to changes in monetary policy expectations. However, Wald tests show that the response substantially declined in size, even more so in the period after October 2008. Nonetheless, it appears that despite the money market tensions as reflected in higher Euribor rates and their significant spread over the OIS rate, changes of monetary policy rate expectations - though to a lesser degree - still significantly drive money market rates.

Our results show that uncertainty in market expectations did not affect money market term rates before August 2007, which confirms earlier evidence by Nautz and Offermanns (2008). During the period August 2007 and October 2008, however, the Euribor rate increases by 14.5, 12.6, and 15.8 basis points ($\hat{\alpha}_{2,2}$), respectively, to a one percent increase of the implied volatility on Euribor futures. This is both statistically and economically highly significant. After October 2008, the uncertainty appears to have diminished substantially. Wald tests even suggest a reduction of the uncertainty to its pre-crisis level. This implies a well contained uncertainty around the central path of monetary policy.

5.2 Impact of Risk Factors and the Persistence of Euribor Rates

Our estimates show that liquidity risk significantly drives Euribor rate dynamics. The KfW-Bund spread affects the 3M Euribor rate throughout the complete sample while for the 6M and 12M Euribor rate it plays a significant role only until October 2008. The effects are both statistically and economically significant. For instance, an increase of liquidity risk in the pre-crisis sample by one basis point raises the 3M, 6M and 12M longer-term rate by 1.11, 1.79 and 3.62 basis points, respectively. In the period between mid 2007 and October 2008, an increase of liquidity risk by the same order of magnitude leads to a rise of the 3M, 6M, and 12M Euribor rate by 0.68, 1.11, and 1.39 basis points, respectively. For the period after October 2008, a rise of the KfW-Bund spread by one basis point is associated with an increase of the 3M Euribor by 0.37 basis points. According to our results credit risk concerns are found to have an impact on the 12M Euribor rate only during the pre-crisis period.

Table 1: The Dynamics of the 3-month Euribor Rate

Dependant Variable: $\Delta R_t(k = 3\text{M})$

Revision in Expectations			*Uncertainty in Expectations*		
$\alpha_{1,1}$	Mar 2004 - Aug 2007	0.271^{***} (4.25)	$\alpha_{2,1}$	Mar 2004 - Aug 2007	0.004 (0.20)
$\alpha_{1,2}$	Aug 2007 - Oct 2008	0.177^{***} (3.37)	$\alpha_{2,2}$	Aug 2007 - Oct 2008	0.145^{**} (2.01)
$\alpha_{1,3}$	Oct 2008 - Dec 2009	0.118^{***} (3.99)	$\alpha_{2,3}$	Oct 2008 - Dec 2009	0.021^{**} (2.00)
Credit Risk			*Liquidity Risk*		
$\beta_{1,1}$	Mar 2004 - Aug 2007	0.001 (1.18)	$\beta_{2,1}$	Mar 2004 - Aug 2007	0.011^{***} (3.14)
$\beta_{1,2}$	Aug 2007 - Oct 2008	0.001 (1.39)	$\beta_{2,2}$	Aug 2007 - Oct 2008	0.007^{**} (2.11)
$\beta_{1,3}$	Oct 2008 - Dec 2009	-0.001 (1.28)	$\beta_{2,3}$	Oct 2008 - Dec 2009	0.004^{***} (3.51)
OMO vol. outstanding			*CB Measures: Ann. Effect*		
γ_1	Mar 2004 - Aug 2007	0.020 (0.80)	γ_4	Ann. of 3M nsOMO	-0.002 (1.26)
γ_2	Aug 2007 - Oct 2008	0.019 (0.47)	γ_5	Ann. of 6M nsOMO	0.002 (0.60)
γ_3	Oct 2008 - Dec 2009	-0.033^{***} (3.48)	γ_6	Ann. of 12M nsOMO	-0.003^{***} (2.81)
Persistence			*Crisis Dummies*		
φ_1	Mar 2004 - Aug 2007	0.157^{***} (3.50)	*cons*		0.002^{***} (6.83)
φ_2	Aug 2007 - Oct 2008	0.574^{***} (6.53)	δ_1	Aug 2007 - Oct 2008	0.001 (0.11)
φ_3	Oct 2008 - Dec 2009	0.803^{***} (17.18)	δ_2	Oct 2008 - Dec 2009	-0.003^{***} (4.37)
R^2		0.63	Obs.		1448

Wald test on parameter equality

$\mathcal{H}_0 : \mathcal{D} = 0$

$\mathcal{D}$:	p-value	$\mathcal{D}$:	p-value
$\alpha_{1,1} - \alpha_{1,2}=$	0.254	$\alpha_{2,1} - \alpha_{2,2}=$	0.050
$\alpha_{1,2} - \alpha_{1,3}=$	0.330	$\alpha_{2,2} - \alpha_{2,3}=$	0.088
$\alpha_{1,1} - \alpha_{1,3}=$	0.030	$\alpha_{2,1} - \alpha_{2,3}=$	0.440
$\gamma_1 - \gamma_2=$	0.974	$\varphi_1 - \varphi_2=$	0.000
$\gamma_2 - \gamma_3=$	0.040	$\varphi_2 - \varphi_3=$	0.022
$\gamma_1 - \gamma_3=$	0.027	$\varphi_1 - \varphi_3=$	0.000

Notes: The estimation model is presented in Equation (2). HAC consistent, absolute t-statistics in parenthesis. ***,** ,* indicate significance at the 1%, 5%, 10% level.

Table 2: The Dynamics of the 6-month Euribor Rate

Dependant Variable: $\Delta R_t(k = 6\text{M})$

Revision in Expectations			*Uncertainty in Expectations*		
$\alpha_{1,1}$	Mar 2004 - Aug 2007	0.234^{***} (4.55)	$\alpha_{2,1}$	Mar 2004 - Aug 2007	0.015 (0.57)
$\alpha_{1,2}$	Aug 2007 - Oct 2008	0.112^{***} (2.78)	$\alpha_{2,2}$	Aug 2007 - Oct 2008	0.126^{**} (1.98)
$\alpha_{1,3}$	Oct 2008 - Dec 2009	0.124^{***} (4.56)	$\alpha_{2,3}$	Oct 2008 - Dec 2009	0.030^{***} (2.61)
Credit Risk			*Liquidity Risk*		
$\beta_{1,1}$	Mar 2004 - Aug 2007	0.054 (0.80)	$\beta_{2,1}$	Mar 2004 - Aug 2007	0.018^{***} (3.23)
$\beta_{1,2}$	Aug 2007 - Oct 2008	-0.004 (0.17)	$\beta_{2,2}$	Aug 2007 - Oct 2008	0.011^{***} (2.97)
$\beta_{1,3}$	Oct 2008 - Dec 2009	-0.008 (0.06)	$\beta_{2,3}$	Oct 2008 - Dec 2009	0.003 (0.26)
OMO vol. outstanding			*CB Measures: Ann. Effect*		
γ_1	Mar 2004 - Aug 2007	0.050 (0.69)	γ_4	Ann. of 3M nsOMO	-0.001 (0.17)
γ_2	Aug 2007 - Oct 2008	-0.033^{**} (2.01)	γ_5	Ann. of 6M nsOMO	0.004 (1.10)
γ_3	Oct 2008 - Dec 2009	-0.024^{***} (2.79)	γ_6	Ann. of 12M nsOMO	-0.002^{**} (2.09)
Persistence			*Crisis Dummies*		
φ_1	Mar 2004 - Aug 2007	0.138^{***} (2.65)	*cons*		0.002^{***} (4.26)
φ_2	Aug 2007 - Oct 2008	0.379^{***} (3.17)	δ_1	Aug 2007 - Oct 2008	0.001 (0.03)
φ_3	Oct 2008 - Dec 2009	0.842^{***} (17.96)	δ_2	Oct 2008 - Dec 2009	-0.003^{***} (4.28)
R^2		0.49	Obs.		1448

Wald test on parameter equality

$\mathcal{H}_0 : \mathcal{D} = 0$

$\mathcal{D}$:	p-value	$\mathcal{D}$:	p-value
$\alpha_{1,1} - \alpha_{1,2}=$	0.065	$\alpha_{2,1} - \alpha_{2,2}=$	0.013
$\alpha_{1,2} - \alpha_{1,3}=$	0.800	$\alpha_{2,2} - \alpha_{2,3}=$	0.048
$\alpha_{1,1} - \alpha_{1,3}=$	0.062	$\alpha_{2,1} - \alpha_{2,3}=$	0.583
$\gamma_1 - \gamma_2=$	0.264	$\varphi_1 - \varphi_2=$	0.065
$\gamma_2 - \gamma_3=$	0.618	$\varphi_2 - \varphi_3=$	0.003
$\gamma_1 - \gamma_3=$	0.230	$\varphi_1 - \varphi_3=$	0.000

Notes: The estimation model is presented in Equation (2). HAC consistent, absolute t-statistics in parenthesis. ***,** ,* indicate significance at the 1%, 5%, 10% level.

Table 3: The Dynamics of the 12-month Euribor Rate

Dependant Variable: $\Delta R_t(k = 12\text{M})$

Revision in Expectations			*Uncertainty in Expectations*		
$\alpha_{1,1}$	Mar 2004 - Aug 2007	0.309^{***} (8.04)	$\alpha_{2,1}$	Mar 2004 - Aug 2007	0.026 (0.57)
$\alpha_{1,2}$	Aug 2007 - Oct 2008	0.137^{***} (3.40)	$\alpha_{2,2}$	Aug 2007 - Oct 2008	0.158^{*} (1.88)
$\alpha_{1,3}$	Oct 2008 - Dec 2009	0.126^{***} (6.34)	$\alpha_{2,3}$	Oct 2008 - Dec 2009	0.028^{***} (2.58)
Credit Risk			*Liquidity Risk*		
$\beta_{1,1}$	Mar 2004 - Aug 2007	0.275^{*} (1.79)	$\beta_{2,1}$	Mar 2004 - Aug 2007	0.036^{***} (4.36)
$\beta_{1,2}$	Aug 2007 - Oct 2008	-0.006 (0.22)	$\beta_{2,2}$	Aug 2007 - Oct 2008	0.014^{***} (2.74)
$\beta_{1,3}$	Oct 2008 - Dec 2009	-0.002 (0.13)	$\beta_{2,3}$	Oct 2008 - Dec 2009	0.002 (1.46)
OMO vol. outstanding			*CB Measures: Ann. Effect*		
γ_1	Mar 2004 - Aug 2007	0.084 (0.51)	γ_4	Ann. of 3M nsOMO	0.005 (0.17)
γ_2	Aug 2007 - Oct 2008	-0.089^{**} (2.04)	γ_5	Ann. of 6M nsOMO	0.004 (0.98)
γ_3	Oct 2008 - Dec 2009	-0.016^{**} (2.26)	γ_6	Ann. of 12M nsOMO	-0.013^{***} (10.72)
Persistence			*Crisis Dummies*		
φ_1	Mar 2004 - Aug 2007	0.078^{**} (1.76)	*cons*		0.002^{**} (2.50)
φ_2	Aug 2007 - Oct 2008	0.163^{**} (1.76)	δ_1	Aug 2007 - Oct 2008	0.001 (0.71)
φ_3	Oct 2008 - Dec 2009	0.830^{***} (17.62)	δ_2	Oct 2008 - Dec 2009	-0.003^{***} (3.61)
R^2		0.32	Obs.		1448

Wald test on parameter equality

$\mathcal{H}_0 : \mathcal{D} = 0$

$\mathcal{D}$:	p-value	$\mathcal{D}$:	p-value
$\alpha_{1,1} - \alpha_{1,2} =$	0.002	$\alpha_{2,1} - \alpha_{2,2} =$	0.096
$\alpha_{1,2} - \alpha_{1,3} =$	0.799	$\alpha_{2,2} - \alpha_{2,3} =$	0.085
$\alpha_{1,1} - \alpha_{1,3} =$	0.000	$\alpha_{2,1} - \alpha_{2,3} =$	0.962
$\gamma_1 - \gamma_2 =$	0.306	$\varphi_1 - \varphi_2 =$	0.409
$\gamma_2 - \gamma_3 =$	0.090	$\varphi_2 - \varphi_3 =$	0.000
$\gamma_1 - \gamma_3 =$	0.544	$\varphi_1 - \varphi_3 =$	0.000

Notes: The estimation model is presented in Equation (2). HAC consistent, absolute t-statistics in parenthesis. ***,** ,* indicate significance at the 1%, 5%, 10% level.

With respect to the persistence in Euribor rates, we find that Euribor rates are characterized by a very "short memory" before the onset of the crisis, facilitating the ECB to effectively steer money market rates, compare Busch and Nautz (2010). However, Euribor rates became significantly more persistent after August 2007. In fact, we observe a threefold increase in persistence for changes of the 3M, 6M, and 12M Euribor rates until October 2008. After October 2008, we even observe a fivefold, sixfold and 12-fold rise for the 3M, 6M and 12M rates, respectively. These estimates also suggest a change in the long-run dynamics during the period after mid 2007 but in particular after October 2008.[19] For instance, the long-term effects of changes in market's expectations on the 3M, 6M, and 12M Euribor before the crisis amounted to 0.32, 0.27, and 0.34, respectively. For the period from August 2007 to October 2008, the effects are 0.42, 0.18, and 0.16, respectively. This effect significantly changes after October 2008: the long-run effects amount to 0.60, 0.79, and 0.74. We interpret the increased persistence as supportive to our finding that the effect of changes to monetary policy expectations on Euribor dynamics has become weaker in the crisis. The greater persistence in money market rates may further indicate that it is more difficult for monetary policy signals to be transmitted along the money market yield curve.

5.3 ECB's liquidity provision

In line with the fact that the ECB's liquidity provision was fully neutral with respect to its monetary policy stance, Euribor rates do not significantly respond to changes of the outstanding volumes before the onset of the crisis. Our results show that the Eurosystem's net increase in the outstanding amounts associated with open market operations helped to reduce Euribor rates. For the 6M and 12M Euribor rate, we see a significant impact on the Euribor rate for the period between August 2007 and October 2008. After October 2008, non-standard measures have a negative impact on all maturities of the Euribor under investigation. This may be explained by the fact that only after October 2008, the ECB provided liquidity without absorbing the excess

[19] The fact that there is a difference between short-term and long-term coefficients is a result of our specification which includes lagged endogenous variables.

liquidity at the end of the reserve maintenance period, i. e. leading to a significant increase in net liquidity provision.[20] In fact, the outstanding volumes associated with refinancing operations increased significantly and reached levels of around € 720 billion by the end of our sample, which corresponds to an increase in the outstanding amounts of open market operation by more than 50%. This implies an overall reduction of the 3M, 6M, and 12M Euribor rate by roughly 160, 120, and 80 basis points ($50 \cdot 100 \cdot \hat{\gamma}_3$), respectively.

Our findings also suggest that the announcement of the supplementary LTROs provided an important stimulus to the reduction of Euribor rates. For instance, the Euribor rates show to have been lower by roughly 0.3, 0.2 and 1.3 basis points, respectively, on days when 12M non-standard measures were announced.[21]

6 Conclusion

In normal times, the ECB is able to influence the term money market rate, i. e. Euribor via signaling its policy intentions. Money market rates in the euro area play a crucial role for the determination of short-term interest rates for retail bank loans and deposit rates. Since the outbreak of the financial crisis in August 2007, however, euro money markets have been severely impaired causing Euribor rates to rise to unprecedented levels with consequences for lending conditions of companies and households. In this paper we have analyzed whether these developments have compromised the effectiveness of monetary policy in steering money market rates. Towards this aim, we have looked at two criteria. First, how well revisions to monetary policy expectations have been reflected in the money market yield curve and second, how the ECB's crisis related (non-standard) monetary policy measures have affected money market rates of three-month, six-month and twelve-month maturity.

Our results reveal that Euribor rates respond to changes in monetary policy expectations before and also during the crisis. However, during the crisis, in particular after

[20] For a complete overview of the consolidated financial statement of the Eurosystem see `www.ecb.int/press/pr/wfs/2012/html/index.en.html`.

[21] The full list of all announcements that we use for our analysis is available on `www.ecb.int/mopo/implement/omo/html/index.en.html#com`.

October 2008, changes in monetary policy expectations seem to matter less. This loss in the effectiveness of monetary policy signaling can be attributed to a rise in the liquidity premium, increased uncertainty about the expected path of future interest rates as well a significantly more persistent Euribor rates during the crisis.

Therefore, our findings clearly point to impairments in the money markets. At the same time, we provide strong evidence that the ECB's crisis-related (non-standard) monetary policy measures have proven effective in reducing money market rates. Before the crisis, monetary policy operations were neutral with respect to the monetary policy stance, i. e. they did not affect money market rates at longer term maturities directly. During the financial crisis, however, the significant expansion of the central bank balance sheet through unlimited liquidity provision at fixed rate have exerted a significant influence on the dynamics of term money market rates at three-month, six-month, and twelve-month maturities. In particular, our results indicate that the ECB's net increase in the outstanding volumes associated with open market operations as of October 2008 accounts for at least a 80 basis point decline in Euribor rates. Moreover, the ECB's monetary policy communication during the crisis appears to have reduced significantly the impact of interest rate uncertainty on Euribor rates in the period after October 2008.

We conclude that part of the loss in the effectiveness of monetary policy during the financial crisis via the traditional interest rate channel was compensated by the effective use of liquidity operations affecting money market rates beyond the daily maturity. Central banks indeed have adequate tools at their disposal to conduct effective monetary policy, also in times of crises.

A Unit Root Tests

This section performs unit root tests on the Euribor and OIS rates for which the Augmented Dickey-Fuller t-statistics are presented in Table 4. For both the pre-crisis and crisis period, the Euribor and OIS rates of all considered maturities have a unit root, i. e. are I(1), and should thus be treated as non-stationary variables. To avoid the issues associated with non-stationarity, the Euribor and OIS rates should be expressed in first differences.

Table 4: Unit-Root Tests

Variable	ADF Test		Variable	ADF Test	
	Pre-crisis	Crisis		Pre-crisis	Crisis
$R(3)$	-0.89	-1.24	$\Delta R(3)$	-24.34***	-5.89***
$R(6)$	-1.15	-0.98	$\Delta R(6)$	-26.59***	-7.35***
$R(12)$	-1.11	-0.74	$\Delta R(12)$	-28.33***	-8.63***
$OIS(3)$	-1.29	-1.23	$\Delta OIS(3)$	-30.76***	-6.87***
$OIS(6)$	-1.22	-0.90	$\Delta OIS(6)$	-31.58***	-19.56***
$OIS(12)$	-1.21	-0.94	$\Delta OIS(12)$	-29.02***	-21.50***

Notes: *** denote the significance at 1 % critical value. The t-statistic of the Augmented Dickey-Fuller (ADF) tests refer to the test equation with a constant, a linear trend and the lag length according to the Schwarz Information criterium. However, all results are robust against variations of the lag length or the deterministics in the equation.

B Structural Break Test

This section uses structural break tests to investigate whether the period after August 9 2007, on the one hand, and October 15 2008, on the other hand, significantly changed the dynamics of Euribor rates. To that aim, the Chow breakpoint test is applied to the following equation of Euribor rate changes:

$$\Delta R_t(k) = \alpha_1 \Delta OIS_t(k) + \alpha_2 \Delta IV(F_t) + \beta_1 \Delta CDS_t + \beta_2 \Delta(KfW - bund)_t + \gamma \Delta ln(OMOs_t) + \varphi \Delta R_{t-1}(k) + \epsilon_t \quad (3)$$

We divide our sample from 10 March 2004 through 31 December 2009 into the following subsamples and test whether there has been a break in all the equation parameters α, β, γ and φ as of August 9 2007 (T_1) and October 15, 2008 (T_2). The Chow breakpoint test compares the sum of squared residuals obtained by fitting equation (3) to the entire sample with the sum of squared residuals obtained when separate equations are fit to each subsample. We report three test statistics for the Chow breakpoint test. The F-statistic is based on the comparison of the restricted and unrestricted sum of squared residuals. The *log likelihood ratio* statistic is based on the comparison of the restricted and unrestricted maximum of the (Gaussian) log likelihood function. The Wald statistic is computed from a standard Wald test of the restriction that the coefficients on the equation parameters are the same in all subsamples. While the F-statistic has an exact finite sample F-distribution, the *LR* and *Wald* test statistic have both an asymptotic χ^2 distribution with d degrees of freedom, where d is the number of parameters in the equation.

The results confirm that the dynamics of Euribor rates have significantly changed after mid 2007 and October 2008, respectively. For all maturities, the test statistics strongly reject the null hypothesis of no structural change as of August 9 2007 and October 15, 2008.

$\mathcal{H}_0$: No break at specified breakpoint						
Statistic	Euribor					
	$k = 3M$		$k = 6M$		$k = 12M$	
	T_1	T_2	T_1	T_2	T_1	T_2
F	8.98 (0.0000)	11.03 (0.0000)	27.97 (0.0000)	24.38 (0.0000)	46.28 (0.0000)	29.68 (0.0000)
LR	88.26 (0.0000)	107.68 (0.0000)	258.73 (0.0000)	228.08 (0.0000)	405.91 (0.0000)	273.17 (0.0000)
$Wald$	66.12 (0.0000)	47.91 (0.0000)	126.64 (0.0000)	99.70 (0.0000)	183.99 (0.0000)	208.22 (0.0000)

Notes: Specified break date and p-values in parenthesis. Subsamples: March 10, 2004 to August 8 2007, August 9 2007 to October 14 2008, and October 15 2008 to December 31, 2009 for the daily Euribor of three-month, six-month, and twelve-month horizon. T_1 denotes August 9 2007 while T_2 refers to October 15, 2008.

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