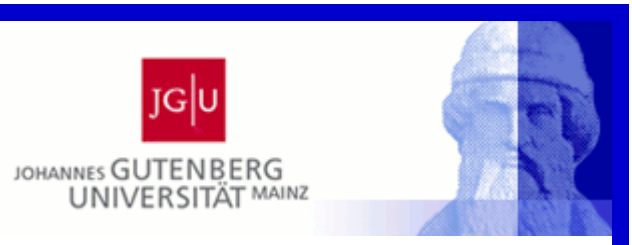

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Monetary Transmission Right from the Start: The (Dis)Connection Between the Money Market and the ECB's Main Refinancing Rates

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Monetary Transmission Right from the Start: The (Dis)Connection Between the Money Market and the ECB's Main Refinancing Rates*

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Abstract

The relation between the ECB's main refinancing (MRO) rates and the money market is key for the monetary transmission process in the euro area. This paper investigates how money market rates respond to the new information revealed by MRO auctions. Our results confirm a stabilizing level relationship between the overnight rate Eonia and MRO rates before the financial crisis. Since the start of the financial crisis, however, we find that MRO auction outcomes even exacerbated the disconnection of money market rates from the policy-intended interest rate level. These findings support the fixed rate full allotment policy introduced by the ECB as an unconventional measure to re-stabilize banks' refinancing conditions.

Keywords: Financial Crisis; Monetary transmission process; Central bank auctions; European Central Bank; Money markets

JEL classification: E43; E52; E58; D44

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1 Introduction

Weekly main refinancing operations (MROs) are of overwhelming importance for the monetary policy implementation of the European Central Bank (ECB). The liquidity supply in MROs should ensure that short-term money market rates closely follow the MRO rates and that their volatility remains well contained, see e. g. Cassola and Morana (2008) and Ejerskov et al. (2008). This central aim of monetary policy implementation has never been an easy task. Even before the financial crisis, a puzzling and unintended upward trend in the spread between the European overnight rate (Eonia) and the MRO rates indicated that the monetary transmission mechanism is not sufficiently understood, see Linzert and Schmidt (2010).[1] Since the start of the financial crisis, spreads between the ECB's main refinancing rates and the money market rates have been huge and persistent. In order to shed more light on the very beginning of the monetary transmission process in the euro area, this paper investigates how the European money market responds to MRO auction outcomes.

On the allotment day, the ECB publishes the number of bidders, total allotment and total bids together with the marginal and the weighted average allotment rate of the MRO. All these variables may contain new information about the expected course of monetary policy and the situation in the money market. This paper assesses the role of MROs for the monetary transmission mechanism by estimating the response of money market rates to the various aspects of a MRO auction outcome.

Our study can be related to two groups of papers. First, there is a growing empirical literature on the dynamics and the volatility of overnight rates. Recent examples include Bartolini and Prati (2006), Pérez Quirós and Rodríguez Mendizábal (2006), Colarossi and Zaghini (2009), and Nautz and Scheithauer (2009). All these contributions investigate how distinguishing features of the central bank's operational framework influence the behavior of overnight rates. They do not focus on the response of the overnight rate to auction outcomes. The second group of papers explores banks' bidding behavior in central bank auctions, see e. g. Linzert et al. (2007), Bindseil et al. (2009), and Cassola et al. (2009). Using individual bidding data, it can be shown that money market conditions significantly affect banks' bidding behavior. These papers try to explain the auction outcome but do not consider its repercussions on the money market.

The current paper fills this gap and explores the impact of the ECB's MRO auctions on short-

[1] In contrast to earlier estimates of the liquidity effect, even the ECB's provision of massive excess liquidity in MROs could not bring the Eonia back to its intended level, see European Central Bank (2006). In the U. S. the empirical relevance of the liquidity effect has been analyzed by e. g. Carpenter and Demiralp (2008) and Thornton (2008).

term money market rates in the euro area using both daily and intra-day data of overnight rates. Longer-term Eonia swap rates are employed to examine how the auctions affect market's expectations about future Eonia movements. Our results show that the recent crisis significantly impeded the first step of the monetary transmission mechanism. Before the financial crisis, MRO auction outcomes helped to stabilize the money market. If e. g. the spread between the Eonia and the new MRO rate was above average, the Eonia would adjust accordingly. Since the outbreak of the crisis, however, the stabilizing effect of MRO auctions on the Eonia level has disappeared. In contrast, MRO auction outcomes distorted by safety bids exacerbated the disconnection of money market rates from the policy-intended interest rate level. Therefore, our results provide strong support for the ECB's decision to re-stabilize banks' refinancing conditions by introducing a fixed rate full allotment policy for the whole maturity spectrum of its refinancing operations as of October 2008.

The remainder of the paper is structured as follows. In Section 2, we briefly review the role of MRO auctions in the operational framework of the ECB and consider the timing of the auctions. Section 3 introduces the auction variables and discusses their expected influence on the money market. Section 4 presents the empirical results on the impact of MRO auction outcomes on money market rates before and during the crisis. Section 5 summarizes our main results and offers some concluding remarks on the choice of MRO auction formats for the post-crisis period.

2 The Role of MRO Auctions in the ECB's Operational Framework

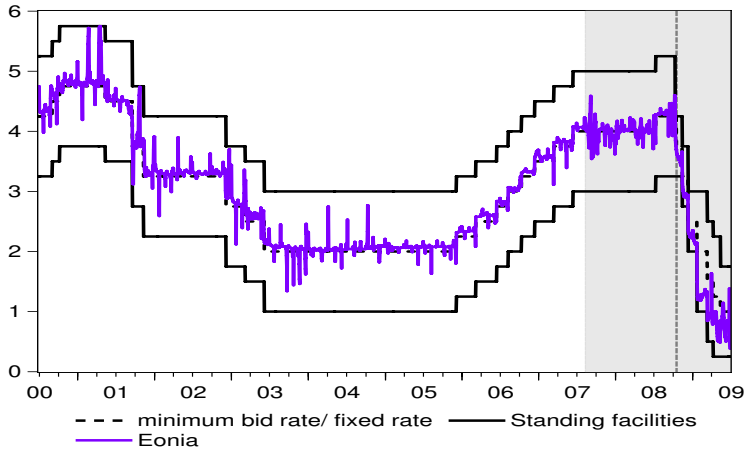
2.1 Monetary Policy Implementation

The ECB implements its monetary policy through a framework in which the banking sector operates in a liquidity deficit vis-á-vis the Eurosystem. The weekly main refinancing operations (MROs) cover the bulk of banks' liquidity demand and play the pivotal role in signalling the monetary policy stance. From June 2000 until October 2008, MROs were conducted as variable rate tenders, i. e. as price-discriminatory multi-unit auctions where banks are allowed to submit multiple price-quantity bids. In variable rate tenders the resulting repo rates partially depend on the bids of the banks and, thus, are not under the ECB's full control. Therefore, the ECB pre-announces a minimum bid rate. The interest rates actually applied in the MROs can be viewed as the first step in the transmission of monetary policy and should determine the level of short-term interest rates in the euro area's money market.

Unlike the U. S. Federal Reserve Bank, the ECB has never announced an explicit operational

target for its monetary policy implementation, see e. g. Ho (2008). However, there is no doubt that the ECB's liquidity policy aims at stabilizing the shortest money market rate, Eonia, to a level close to its main refinancing rates, see e. g. Cassola and Morana (2008) and Ejerskov et al. (2008). Figure 1 shows the corridor in which the Eonia fluctuates between the two standing facilities and the minimum bid rate as its mid-point.

Figure 1: The interest rate corridor of the ECB



Notes: The light shaded area refers to the crisis period as of August 9, 2007. The dashed vertical line represents the ECB's adoption of the fixed rate tender procedure with full allotment as of October 15, 2008.

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 liquidity shortages in the money market. In the euro area, the overnight rate rose substantially following an increased liquidity demand in the overnight market. As a consequence, the ECB increased the amount of liquidity in its weekly MROs significantly. In order to account for the changes in the demand and supply of liquidity in the ECB's MROs, we allow money markets to respond differently to auction results after August 2007. Therefore, we explore the link between the Eonia and MROs for the crisis and pre-crisis sample separately. In fact, splitting our sample on August 9, 2007 is also implied by structural breakpoint tests, see Section B in the Appendix.

After Lehman Brothers filed for bankruptcy on September 15, 2008, the crisis intensified. Banks became even more reluctant to engage in interbank money market trading and relied to an increasing extent on the ECB's refinancing operations, see e. g. Hauck and Neyer (2010). On October 15, 2008 the ECB responded to the exacerbated crisis and switched from the variable rate tender format to a fixed rate full allotment policy, hence satisfying the full liquidity demand of the

banking sector.[2] The information content of an auction outcome is very limited under this format: In a fixed rate tender, the repo rate is pre-announced and all MRO rates are equal by construction. Moreover, due to full allotment, the cover-to-bid ratio is always one. Therefore, in the following empirical analysis on the information content of MROs, we shall focus on the variable rate tender period. Yet, our results may shed light on the rationale behind the ECB's switch to the fixed rate full allotment tender format.

2.2 Measuring the Money Market Response to an MRO Auction Outcome

In the MROs of the ECB, banks are invited to submit their bids from Monday 3:30 p. m. CET to Tuesday 9:30 a. m. CET. At Tuesday 11:20 a. m. CET, the ECB communicates the auction outcome via its wire service. The response of the money market to an auction outcome should be reflected in overnight rates observed immediately after the auction results are available. Let i_b and i_a be the market rates valid *b*efore and *a*fter banks are informed about the auction outcomes. The money market response to the auction is then revealed in $\Delta i = i_a - i_b$. We measure Δi in three ways and thereby cover three main trading segments of the money market. First, in line with the empirical literature, we use daily data of the Eonia, the European Over-Night Index Average published by the ECB.[3] Eonia rates refer to transactions carried out before the closing of real-time gross settlement (RTGS) system at 6.00 p. m. CET and are published on the same evening. Since the bulk of money market transactions are carried out after the auction result is announced, the timing of MROs suggests to use Eonia rates of Monday (i_b) and Tuesday (i_a) to measure the money market reaction to an auction outcome.

If money markets react quickly to new information about the liquidity situation, the *average* overnight rate at the auction day might be only a poor approximation for i_a and similar problems may apply to i_b. Therefore, in a second specification of Δi, we use intra-day broker quotes collected from Reuters at 9:30 a. m. CET and 11:25 a. m. CET for i_b and i_a, respectively. These rates are very close to the end of bid submission and the announcement of the auction outcome. Yet the available intra-day data bears two shortcomings. Firstly, intra-day data cover only that part

[2] On March 4, 2010 the ECB announced that the full allotment policy for MROs will be applied at least until October 2010, see ECB's press release webpage. For further explanations, refer to European Central Bank (2010).

[3] The Eonia is based on a panel of approx. 50 banks with the highest business volume in the euro area money market, see http://www.euribor.org. Following European Central Bank (2007), the unsecured market remains mainly an overnight market segment, with roughly 70% of the volumes both in the lending and borrowing activities in the shortest maturity bucket.

of the 'over the counter' (OTC) market trading that is processed through voice brokers. [4] Thus, transactions between banks directly are missing. And secondly, in contrast to the daily Eonia data, intra-day data only refer to unbinding quotes rather than actual transactions.

A third approximation of Δi uses daily data of Eonia swap rates with one-week maturity obtained from Reuters. The Eonia swap market, in general, serves as the main instrument to manage short-term interest risk exposures and covers roughly 40% of the overall OTC derivatives market, see e. g. European Central Bank (2007). The one-week swap rate corresponds to the maturity of the MROs and measures the expected average Eonia over the next week. Thus, it is less affected by outliers than the daily Eonia. Because MROs are conducted only once a week, the one-week Eonia swap rate cannot be affected by expectations about future auction outcomes at an auction day. Since March 2008, the announcement of Eonia swap rates has changed from 4:30 p. m. CET to 11 a. m. CET. In line with the timing of MROs, the definition of Δi is adjusted accordingly.

Starting with the first price-discriminatory multi-unit auction on June 27, 2000 we have collected 434 auctions until October 14, 2008. The intra-day data is only available for December 4, 2000 to June 17, 2008. For the sake of comparability, we will run all our regressions from December 4, 2000 to June 17, 2008. At the end of the reserve maintenance period, when no further MRO will be conducted, liquidity shortages or excess reserves can lead to dramatic increases of overnight rate volatility. It is well understood by the market that these seasonal interest rate fluctuations are temporary and unrelated to monetary policy signals, see e. g. Nautz and Offermanns (2008). To ensure that our results will not depend on the large Eonia movements at the very last day of the reserve period, we excluded the auctions performed at those particular days from our regressions.[5] After these sample adjustments, we are left with 282 and 33 auctions before and during the crisis, respectively.

[4] According to European Central Bank (2007), more than 90% of all interbank transactions in the OTC derivatives market (other than foreign exchange swaps) are traded directly or through voice brokers. Since data on bilateral trading is notoriously hard to obtain, we use transactions through voice brokers that account for 27% of the total turnover in OTC derivatives.

[5] For the sake of robustness, two further observations were identified as outliers: the MRO with anomalous allotment one week after the terrorist attack on September 11, 2001 and the MRO distorted by the announcement of the six-month supplementary operation in April 2008.

3 The MRO Auction Outcomes: Variables and Predictions

On the allotment day, the ECB publishes (i) the marginal rate (r_m) of the MRO, (ii) the quantity weighted average rate (r_w) of all successful bids, (iii) total bids and total allotments, and (iv) the number of bidders. All these variables may contain new information about the situation in the money market and the policy-intended interest rate level.

The ***marginal rate*** or stop-out rate of a MRO, r_m, depends on both, banks' bidding behavior and the ECB's allotment decision. In any case, deviations of the marginal rate from the overnight rate valid immediately before the auction, $r_m - i_b$, should imply that the overnight rate i_a adjusts accordingly. In an error-correction type adjustment equation of Δi, the coefficient of $r_m - i_b$ is expected to be positive.

Before the crisis, the ***weighted average rate*** of a MRO, r_w, used to be only a few basis points above the marginal rate. By contrast, after August 2007, the MRO spread, $r_w - r_m$, increased up to 30 basis points, see Figure A.1. The MRO spread can be large for two reasons. On the one hand, it may indicate that the bulk of bids had been submitted at relatively high rates because the demand for liquidity had been stronger than expected. Particularly in the recent financial crisis, banks faced a great uncertainty regarding their future liquidity situation. According to Cassola et al. (2009), banks submitted more aggressive bids in order to make sure that they receive at least a minimum level of liquidity. On the other hand, large MRO spreads may reveal bidders' uncertainty about the auction's marginal rate, see e. g. Välimäki (2008). The increased heterogeneity of values for liquidity revealed by the auction and the failure of the interbank market to lead to an efficient allocation of liquidity among banks in the course of the crisis made it very difficult to forecast the marginal rate of MRO auctions. For both reasons, a MRO auction revealing a large MRO spread should lead to an upward pressure on the overnight rate.

The ***cover-to-bid ratio***, CBR, of a MRO is defined as the ratio between the ECB's total allotment and the banks' total bid volume, compare Figure A.2. Large cover-to-bid ratios indicate that banks received a lot of refinancing relative to their bids. One might expect that overnight rates should always decrease with increasing cover-to-bid ratios. However, as Linzert et al. (2007) already emphasized, a low cover-to-bid ratio only leads to money market tensions if it resulted from banks' misperceptions of the marginal rate and the situation in the money market. If banks bid seriously and the marginal rate of the MRO simply exceeded banks' willingness to pay, a low cover-to-bid ratio will not necessarily lead to increasing overnight rates.

Until March 2004, banks anticipated future rate cuts of the ECB on several occasions and, therefore, simply refrained from bidding. As a result, banks' total bid volume was so low that the ECB could not allot the intended volume of reserves. Due to banks' underbidding, the cover-to-bid ratio peaked to one but due to the lack of reserves overnight rates increased sharply at the auction day. In order to stop the disturbing strategic bidding behavior of banks, the ECB adjusted its operational framework in March 2004. Reducing the MRO maturity from two to one week and synchronizing its interest rate decisions with the reserve requirement periods ensured that auction results are not affected by banks' expectations about future policy rates, see e. g. European Central Bank (2003). To avoid that our results are driven by underbidding episodes, we exclude these observations from the following regressions and allow for a different information content of cover-to-bid ratios before and after March 2004.

The ***number of bidders*** in MROs has significantly declined since June 2000, see Figure A.3. Following e. g. Bindseil et al. (2009), we estimated the new information contained in the number of bidders, i. e. the unexpected part in this variable, employing a univariate forecast equation, see Section C in the Appendix. Note that alternative forecast and de-trending methods would not affect our results in a significant way. In case of a surprisingly large number of bidders which should reveal an unexpectedly high demand for refinancing, the overnight rate should increase.

Daily autonomous liquidity factors and reserve requirements drive banks' liquidity needs. Since June 2000, the ECB uses weekly autonomous factors forecasts to rationalize its current allotment decision and to determine its benchmark allotment. If actual autonomous factors are higher than the ECB's benchmark allotment calculation would suggest, the liquidity situation should be tight leading to tensions in the overnight rate, see Linzert and Schmidt (2010). Therefore, the difference between ***updated forecasts and forecasted autonomous factors***, ΔAF, should be included as a control variable in the empirical analysis of the link between MROs and the money market. While the ECB's forecast of autonomous factors is known to the banks before the MRO auction is conducted, the updated values are provided on the allotment day together with the MRO auction results, between 11:15 a. m. CET and 11:20 a. m. CET. Therefore, we would expect ΔAF to increase daily overnight rates.

4 The Response of Money Market Rates to MRO Auction Outcomes

According to the martingale hypothesis, the overnight rate on any day corresponds to the expected overnight rates on the following days of the same reserve maintenance period, see e. g. Bindseil (2004a). Therefore, within the reserve maintenance period, money market rates should only react to new information and, in particular, to the unexpected components of an auction outcome. As a consequence, our empirical results on the relationship between the ECB's MRO auctions and the money market are based on the following error-correction type adjustment equation for the money market rate,

$$\begin{aligned} \Delta i_t &= c + \alpha(r_m - i_b)_t + \beta(r_w - r_m)_t \\ &+ \gamma_C CBR_t + \gamma_B B_t + \gamma_A \Delta AF_t + \varepsilon_t, \end{aligned} \tag{1}$$

where for each auction t, $\Delta i_t = i_{a,t} - i_{b,t}$ denotes the change of the money market rate immediately after the MRO auction results have been published. α and β determine the impact of the marginal (r_m) and the weighted average MRO rate (r_w) on the Eonia. Since $r_w - r_m = (r_w - i_b) - (r_m - i_b)$, equation (1) is a re-parameterization of the adjustment equation which includes both equilibrium relationships between the auction and the money market rate, i. e. $(r_m - i_b)$ and $(r_w - i_b)$. Therefore, $\alpha = 0$ implies that the Eonia is disconnected from *both* MRO rates, since there is neither an equilibrium relation with the marginal nor with the weighted average MRO rate. In particular, in case of $\alpha = 0$ and $\beta \neq 0$, increased MRO spreads, $r_w - r_m$, may even exacerbate the disconnection of money market rates from the policy-intended interest rate level. In case of $\alpha \neq 0$ and $\beta = 0$, there is an equilibrium relation between the levels of the Eonia and the marginal rate while the weighted average rate plays no additional role. $\alpha = \beta \neq 0$ implies that $\alpha(r_m - i_b) + \alpha(r_w - r_m) = \alpha(r_w - i_b)$. In this case, the overnight rate is predominantly affected by the weighted average MRO rate. CBR and B denote the auction's cover to bid ratio and the unexpected part in the number of bidders, ΔAF controls for news concerning autonomous factors. According to Section 3, the expected signs of the coefficients are $\gamma_C < 0, \gamma_B > 0, \gamma_A > 0$.

4.1 The Connection between the Eonia and the MRO rates before the Financial Crisis

Table 1 shows the results obtained for the change of the Eonia in response to a MRO auction outcome. In the pre-crisis sample, the estimates indicate a significant and plausibly signed response of the overnight rate to the newly announced main refinancing rates. Irrespective of the

interest rate measure, $\widehat{\alpha} > 0$ implies an error-correction type level relationship between the Eonia and MRO rates. Specifically, for the daily and intra-day Eonia data, Wald tests cannot reject the null-hypothesis that $\alpha = \beta$. This suggests that the weighted average MRO rate, not the marginal rate, governs the level of the overnight rate. For the one-week Eonia swap rates, the relevant information revealed by MRO rates is contained in the marginal rate. In fact, the corresponding adjustment coefficient $\widehat{\alpha} = 0.8586$ is very close to one. Thus, news about the marginal MRO rate strongly influence market's expectations about the Eonia of the following week. In line with the central role of MROs in the transmission process of monetary policy, the evidence in favor of an error-correction type adjustment of the Eonia confirms that MRO auctions stabilized the Eonia before the crisis.

The results obtained for the impact of the cover-to-bid ratio CBR are also in line with expectations. Before the introduction of the new operational framework in 2004, results concerning the significance and sign of the estimated CBR coefficients are mixed which reflects the distortions in the CBR implied by banks' strategic bidding behavior. After March 2004, the ECB's reform apparently re-established the information content of CBRs about banks' liquidity situation. According to our estimates, an increase of the cover-to-bid ratio by ten percentage points decreases the Eonia by about 0.5 basis points.

Further plausible, yet less significant results are obtained for the number of bidders. For daily data, we estimate that an unexpected increase of the number of bidders by 100 would decrease the Eonia by about 3 basis points. The results obtained for ΔAF, the variable reflecting news about autonomous factors, are more puzzling. Although the ECB has always been eager to estimate and publish its forecasts on autonomous factors on a regular basis, the evidence on the information content of this variable for the money market is rather weak.

Table 1: The Money Market Response to a MRO Outcome

Money Market Response (Δi_t)

$$\Delta i_t = c + \alpha(r_m - i_b)_t + \beta(r_w - r_m)_t + \gamma_C CBR_t + \gamma_B B_t + \gamma_A \Delta AF_t + \epsilon_t$$

Auction Variables	Pre–Crisis: June 2000 - August 2007			Crisis: August 2007 - June 2008		
	Daily Eonia	Intra Day Data	1–Week Eonia Swap Rates	Daily Eonia	Intra Day Data	1–Week Eonia Swap Rates
$(r_m - i_b)$	0.5190^{***} [0.1301]	0.2655^{***} [0.0921]	0.8587^{***} [0.1209]	-0.0725 [0.0687]	0.0583 [0.0674]	-0.0050 [0.0795]
$(r_w - r_m)$	0.5166^{**} [0.2354]	0.2953^{*} [0.1539]	0.1467 [0.2295]	1.4565^{*} [0.8733]	1.9740^{***} [0.7260]	0.7891^{*} [0.4014]
Cover-to-Bid Ratio (CBR)						
before March 2004	0.0922^{***} [0.0318]	-0.0287^{**} [0.0119]	-0.0036 [0.0221]			
after March 2004	-0.0649^{**} [0.0295]	-0.0541^{**} [0.0223]	-0.0287 [0.0285]	-0.2359^{*} [0.1227]	-0.2523^{*} [0.1379]	-0.2395^{***} [0.0600]
Number of Bidders (B)	0.0003^{*} [0.0002]	0.0001 [0.0001]	0.0000 [0.0010]	0.0012^{***} [0.0003]	0.0005 [0.0003]	0.0034^{*} [0.0017]
Autonomous Factors (ΔAF)	0.0009^{**} [0.0004]	0.0002 [0.0003]	-0.0006^{***} [0.0002]	0.0015^{*} [0.0009]	0.0001 [0.0012]	-0.0002 [0.0007]
Obs.	282	282	282	33	33	33
R^2	0.58	0.45	0.65	0.72	0.41	0.40

Wald tests of parameter equality: $H_0 : \alpha = \beta$ vs $H_1 : \alpha \neq \beta$

p-value	0.98	0.82	0.00	0.08	0.01	0.05

Notes: ***,** ,* indicate significance at the 1%, 5%, 10% level. Newey-West HAC standard errors in parentheses. The index t denotes the number of the MROs covering the period December 2000 to June 2008.

4.2 The Disconnection between the Eonia and the MRO Rates during the Financial Crisis

For the crisis period, the results for the empirical relationship between the Eonia and the MRO rates are shown in the right panel of Table 1. They differ from those obtained for the pre-crisis period in two important aspects. First, the estimates imply that the Eonia and the effective key interest rates of the ECB have been disconnected. There is no significant error-correction type adjustment of the Eonia to the level of the MRO rates in the crisis period, i. e. $\alpha = 0$. As a consequence, MRO rates failed to stabilize the Eonia in the crisis. Second, according to the large and significant estimates for β the main information revealed by MRO auctions is now contained in the spread between the MRO rates $(r_w - r_m)$ and not in their levels.

During the crisis, huge MRO spreads inflated by safety bids stirred by banks' uncertainty about their refinancing conditions increased the Eonia and exacerbated the disconnection of money market rates from the policy-intended interest rate level. In sharp contrast to their stabilizing effect before the crisis, the outcomes of MRO auctions thus contributed to de-stabilize money market rates. In a vicious circle, a large MRO spread increased the Eonia, impaired banks' refinancing conditions and hence created even higher MRO spreads. In view of these problems, our empirical results strongly support the ECB's decision to re-stabilize banks' refinancing conditions by introducing a fixed rate full allotment policy in its MROs as of October 2008.

Probably reflecting the decreasing role of the main refinancing rates, the estimated adjustment equation of the Eonia indicates a growing importance of the refinancing volumes allotted in the MRO auctions. According to the estimates, an increase in the cover-to-bid ratio CBR by 10 percentage points would lower the Eonia by roughly 2.5 basis points. Note that a stronger effect on the Eonia can also be observed for the number of bidders.

4.3 MRO Auctions and Longer-Term Interest Rates during the Crisis

In October 2008, the ECB stopped the de-stabilizing effect of the MRO spread by switching the MRO auction format from variable rate to fixed rate tenders with full allotment. In a fixed rate tender with full allotment, all information about the MRO related refinancing conditions is already pre-announced. The new auction format ensures that the cover-to-bid ratio equals one and that the MRO spread is zero by construction. According to our estimates for the Eonia, both measures have contributed to improve banks' refinancing conditions.

However, the ECB took additional, even more unconventional measures to stabilize the situ-

ation in the money market. Before the crisis, the ECB was very reluctant to give strong signals about the policy-intended level of longer-term money market rates. As a consequence, longer-term refinancing operations (LTROs) have always been conducted as variable rate tenders without minimum bid rate, see Linzert et al. (2007). Since October 2008, however, the fixed rate full allotment policy has been also applied to the ECB's longer-term refinancing operations. Moreover, while the maximum maturity of LTROs has been three month before the crisis, the ECB additionally introduced LTROs with maturities of one, six and even twelve months. In order to shed more light on the rationale behind these measures, we investigate whether the de-stabilizing effects of MROs observed for the Eonia can also be found for longer-term money market rates.

To that aim, we adopt the empirical approach of the previous sections and regress the change of longer-term Eonia swap rates at an auction day on the variables characterizing the MRO auction outcome. The Eonia swap market is the most important derivative market segment in the euro area, see Durré (2006). The change of the Eonia swap rate at the auction day should reflect the impact of the auction outcome on market's expectations about future Eonia rates, see Taylor and Williams (2009).

The results obtained for the swap rates are very similar to those obtained for the Eonia for all maturities under consideration, compare Table 1 and Table 2. In particular, there is clear evidence suggesting the absence of a stabilizing level relationship between the longer-term money market rates and the MRO rates, i. e. $\alpha = 0$. As expected, longer-term money market rates react stronger to news about the future path of short-term rates and less to its current level. It is more striking, however, that large MRO spreads $(r_w - r_m)$ led also to significant and presumably policy-unintended increases of the longer-term money market rates, i. e. $\beta > 0$.

It is well-known that interest rate expectations affect the bidding behavior and, thereby, the results of MRO auctions, see e. g. Bindseil et al. (2009). However, Table 2 shows that - vice versa - MRO auctions can reveal information that may also affect banks' interest rate expectations. The significant response of longer-term swap rates suggests that the large MRO spreads observed until October 2008 even de-stabilized longer-term money market rates. These results provide strong support for the ECB's switch to the fixed rate full allotment policy even in its longer-term refinancing operations.

Table 2: The Longer-Term Money Market Response to a MRO Outcome during the Crisis

	Response of longer-term money market rates (Δi_t)			
	$\Delta i_t = c + \alpha(r_m - i_b)_t + \beta(r_w - r_m)_t + \gamma_C CBR_t + \gamma_B B_t + \gamma_A \Delta AF_t + \epsilon_t$			
	Crisis: August 2007 - June 2008			
Auction Variables	1–Month Eonia Swap Rates	3–Month Eonia Swap Rates	6–Month Eonia Swap Rates	12–Month Eonia Swap Rates
$(r_m - i_b)$	-0.0050 [0.0400]	0.0582 [0.0460]	0.0570 [0.0528]	0.0425 [0.0426]
$(r_w - r_m)$	0.5848^{***} [0.1829]	0.6537^{**} [0.2589]	0.7844^{**} [0.3213]	1.3251^{**} [0.5366]
Cover-to-Bid Ratio (CBR)	-0.1341^{***} [0.0304]	-0.0868^{***} [0.00313]	-0.0669 [0.0570]	-0.1458^{*} [0.0866]
Number of Bidders (B)	0.0002^{**} [0.0001]	0.0003^{***} [0.0001]	0.0002^{*} [0.0001]	0.0005^{**} [0.0002]
Autonomous Factors (ΔAF)	0.0001 [0.0003]	0.0003 [0.0004]	0.0001 [0.0005]	-0.0002 [0.0008]
Obs.	33	33	33	33
R^2	0.53	0.35	0.21	0.25

Notes: For further explanations, see Table 1.

5 Concluding Remarks

The interest rates applied in the main refinancing operations (MROs) of the ECB constitute the very beginning of the monetary transmission process in the euro area. For the implementation of monetary policy, the connection between the main refinancing rates and the short-term interest rates in the money market is of particular importance. In line with their predominant role for monetary policy implementation, the results of MRO auctions should have a strong and stabilizing impact on money market conditions. This paper assessed the empirical relationship between MRO auctions and the money market by investigating the response of money market rates to MRO auction outcomes.

Our results show that the financial crisis distorted the relationship between MROs and the money market in two important ways. First, we find that the level of money market rates has been disconnected from MRO rates since the outbreak of the crisis in August 2007. In contrast to the pre-crisis period, MRO auction outcomes fail to stabilize money market rates during the financial crisis. This implies that the first step of the transmission channel of monetary policy has been interrupted.

The second change in the relationship between MRO auctions and the money market concerns the role of the MRO spread, i. e. the difference between the weighted average and the marginal MRO rate. While MRO spreads have been typically small before the crisis, in the crisis MRO spreads were inflated by safety bids reflecting the increased uncertainty of banks about their refinancing conditions. In contrast to the stabilizing impact of MRO auctions before the crisis, the response of money market rates to the MRO spreads de-stabilized money market conditions by exacerbating the disconnection of money market rates from the policy-intended interest rate level. This self-enforcing destabilization is also found for longer-term money market rates. Both findings strongly support the ECB's decision made in October 2008 to re-stabilize banks' refinancing conditions by adopting a fixed rate full allotment policy in its MROs and also in its longer-term refinancing operations (LTROs).

The ECB has repeatedly emphasized that the conduct of MROs as 'fixed rate tenders with full allotment' can only be a temporary measure in response to the financial crisis, see e. g. European Central Bank (2010). How should the ECB perform its MRO auctions after the crisis? According to the empirical auction literature the optimal choice of the auction format is not obvious. In particular, the ECB experienced that the rationing of bids in a 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 Oechssler (2006). In June 2000, the ECB stopped banks' overbidding by switching to a price-discriminatory variable rate tender format. Since successful banks 'pay what they bid', the effective refinancing rate differs across banks. This paper demonstrated that - particularly in times of market stress - large MRO spreads, defined as the difference between the weighted average and marginal MRO rate, may de-stabilize money market rates in a significant way. It is therefore worth noting that the price-discriminatory variable rate tender is not the only option of the ECB. In particular, the Dutch or competitive auction format as recently conducted by the Federal Reserve System in its term securities lending facility (TSLF) could be an alternative to the ECB's standard variable rate tender, see e. g. Fleming et al. (2010). In the competitive auction format, the probably de-stabilizing MRO spreads are always zero because each successful bidder pays simply the marginal rate.

References

Andrews, D.W.K. (1993): Tests for Parameter Instability and Structural Change With Unknown Change Point, *Econometrica*, 61(4), 821–856.

Bartolini, L. and A. Prati (2006): Cross-Country Differences in Monetary Policy Execution and Money Market Rates' Volatility, *European Economic Review*, 50(2), 349–376.

Bindseil, U. (2004a): *Monetary Policy Implementation: Theory, Past, and Present*, Oxford: Oxford University Press.

Bindseil, U. (2004b): Over- and Underbidding in Central Bank Open Market Operations Conducted as Fixed Rate Tender, *German Economic Review*, 6(1), 95–130.

Bindseil, U., K.G. Nyborg and I. Strebulaev (2009): Repo Auctions and the Market for Liquidity, *Journal of Money, Credit, and Banking*, 41(7), 1391–1421.

Carpenter, S. and S. Demiralp (2008): The Liquidity Effect in the Federal Funds Market: Evidence at the Monthly Frequency, *Journal of Money, Credit and Banking*, 40(1), 1–24.

Cassola, N., A. Hortacsu and J. Kastl (2009): The 2007 Subprime Market Crisis Through the Lens of European Central Bank Auctions for Short-Term Funds, Working Paper No. 15158, National Bureau of Economic Research.

Cassola, N. and C. Morana (2008): Modeling Short-Term Interest Rate Spreads in the Euro Money Market, *International Journal of Central Banking*, 4(4), 1–38.

Colarossi, S. and A. Zaghini (2009): Gradualism, Transparency and Improved Operational Framework: A Look at the Overnight Volatility Transmission, *International Finance*, 12(2), 151–170.

Durré, A. (2006): The Liquidity Premium in the Money Market: A Comparison of German Mark Period and the Euro Area, *German Economic Review*, 7(2), 163–187.

Ejerskov, S., C.M. Moss and L. Stracca (2008): How Does the ECB Implement Monetary Policy?, *Journal of International Money and Finance*, 27(8), 1199–1214.

European Central Bank (2003): Changes to the Eurosystem's Operational Framework for Monetary Policy, Monthly Bulletin, August.

European Central Bank (2006): The Eurosystem's Operational Framework and the Volatility of the Overnight Rate, Monthly Bulletin, July.

European Central Bank (2007): *Euro Money Market Study 2006*.

European Central Bank (2010): The ECB's Monetary Policy Stance During the Financial Crisis, Monthly Bulletin, January.

Fleming, M.J., W.B. Hrung and F.M. Keane (2010): Repo Market Effects of the Term Securities Lending Facility, *American Economic Review: Papers and Proceedings*, 100(2), 591–596.

Hansen, B.E. (1997): Approximate Asymptotic P Values for Structural-Change Tests, *Journal of Business and Economic Statistics*, 15(1), 60–67.

Hauck, A. and U. Neyer (2010): The Euro Area Interbank Market and the Liquidity Management of the Eurosystem in the Financial Crisis, Discussion Paper on Economics, Finance, and Taxation No. 02, Heine-Universität Düsseldorf.

Ho, C. (2008): Implementing monetary policy in the 2000s: Operating procedures in Asia and beyond, Working Paper No. 253, Bank for International Settlements.

Linzert, T., D. Nautz and U. Bindseil (2007): Bidding behavior in the longer term refinancing operations of the European Central Bank: Evidence from a panel sample selection model, *Journal of Banking and Finance*, 31(5), 1521–1543.

Linzert, T. and S. Schmidt (2010): What Explains the Spread Between the Euro Overnight Rate and the ECB's Policy Rate?, *International Journal of Finance and Economics, forthcoming*.

Nautz, D. and J. Oechssler (2006): Overbidding in Fixed Rate Tenders – An Empirical Assessment of Alternative Explanations, *European Economic Review*, 50(3), 631–646.

Nautz, D. and C.J. Offermanns (2008): Volatility Transmission in the European Money Market, *North American Journal of Economics and Finance*, 19(1), 23–39.

Nautz, D. and J. Scheithauer (2009): Monetary Policy Implementation and Overnight Rate Persistence, SFB 649 Discussion Paper No. 53, Humboldt-Universität Berlin.

Pérez Quirós, G. and H. Rodríguez Mendizábal (2006): The Daily Market for Funds in Europe: What Has Changed with the EMU?, *Journal of Money, Credit, and Banking*, 38(1), 91–118.

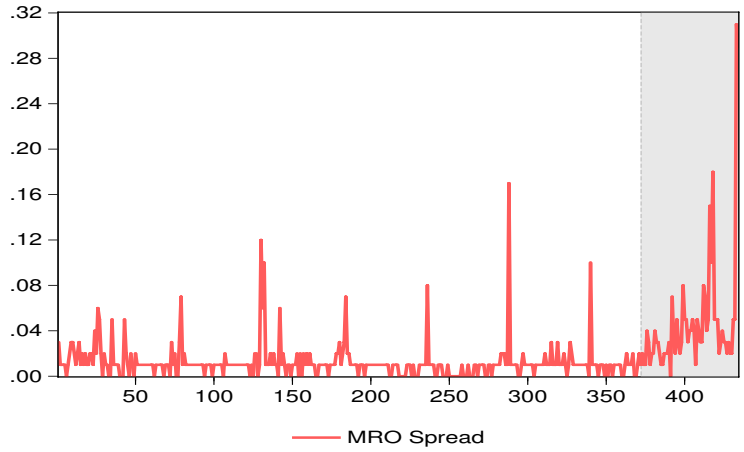
Taylor, J.B. and J.C. Williams (2009): A Black Swan in the Money Market, *American Economic Journal: Macroeconomics*, 1(1), 58–83.

Thornton, D.L. (2008): The Daily and Policy-Relevant Liquidity Effects, Working Paper No. 984, European Central Bank.

Välimäki, T. (2008): Why the Effective Price for Money Exceeds the Policy rate in the ECB Tenders, Working Paper No. 981, European Central Bank.

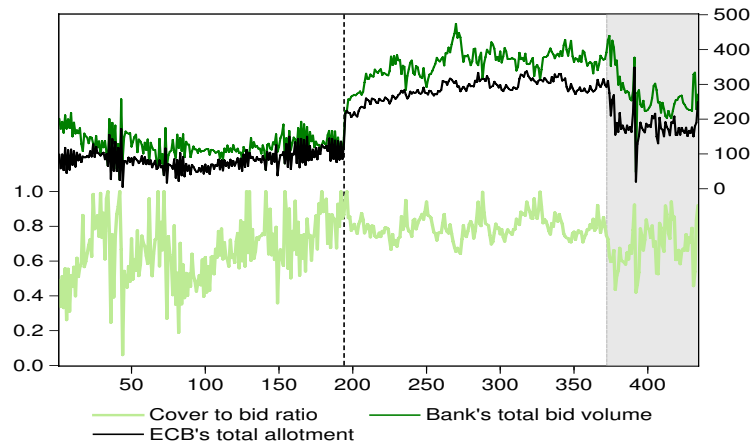
A Figures

Figure A.1: The spread between the MRO rates (in percent)



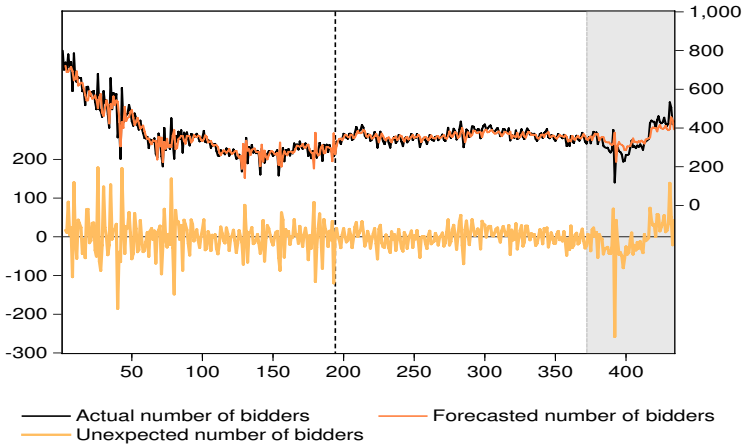
Notes: The MRO spread is defined as the difference between the weighted average and marginal MRO rate. Since the daily dataset has been pared down to the auction relevant days, the drawn data has *not* a daily frequency. The x-axis, therefore, refers to respective auction t. The light shaded area refers to the crisis period as of August 9, 2007.

Figure A.2: The MRO's cover-to-bid ratio



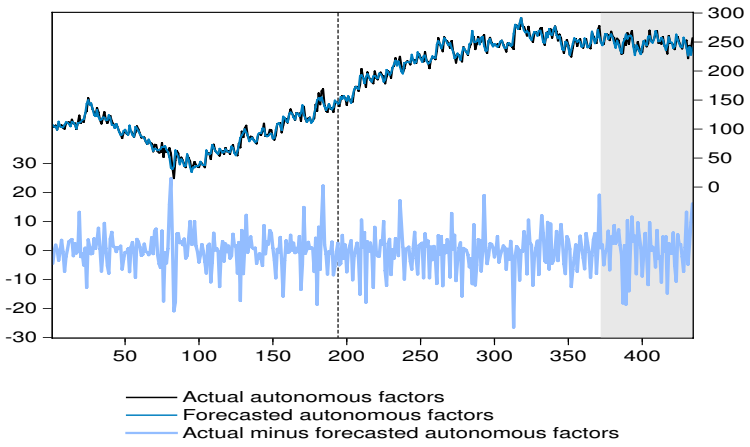
Notes: The aggregate bid volume and total allotment are in EUR billions. The black dashed line represents the introduction of the new operational framework as of March 2004. For further explanations, see Figure A.1.

Figure A.3: The number of bidders in MROs



Notes: For further explanations, see Figure A.1 and Figure A.2.

Figure A.4: Updated forecasts minus forecasted autonomous factors around MROs (in EUR billions)



Notes: For further explanations, see Figure A.1 and Figure A.2

B Structural break test

This section uses structural break tests to investigate whether the financial crisis had a significant impact on the relationship between the ECB's MRO auctions and the money market. To that aim, the Quandt-Andrews test for unknown breakpoints is applied to the error-correction type adjustment equation of the Eonia, compare equation (1):

$$\begin{aligned}\Delta i_t &= c + \alpha(r_m - i_b)_t + \beta(r_w - r_m)_t \\ &+ \gamma_C CBR_t + \gamma_B B_t + \gamma_A \Delta AF_t + \varepsilon_t,\end{aligned}$$

We test whether there has been a break in the equation parameters c, α, β, γ_B, and γ_A for the full sample from June 27, 2000 to October 14, 2008.[6] The Quandt-Andrews test is based on standard F-statistics, see Andrews (1993). $Max\ F$ denotes the maximum of the individual *F*-statistics while the *Ave* statistic refers to their average. Since the break point is unknown, the asymptotic distribution of both test statistics are non standard and depend on the number of coefficients that are allowed to break and on the fraction of the sample that is examined.[7] Approximate asymptotic *p*-values are calculated following Hansen (1997).

Table B.1: Quandt-Andrews unknown breakpoint test

Statistic	Daily Eonia	Intra Day Data
Max F (08/09/2007)	19.06 [0.0556]	17.77 [0.0878]
Ave F	11.54 [0.0047]	13.22 [0.0012]

Notes: Estimated break date and approximate asymptotic *p*-values in line with Hansen (1997) in parenthesis. Test sample: June 27, 2000 to October 14, 2008 for daily Eonia and December 4, 2000 to June 17, 2008 for intra day data. Number of breaks compared: 318 and 284, respectively.

The results confirm that the role of MRO auctions for the money market has significantly changed since the start of the financial crisis. For both, daily and intra-day data, the $Max\ F$ statistics chooses the first MRO auction after the outbreak of the crisis as the main candidate for a significant break point.

[6] Note that we already accounted a structural change in the role of CBR stirred by the reform of the ECB's operational framework as of March 2004. Therefore, we have excluded γ_C from the test.

[7] Note that the distributions become degenerate as the first period tested approaches the beginning of the equation sample, or the end period approaches the end of the equation sample. To compensate for this behavior it is generally suggested to exclude the end of the equation sample from the testing procedure. Following Andrews (1993), we apply a symmetric "trimming" of 5%.

C Forecast equation of number of bidders

Following e.g. Bindseil et al. (2009) and Linzert et al. (2007), we estimate the unexpected part in the number of bidders by regressing the number of bidders (B_t) in the current auction *t* on the number of bidders in previous auctions. With respect to the changes in seasonality and maturity in the ECB's operational framework as of March 2004, we estimate the forecast equations for each subperiod separately:

$$\begin{aligned} B_t^{OldFramework} &= \underset{(7.7)}{19.83} + \underset{(0.05)}{0.39}\, B_{t-1} + \underset{(0.05)}{0.52}\, B_{t-2} \\ &- \underset{(15.90)}{73.98}\, D_t^{Underbid} + \underset{(93.08)}{92.45}\, D_{t-1}^{Underbid} + \underset{(16.17)}{21.07}\, D_{t-2}^{Underbid}, \end{aligned} \tag{2}$$

with $R^2 = 0.86$ for the sample prior to March 2004 and

$$B_t^{NewFramework} = \underset{(27.54)}{101.61} + \underset{(0.08)}{0.72}\, B_{t-1}, \tag{3}$$

with $R^2 = 0.52$ after March 2004 until October 2008. Newey-West HAC standard errors are reported in parentheses. $D_t^{Underbid}$ is a dummy variable where $D_t^{Underbid} = 1$ captures the underbidding episodes that occurred in auction *t*.[8] The bi-weekly and weekly maturity of the MROs before and after March 2004, respectively, suggests the choice of the lag structure.

[8]The underbidding events refer to the MROs on 13 Feb, 10 Apr, 9 Oct and 6 Nov 2001, 3 Dec and 17 Dec 2002, 3 Mar, 3 Jun and 25 Nov 2003 and 20 Feb , see Bindseil (2004b).