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How stressed are banks in the interbank market?

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Non-technical Summary

Until October 2008, the Eurosystem conducted its liquidity providing main refinancing operations (MROs) as variable rate tenders, where banks bid for central bank reserves and pay according to their submissions. Apart from MROs, banks in the euro area are granted a standing facility to seek lender of last resort (LOLR) assistance from the Eurosystem's marginal lending facility. Since the LOLR rate is usually 100 basis points above the key policy rate that prevails in MROs, any recourse to the marginal lending facility renders a good indicator for banks' urgent liquidity needs.

In this paper we study whether a bank's bidding behavior in the Eurosystem's weekly main refinancing operations (MRO) relates to its recourse to the marginal lending facility and thereby may serve as an early warning indicator for banking distress. To that aim, we relate each bank's behavior in the Eurosystem's MROs to their lender of last resort (LOLR) recourses. Implicitly, this approach assumes that banks' behavior reflects their refinancing conditions in interbank money markets. It is reasonable to believe that the price a particular bank pays in the interbank market for liquidity, its collateral constraints and the credit rationing it potentially faces should affect its willingness-to-pay for liquidity in the Eurosystem's MROs. Provided it has sufficient eligible collateral, the price a bank is willing to pay for reserves in the MROs should reflect its opportunity costs for obtaining liquidity elsewhere. Hence, a bank's willingness-to-pay in an MRO reflects the extent to which a bank is short in liquidity and is squeezed in the interbank markets before she seeks LOLR assistance.

Our exercise provides strong evidence for this intuition. In fact, our findings suggest that central banks and banking supervisors can use banks' bidding behavior as a stress indicator for signaling bank's specific liquidity squeezes. In contrast to the related literature, our findings also imply that there is a strong correlation between the aggressiveness of bids and the likelihood with which a bank draws on the Eurosystem's LOLR facility. The decision to take recourse to the MLF is an indication for a bank being liquidity squeezed, which is undoubtedly not blurred by strategic behavior. Thus the strong correlation of banks willingness-to-pay in an auction and their subsequent propensity to draw on the LOLR facility shows that the bidding behavior is indeed driven to a large extent by bank specific liquidity needs and not only by the winner's curse or bid shading considerations.

Nicht-technische Zusammenfassung

Bis Oktober 2008 wurden die Hauptrefinanzierungsgeschäfte des Eurosystems als variable Zinstender durchgeführt, in denen Banken für Zentralbankliquidität bieten und entsprechend ihrer Gebote zahlen müssen. Neben dieser Möglichkeit, sich mit Zentralbankliquidität zu versorgen, hatten Banken des Euroraums einen ständigen Zugang zur Spitzenrefinanzierungsfaszilität. Da der Zinssatz in der Spitzenrefinanzierungsfaszilität 100 Basispunkte über dem Mindestbietungssatz in den Hauptrefinanzierungsgeschäften und damit typischerweise auch deutlich über den Durchschnittszinssätzen am Interbankengeldmarkt lag, ist der Rückgriff auf die Spitzenrefinanzierungsfaszilität ein gutes Indiz für einen akuten Liquiditätsengpass einer Bank.

Diese Studie untersucht, inwieweit das Bietungsverhalten von Banken in den Hauptrefinanzierungsgeschäften Aufschluss über die Wahrscheinlichkeit gibt, mit der eine Bank in der Folge Rückgriff auf die Spitzenrefinanzierungsfaszilität nehmen muss, und damit als Stressbarometer dienen kann, um Refinanzierungsschwierigkeiten im Voraus zu erkennen. Um dies zu überprüfen, kombinieren wir die Spitzenrefinanzierungszugriffe aller Banken im Euroraum mit ihrem Bietungsverhalten in den Hauptrefinanzierungsgeschäften. Die implizite Annahme hierbei ist, dass das Bieteverhalten der Banken relevante Information darüber enthält, wie gut sie sich an den Finanzmärkten refinanzieren kann. Aufgrund von Arbitrageüberlegungen ist anzunehmen, dass eine Bank insbesondere dann aggressiv für Zentralbankliquidität bietet, wenn sie in den Interbankgeldmärkten einen hohen Risikoaufschlag zahlen muss oder davon gänzlich abgeschnitten wird. Insofern sollten sich Refinanzierungsschwierigkeiten bereits im Bietungsverhalten niederschlagen, bevor sie zu einem Zugriff auf die Spitzenrefinanzierungsfaszilität führen.

Unsere Ergebnisse bestätigen diese Intuition. Sie zeigen, dass in der Tat die Zahlungsbereitschaft von Banken in Hauptrefinanzierungsgeschäften gut geeignet ist, um die Wahrscheinlichkeit eines Zugriffs auf die Spitzenrefinanzierungsfazilität und damit eines Liquiditätsengpasses vorherzusagen. Neben dem empirischen Nachweis, dass das Bietungsverhalten ein guter kurzfristiger Stressindikator ist, liefert diese Studie einen weiteren Beitrag. Sie zeigt, dass – anders als die Literatur es bisher geglaubt hat – die Zahlungsbereitschaft der Banken in Offenmarktgeschäften der Eurosystems eher durch ihre Liquiditätsbedürfnisse getrieben ist als durch strategische Überlegungen bezüglich des Auktionsverlaufs.

Bundesbank Discussion Paper No 40/2013

How stressed are banks in the interbank market?*

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Abstract

We use a unique data set that comprises each bank's bids in the Eurosystem's main refinancing operations and its recourse to the LOLR facility (a) to derive banks' willingness-to-pay for liquidity through a one-week repo and (b) to show that a bank's willingness-to-pay is a good indicator for the probability that this bank draws on the LOLR facility. Our results suggest (i) that banks' willingness-to-pay for liquidity indeed reflects refinancing conditions in the interbank market and (ii) that the willingness-to-pay can serve as an early warning indicator for banking distress.

Keywords: Banks, liquidity, LOLR facility, repos, money markets, frictions

JEL Classification: D44, E42, E58, G21

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1 Introduction

There is a large literature that uses the bidding behavior of banks observed in central bank's repo auctions to study frictions in the interbank market.[1] This literature argues that arbitrage considerations induce banks to bid more aggressively for liquidity in these multi-unit price-discriminatory auctions, if they pay a higher premium or are even rationed in the interbank market. Thus, the aggressiveness with which banks bid in these auctions should reflect their funding constraints in interbank markets, or more precisely, the funding constraint that banks faced and expect to face in interbank markets after the auction.[2] This, however, suggests that banks' bidding behavior can serve as an early warning indicator for individual banks' liquidity crisis.

In this paper we employ a response propensity model to study how a bank's bidding behavior in the Eurosystem's weekly main refinancing operations relates to its recourse to the marginal lending facility. This lender of last resort (LOLR) facility grants euro area banks anytime access to overnight funding at a penalty rate against good collateral, similar to the FED's discount window. So, any recourse to the LOLR facility may give some indication for tensions and liquidity shortages that a bank faces in the interbank market.

We find that a higher quantity-weighted average rate that a bank effectively pays in an auction is indeed a good indicator not only for the probability with which the bank seeks LOLR assistance on the auction day but also for the probability with which it borrows from the marginal lending facility over the entire period until the next main refinancing operation is held. These results are not driven by the periods of elevated uncertainty in the interbank market or the crisis period in general. Controlling for the volatility of the overnight interbank rate and including monthly time fixed effects does not change our findings.

These findings are important for two reasons. First, they suggest that central banks and banking supervisors can use banks' bidding behavior as a stress indicator for signaling bank's specific liquidity squeezes. Second, the aforementioned literature that analyzes

[1] See, for example, Craig and Fecht (2007), Linzert et al. (2007), Bindseil et al. (2009), Eisenschmidt et al. (2009) and Fecht et al. (2011) using European MRO data and Armantier et al. (2011) using U.S. TAF data.

[2] Nyborg and Strebulaev (2004) develop this argument in a theoretical model of auctions.

bank's bidding behavior in liquidity auctions to shed light on the frictions prevailing in the interbank market is challenged by the view that the bids are less driven by opportunity costs or arbitrage considerations rather than by strategic considerations as regards the auction outcome. Bidding close to the marginal bid rate (the expected cut-off rate in the auctions), which is of course an endogenous auction outcome though, minimizes the costs of raising liquidity in the auction. Following that line of thinking, more aggressive bids should be a reflection of a higher expected marginal bid rate or more uncertain expectations about the marginal bid rate.[3] Our finding, however, indicates that there is a strong correlation between the aggressiveness of bids and the likelihood with which a bank draws on the marginal lending facility. While a banks' bidding behavior might be affected by strategic considerations, the decision to draw on the MLF is clearly indicating that a bank has no alternative refinancing options. Thus our results show that also the bidding behavior is indeed driven to a large extent by bank specific liquidity needs and not only by the winner's curse or bid shading considerations.

The remainder of the paper is organized as follows. The next section gives a brief overview of the Eurosystem's operational framework. Section 3 describes our data set. In section 4 we report some descriptive statistics on banks' bidding behavior in the euro area, their recourse to the marginal lending facility and the interrelation of the two. Section 5 describes our panel logit model and section 6 provides the results of this approach. In section 7 we perform some robustness checks. Section 8 concludes and derives some policy implications from our findings.

2 Open Market Operations and the LOLR Facility

Banks operating in the euro area are required to hold reserves on their accounts with the European Central Bank (ECB). These reserve requirements specify an *average* for the end-of-day balances that banks have to hold with the central bank over a reserve maintenance period (RMP). Any under-fulfillment of these requirements will be penalized accordingly.[4]

The imposition of reserve requirements on the banking sector creates a demand for

[3] See, for example, Nautz (1997) and Nautz and Wolfstetter (1997).

[4] There is an interest rate paid on the required reserve holdings, albeit the amounts held in excess remain unremunerated. The Eurosystem applies a certain discretion on how to penalize under-fulfillments. Nevertheless, the penalty rate imposed on reserve deficiencies is the highest interest rate charged such that under-fulfilling the reserve requirements becomes the costliest option.

central bank reserves. The Eurosystem serves this liquidity demand through open market operations (OMOs). These operations are conducted as auctions and are – unlike to the U. S. – accessible to any euro area financial institution that is required to hold minimum reserves with the Eurosystem. During our sample period, the bulk of liquidity allocation was initiated by weekly main refinancing operations (MROs). In the MROs, banks bid for reversed repurchase agreements (repos) with a maturity of one week.[5] In order to obtain liquidity in an MRO a bank must hold securities eligible as collateral in those repos. In placing their bids, banks may submit up to 10 bid-quantity schedules where the tick size is 1 basis point and the quantity multiple is 100,000 euros. In order to be valid, bids must not be lower than the key monetary policy rate (minimum bid rate) set by the Governing Council of the Eurosystem in the second meeting of each month. As MROs are executed in a multi-unit price discriminatory fashion, each successful bidder is obliged to pay according to its submission.

Additionally, the Eurosystem also facilitates the liquidity management of euro area banks through longer-term refinancing operations (LTROs) and fine-tuning operations (FTOs). During our sample period, there has been only one LTRO in each RMP and the liquidity amount allotted was - compared to MROs - small in size. The FTOs are executed through quick tenders or bilateral procedures with a small preselected group of large banks at very short maturities on an ad hoc basis. Unlike the U. S. Fed, the ECB makes only very infrequent use of its FTOs. Hence, between two consecutive open market operations financial institutions need to draw on financial markets in order to overcome potential liquidity shortages. In particular the unsecured and secured interbank money markets play the primary role in reallocating central bank money. But even in normal times, banks are likely to pay a premium in accordance with their credit and collateral risk, when borrowing in the unsecured and secured money market, respectively. Particularly risky banks might not be able to borrow at all without pledging collateral. Moreover, due to tighter collateral requirements and increasing haircuts (than in OMO auctions) some banks might be collateral constrained in the secured interbank money markets even though they disposition of sufficient eligible collateral for transactions with the Eurosystem. In times of market stress, when the proper functioning of broader financial markets is severely

[5]During our sample period, MROs played even a more pronounced role in signaling the stance of monetary policy and steering short-term money market rates.

impaired, the collateral value of an asset in market transactions might also be depressed, which further restrains banks' ability to borrow in the secured market. Furthermore, in crisis periods elevated systemic risk might also derogate the credit quality of otherwise safe banks restraining also their ability to borrow in the unsecured market.

Therefore, the Eurosystem additionally facilitates bank's liquidity management by the so called marginal lending facility (MLF).[6] Similar to the U. S. Fed's discount window, the MLF grants Eurozone banks unlimited and anytime-access to overnight liquidity. However, in contrast to the U. S. the identity of banks' taking recourse to the MLF cannot be inferred by financial markets. Therefore, there is *no* stigma attached to the MLF borrowing, which might prevent banks from using it whenever there is a need to overcome temporary liquidity fluctuations. When drawing on the marginal lending facility, banks need to fulfill the same general eligibility requirements as those imposed on the main refinancing operations. In particular, they have to back their borrowing with sufficient eligible collateral. The interest rate applied to this lender of last resort facility (marginal lending rate) is usually 100 basis points above the central bank's key policy rate.[7] The marginal lending rate is pre-specified and uniform in order to ensure equal treatment of institutions across the euro area [see e.g. European Central Bank (2011)].

3 Data

Our analysis uses two data sets supplied by the Bundesbank. First, we have the complete set of bids made by all registered financial institutions in the euro area. All collected bid-quantity schedules are broken down by bidder and cover all 197 main refinancing operations in the period from January 5, 2005 through October 8, 2008. In October 2008 the Eurosystem changed its auction design and switched to a fixed-rate and full-allotment policy rendering it impossible to derive banks' willingness-to-pay for liquidity from their bidding behavior in OMOs. A bank is considered a bidder in our analysis when it has bid at least once, and therefore appears in our auction data set. Our MRO data covers a total of 1055 different banks that submitted a total of 118225 bid-quantity schedules. On

[6] Banks with excess liquidity may use the deposit facility and thereby avoid having unremunerated reserves. The interest rate paid was, however, 100 basis points below the ECB's minimum bid rate. For more information see European Central Bank (2010).

[7] Note that although the marginal lending rate is well above the key monetary policy rate, it is well below the penalty rate applied to the reserve deficiencies.

average, 321 banks participated in an MRO auctions during our sample.

We have also each bank's recourse to the Eurosystem's LOLR facility for the same period of time. In total, our data covers 3,208 LOLR recourses from 414 different banks in the euro area. The MLF volumes observed range from a minimum of € 1 to a maximum of € 12 billions. Small MLF recourses are a result of a standardized process that prevents Eurozone banks to have a negative end-of-business-day current account. At the end of any given day, all current accounts held with the Eurosystem – that otherwise would be negative – are balanced out with central bank reserves at the marginal lending rate provided the respective bank has sufficient collateral in its pool with the Eurosystem.

Applying a unique bank code to merge both data sources, we are able to track banks over time and merge each MRO bidder with its LOLR recourses. Since we are interested in using the bank's bids in MROs to estimate the likelihood of a subsequent recourse to MLF, our final data set covers only the MLF recourses of those banks that participated in the MRO prior to their recourses.[8] Table 1 provides summary statistics of our merged dataset. From a total of 1055 MRO bidders only 295 banks took recourse to the MLF. For our further analysis we differentiate the recourses to the MLF according to the day on which they occurred around an MRO. We consider separately MLF recourses (i) on the respective auction day, (ii) on the settlement day of an auction, which is also the day when the previous auction matures, and (iii) on the remaining days until the next auction takes place. Figure 1 illustrates the timing. While 110 banks used the MLF on the very same day on which they also participated in a repo auction, 88 banks drew on the LOLR facility on the settlement day of the respective auction to which they had submitted a bid. On one of the remaining days until the next auction 97 financial institutions reverted to the MLF. The 110 and 88 banks used the LOLR facility 372 and 189 times, respectively, on repo auction days and demanded an average volume of € 175 and € 146 millions, respectively. In the days subsequent to an MRO auction, the observed 97 banks drew on the MLF in 394 occasions with an average value of € 314 millions. In total, 30% of all LOLR recourses can be assigned to MRO bidders, who at the same time account for more than 60% of total

[8]Note that the decision to participate in MROs is of course endogenous and also driven by banks' refinancing conditions in interbank markets. But since we are interested in the correlation (rather than causality) between our *distance* measure and the LOLR assistance, endogeneity is not that big of a concern in our study. Even if we were to correct for a sample selection bias, we expect our results to strengthen further.

MLF volumes. These observations show that at the aggregate level (i) the MLF is used regularly and that (ii) LOLR recourses can predominantly be assigned to MRO bidding banks. The latter particularly implies that there is indeed a relationship between MRO bidding banks and their regress to the LOLR facility.

4 Bank's Stress Status and Willingness-to-Pay

The price a particular bank pays in the interbank market for liquidity, its collateral constraints and the credit rationing it potentially faces should affect its willingness-to-pay for liquidity in the Eurosystem's MROs. Provided it has sufficient eligible collateral the price a bank is willing to pay for reserves in the MROs should reflect its opportunity costs for obtaining liquidity elsewhere. Hence, a bank's willingness-to-pay in an MRO reflects the extent to which a bank is short in liquidity and is squeezed in the interbank markets.

Since MROs were held until October 2008 as pay-your-bid auctions banks' bid-quantity schedules submitted to the Eurosystem's main refinancing operations are a good indication for the price the respective bank was willing to pay for a collateralized loan from the central bank. As banks participating in MROs may provide up to 10 bid-quantity pairs, we determine for each bank its willingness-to-pay as the quantity-weighted interest rate:

$$\text{willingness to pay}_{it} \quad = \quad \frac{\sum_{j=1}^{m}(\text{bid}_{ijt} \cdot \text{bid volume}_{ijt})}{\text{total bid volume}_{it}} \tag{1}$$

where i refers to the bank, j to its bid-quantity pair observed in the auction t.

Of course rather than submitting bids that reflect their opportunity costs of obtaining liquidity elsewhere, banks might also have an incentive to bid as closely above to the marginal bid rate (the expected cut-off rate in the auctions) as possible. Doing so they could obtain liquidity at a rate lower than their opportunity cost and extract a rent.[9] However, the risk associated with such a strategy is increasing in the opportunity costs of obtaining liquidity elsewhere. Thus whether banks behave strategically and engage in bid shading or whether they rather submit demand schedules reflecting indeed their willingness-to-pay is an empirical question. By assessing the extent to which banks' bids convey information about banks' subsequent recourse to the MLF, we explicitly address this question in our paper.

[9]For the bid shading behavior of banks in Eurosystem's MROs refer to Nautz (1995) and Nautz and Wolfstetter (1997).

However, in order to mitigate the influence of such a strategic behavior on our measure for the willingness-to-pay we focus only on (ex-post) successful bid-quantity schedules. This excludes bids below the marginal bid rate but above (and equal to) the minimum bid rate. Such bids are likely placed strategically.

Obviously, the quantity-weighted average rate paid for liquidity by banks (willingness-to-pay) is also driven by the monetary policy rate. In order to make banks' willingness-to-pay intertemporally comparable we normalize the quantity-weighted average rate and derive the variable *distance*.

$$\text{distance}_{it} \quad = \quad \text{MLF}_t - \text{willingness to pay}_{it} \tag{2}$$

This measure compares each bank's willingness-to-pay for reverse repos with the uniform marginal lending rate (MLF) prevailing on that specific auction day. It therefore provides an indication of how costly it is for a bank to borrow from the MLF rather than obtaining liquidity in MROs (or in the interbank market given that willingness-to-pay captures also these opportunity costs). Since the same eligibility criteria apply to both liquidity providing instruments, potential collateral constraints affect the access to both the liquidity facilities in the same way. Note, however, that in our sample period the difference between the marginal lending rate and the minimum bid rate was kept at 100 basis points. So normalizing the willingness-to-pay with the marginal lending rate or the minimum bid rate is equivalent for our analysis.

Since submitted bids must not be below the minimum bid rate and arbitrage opportunities prevent bids from exceeding the MLF rate, *distance* takes values only between 0% and 1%. A high value of *distance* means that the bank's willingness-to-pay deviates substantially from the interest rate charged at the MLF. Low values of *distance* suggest that the bank's individual value for reverse transactions with the Eurosystem is very close to the MLF penalty rate. Heterogeneity among banks' *distance* measures at a given point in time, however, should still reflect differences in the alternative opportunities costs of refinancing.

Table 2 provides summary statistics on bidding bank's willingness-to-pay and our *distance* measure. It shows that the quantity-weighted average rate paid varies between roughly 2% and 5.25% during our sample. It also reflects that banks received funding at interest rates, which were on average 86 basis points below the marginal lending rate. Yet, the minimum and the maximum values of *distance* reveal that during our sample, we ob-

serve occasions on which banks bid at the minimum bid rate and instances when they bid at the marginal lending rate. Moreover, a standard deviation of 12 basis points discloses substantial differences in banks' willingness-to-pay and hence their *distance* to the MLF rate.[10] If *distance* is indeed a proper measure that serves as an indicator for bank's individual stress in the interbank market, it should be able to predict whether a bank might actually draw on the marginal lending facility. Therefore, our following empirical analysis focuses on the predictive power of *distance* for the individual probability of bank's recourse to the marginal lending facility.

5 Model and Variables

To model each bank's response probability of drawing on the MLF, we assume an underlying latent variable model with the unobservable y_{it}^* that represents bank i's propensity (or 'utility') to draw on the MLF that is determined by

$$y_{it}^* = G(\cdot), \quad y_{it} = 1[y_{it}^* > 0], \tag{3}$$

with $1[\cdot]$ as the indicator function to define the binary outcome of its discrete realization y_{it}, which takes on the value one if the respective bank has used the marginal lending facility and zero otherwise. We start with a pooled estimation for our panel logit model. In a second step, we study the validity of our pooled approach. The modern approach to panel data analysis treats unobserved heterogeneity as random draws along with the observed data, and that is the second approach we will take here by employing the random effects estimation. In the robustness section we also report estimations using fixed effects. The results are qualitatively and quantitatively very similar. However, for our fixed effects models we can only consider MRO participants where an MLF recourse could be observed, which reduces our sample size substantially and thus represents our robustness model.

We start with two baseline models. Model 1 refers to a specification where *distance* enters the regression equation linearly. If the variable *distance* is a proper indicator for the bank's stress, the estimated coefficient should be negatively signed. That is, a lower value of *distance* should increase the individual bank's propensity to draw on the marginal lending facility and vice versa. However, the closer each bank's willingness-to-pay gets to

[10] Normally, the quantity-weighted average rate of an MRO deviates by only 2 to 3 basis points from the minimum bid rate.

the MLF rate, the more sensitive the response probability might become. This, however, would suggest the inclusion of a term with a nonlinear nature. Therefore, we set up Model 2 where *distance* is also allowed to enter quadratically. If lower values of *distance* increase the response probability in a nonlinear fashion, we expect the estimated coefficient to be significant and positively signed.

In a further step, we extend our baseline models by including additional variables. In periods of elevated uncertainty in money markets banks might bid more aggressively in the auctions in order contain their dependency on volatile interbank markets. Banks might use the repo auctions as safe haven and submit more aggressive bids in order to make sure that they receive at least a minimum level of liquidity, see e.g. Cassola et al. (2011). Due to this elevated uncertainty banks might at the same time also have a stronger tendency to draw on the marginal lending facility. Moreover, following the literature on price-discriminatory auctions, a higher uncertainty regarding the auctioned good is associated with a higher risk of over-valuation yielding a higher dispersion in submitted bids and lower incentives for bid shading.[11] Hence, we need to account for any uncertainty regarding the auctioned good prevailing in the market. The one-week Eurepo rate is the rate for secured interbank lending with the same maturity as MROs. This market is very liquid and represents the closest substitute for liquidity obtained in the auction, since both collateralization and the maturity are similar. Thus the realized volatility of the daily repo rate over the past month up to the day of any given auction should give some indication about the uncertainty regarding the auctioned good. This measure is included as variable *uncertainty* in our third model. In order to take also into account that any bid shading that may be reflected in our *distance* variable could vary with the market uncertainty we also include an interaction term between the bank specific *distance* variable and the variable *uncertainty*.

Additionally, bank's willingness-to-pay in MRO auctions as well as their propensity to draw on the MLF might be related to alternative refinancing opportunities such as longer-term repo auctions (LTRO). If banks consider these operations as substitutes for MRO auctions, banks may bid significantly different in the proceeding MRO, see e. g. Eisenschmidt et al. (2009). Generally, LTROs are conducted on the basis of an indicative

[11] See Nautz (1995), Nautz (1997), and Nautz and Wolfstetter (1997). To some extent we account for this effect already by including solely successful bids. But admittedly, this might solve potential bid shading issues only partly as it is reasonable to believe that under uncertainty some financial institutions might face difficulties in seeking funding from alternative refinancing sources as well.

calendar that is announced three months prior to the year for which it is valid. In normal cases, LTROs are conducted once a month and between two consecutive MRO auctions. To account for imminent longer-term repo auctions, we will construct the binary variable D_{LTRO} that takes the value 1 if an LTRO was conducted and zero otherwise.[12]

As an additional liquidity providing measure, the Eurosystem started to allot *supplementary* LTROs (sLTRO) during the crisis [European Central Bank (2010)]. These operations were part of the unconventional toolkit to alleviate the strains in money markets and to meet banks' increased liquidity demand. As an alternative specification, we introduce in Model 6 a binary variable which is equal to 1 when a sLTROs was conducted and zero otherwise.

Finally, one could have the notion that apart from money market uncertainty and from the availability of LTROs there might be other aggregate unobserved factors affecting simultaneously banks' willingness-to-pay for liquidity in MROs and their respective subsequent propensity to take recourse to the MLF. In order to take care of such concerns we also run our panel logit estimates with random bank effects and at the same time control for monthly time fixed effects. These time fixed effects should capture the influence of any aggregate unobserved variable that might drive our results. However, our aim is to show that there is a strong correlation between banks' willingness-to-pay in an auction and its probability for a subsequent recourse to the MLF. We do not want to identify a causal relationship between the two measures. In other words, a time fixed effect might pick up the correlation between different banks' willingness-to-pay for liquidity due to, for instance, elevated systemic risk or other tensions in money markets, which also increases the likelihood of a recourse to the MLF for each bank. The correlation of a bank's *distance* measure with an LOLR assistance and its predictive power for the banks' subsequent recourse to the MLF is based on the fact that the willingness-to-pay for liquidity in an auction comprises this information. Thus if after allowing for time fixed effects the *distance* measure appears to be still a significant determinant for a banks' subsequent recourse to the LOLR facility, it does not really question whether the *distance* measure is a good predictor for a banks' distress. It rather reveals that the idiosyncratic, i.e. bank specific, component in this relation is small.

[12] For a full list of all operations refer to `http://www.ecb.int/mopo/implement/omo/html/top_history.en.html`.

As Table 1 indicates, our data set also includes small LOLR recourses below € 100. These recourses are presumably not a result of a bank's difficulty in acquiring funds from financial markets. These are rather standardized and automatic MLF recourses that occur to assure non-negative current accounts at close of each business day. Since the costs of paying the marginal rate rather than a lower rate (in interbank money market or in an auction) are negligible for small amounts banks presumably do not care about those MLF recourses. However, including these observations in our analysis has an impact on the estimated propensity. Therefore, we will run our estimations for LOLR recourses also for amounts exceeding the value of € 1 million.[13]

For each of these models, our left-hand side variable is specified in three different ways. First, we consider bank's LOLR recourses conducted on MRO *auction days*. In this respect, we focus on whether *distance* has a predictive power for the bank's propensity of seeking LOLR assistance on the very same day. Second, we study further whether *distance* is explanatory for any of the MRO bidder's LOLR recourses one *day after* the repo auction they had attended. This is the day on which the previous auction's repo contract matures. And third, we take any MRO bidding bank into account that has received funding from the MLF on *any* of the days subsequent to the settlement of the repo auction. These are typically three to four days. This third specification is particularly important for our question of whether *distance* can be considered as an early warning indicator for banks' LOLR recourse. This third specification aims to analyze whether *distance* can be considered as a proper measure to predict the recourse propensity few days later.

6 Empirical Results

The results of our estimations are presented in Table 3 through Table 5, where Table 3, Table 4, and Table 5 refer to specification 1, 2, and 3, respectively, i.e. whether the MLF recourse occurred on the auction day, the settlement day of an MRO or on one of the remaining days between two consecutive MROs. Standard errors are presented in parentheses.

Overall the estimates we obtain across the different models and specification are very robust and consistent. The first four columns of each table reflect our basic Model 1

[13] We have chosen different thresholds (not reported). However, the results remain qualitatively similar.

and 2. The signs of the *distance*-coefficients are highly significant and plausible across models and specifications. That is, the estimated coefficient of β indicates that lower values of *distance* increase the propensity to draw on the LOLR facility. With respect to the estimated coefficient of the quadratic term, the results show that at a lower level of *distance* the propensity of a recourse responds more sensitive to *distance*, i.e. when a bank is bidding very aggressively and willing to pay close to the marginal lending rate variations in its bidding behavior convey more precise information about the probability that this bank suffers from a severe liquidity shortage and has to turn to the LOLR for assistance. Interestingly, Table 5 reveals that, in general, *distance* is also able to predict the propensity of whether financial institutions will seek LOLR assistance in the days subsequent to a repo auction. It is also noteworthy that our results are qualitatively and quantitatively very similar if we focus our analysis on MLF recourses beyond € 1 million, see Table 6 to Table 8.

In model 4 we include as a first control variable the standard deviation of the daily one-week Eurepo over the previous month and the interaction term of this *uncertainty* measure with our key variable of interest, the *distance* measure. We do not find evidence that a higher aggregate uncertainty in interbank markets leads indeed to a higher propensity of a recourse to the MLF. Also the information content of banks' bidding behavior for the likelihood of a future recourse to the MLF is not significantly different in times of elevated uncertainty in interbank markets. More importantly, though, is that the inclusion of these two control variables does not change the statistical and economic significance of our *distance* measure. This suggests that bid shading does not significantly impair the information content of banks' bidding behavior for assessing their propensity to take recourse to the MLF and *distance* seems to indeed reflect banks opportunity costs of obtaining liquidity.

The estimates of model 5 indicate that indeed the ability to obtain liquidity in an LTRO affects the probability with which a bank draws on the MLF. If a regular LTRO follows on an MRO the likelihood that a bank demands subsequently liquidity in the MLF is lower. With respect to the supplementary LTROs that the Eurosystem conducted to mitigate tensions in the financial system the results are different. In periods with an sLTRO (model 6) after an MRO the probability of a recourse was actually elevated. This likely reflects the fact that during the crisis period when sLTROs were maintained banks had a higher propensity to rely on LOLR liquidity support. However, most importantly our key results

remain unchanged when controlling for the different types of imminent LTROs suggesting that our key results are not driven by an unobserved variable bias introduced through LTROs.

Finally, the results of model 7, which includes monthly time fixed effects, show that indeed there is an omitted aggregate factor or cross-section correlation between banks' bidding behavior as well as their recourse to the MLF playing a role. After the inclusion of monthly time fixed effects the results are statistically still significant. However, as already discussed this only means that idiosyncratic (bank specific shocks) are less relevant for the predictive power of the *distance*. The predictive power rather results from the fact that also general aggregate market developments and systemic risk considerations which affect each banks propensity to take recourse to the MLF are also comprised in this measure. Including time-varying fixed effects in the models 2 through 4 would lead to the same conclusion.[14]

Additionally, we calculate the predictive margin of different states of *distance* for a positive outcome. This allows us to compare the probabilities of drawing on the MLF between an average bank with a *distance* value close to zero and a bank with a value close to one. Since we are mostly interested in whether *distance* can be considered as an early warning indicator for a LOLR assistance on any of the subsequent days, we will focus on the predictive margins of *distance*, exemplarily for the specification 3 of Model 2. Figure 2 shows the results for LOLR recourses between two consecutive auctions. Panel (a) refers to the estimates based on the full data set, while panel (b) shows the predictive margin where only LOLR recourses above the 1 € million threshold are considered. The dotted lines denote the 95% confidence interval.

In both figures, the predicted probability of a specific bank to draw on the MLF increases as *distance* approaches the value zero, i. e. the willingness-to-pay reaches the level of the LOLR rate. Similarly, the model assigns an almost zero probability to an MLF recourse when *distance* is close to the value one. Furthermore, both figures reveal that each bank's propensity responds almost only upon a given '*threshold*' (tipping point) in a statistically significant way. That is, once a bank's willingness-to-pay is sufficiently close to the MLF rate, our model assigns a notable probability of drawing on the MLF to that

[14] To save space, however, we excluded the respective tables, which may be provided at any time upon request.

bank, which increases non-linearly with a decreasing *distance* to the LOLR rate.

Based on these findings, we generally conclude that there is indeed a strong link between bank's bidding behavior in Eurosystem's repo auctions and the respective bank's propensity to draw on the MLF. In fact, our *distance* measure is found to provide a helpful indication of bank's stress status and to predict a bank's propensity of drawing on the marginal lending facility, even for days following a repo auction.

7 Robustness Check

In this subsection, we provide several additional analyses to test the validity of the empirical specification and the robustness of the results. In particular we re-estimate the various models using fixed effects rather than random effects.

Obviously, it seems reasonable to assume that the propensity of banks to take recourse to the MLF is also driven by unobserved bank characteristics. These characteristics are likely affecting banks' bidding behaviors. As long as these bank characteristics are persistent and not varying substantially over our sample period including bank fixed effects would capture such unobserved characteristics. A key problem, though, is that we cannot include bank fixed effects in our model as long as observations are included in our sample for banks that bid in auctions but did not draw on the MLF. Thus in order to estimate a fixed effect model we have to confine our analysis to those banks that took at least once a recourse to the MLF on the respective day of the MRO and bid in the preceding auction. This reduces our data set from 1055 banks to (i) 110, (ii) 88 and (iii) 96 in the respective specification and from 63,408 observations to 12,475, 10,265 and 11,056, respectively. This substantial drop in sample size bears the risk of a potential selection bias. Therefore, we consider the estimates with bank fixed effect rather as a robustness exercise.

The results for the various models based on the different specifications using bank fixed effect estimates are presented in Table 6, 7 and 8. Across the board and quite surprisingly the results basically do not change neither qualitatively nor quantitatively.

8 Concluding remarks

In this paper, we relate each bank's behavior in the Eurosystem's main liquidity providing operations (main refinancing operations, MROs) to their lender of last resort (LOLR)

recourses to derive an indicator for bank's stress level in seeking refinancing in the euro area money market. Our results suggest (i) that banks' willingness-to-pay for central bank reserves indeed reflects refinancing conditions in the interbank market and (ii) that the willingness-to-pay can serve as an early warning indicator for banking distress.

The contribution of these result to the existing literature is twofold. First, they suggest that central banks and banking supervisors can use banks' bidding behavior as a stress indicator for signaling bank's specific liquidity squeezes. Second, the related literature that analyzes bank's bidding behavior in liquidity auctions to shed light on the frictions prevailing in the interbank market [Craig and Fecht (2007), Linzert et al. (2007), Bindseil et al. (2009), Eisenschmidt et al. (2009) and Fecht et al. (2011)] is challenged. They take the view that the bids are less driven by opportunity costs or arbitrage considerations rather than by strategic considerations as regards the auction outcome. Our findings, however, imply that there is a strong correlation between the aggressiveness of bids and the likelihood with which a bank draws on the Eurosystem's LOLR facility. The decision to take recourse to the MLF is an indication for a bank being liquidity squeezed, which is undoubtedly not blurred by strategic behavior. Thus the strong correlation of banks willingness-to-pay in an auction and their subsequent propensity to draw on the LOLR facility shows that the bidding behavior is indeed driven to a large extent by bank specific liquidity needs and not only by the winner's curse or bid shading considerations.

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A Tables

Table 1: Summary statistics on LOLR recourses

The purpose of this table is to provide summary statistics on the LOLR recourses of all financial institutions in the euro area during the period January 5, 2005 to October 8, 2008. The upper part of the table refers to the full and raw dataset with all reported LOLR recourses. The lower section, however, reflects only MLFs from MRO bidding banks. The descriptive statistics hence focus on the different subsamples as a result of our three specifications, i.e. (i) LOLR recourse on auction day, (ii) LOLR recourse on the day when previous auction's repo matures, and (iii) LOLR between two consecutive auctions.

All recourses		in % of total			in € millions			
Total amount drawn from (in € million)	354,561	100%	Variable	Obs.	Mean	Std.	Min.	Max.
Total number of recourses	3,208	100%	MLF	3208	111	585	0.000001	11,500
Number of banks	414							
Recourse on auction day								
Total amount drawn from (in € million)	64,950	18%	Variable	Obs.	Mean	Std.	Min.	Max.
Total number of recourses	372	12%	MLF	372	175	748	0.000081	11,300
Number of banks	110	–						
Recourse volume >1 € million	121 of the 372 recourses dropped							
Recourse on settlement day								
Total amount drawn from (in € million)	27,527	8%	Variable	Obs.	Mean	Std.	Min.	Max.
Total number of recourses	189	6%	MLF	189	146	881	0.0001	10,800
Number of banks	88	–						
Recourse volume >1 € million	74 of the 189 recourses dropped							
Recourse between settlement and next auction day								
Total MLF amount drawn from (in € million)	123,835 €	35%	Variable	Obs.	Mean	Std.	Min.	Max.
Total number of recourses	394	12%	MLF	394	314	1149	0.0001	11,500
Number of banks	97	–						
Recourse volume >1 € million	167 of the 394 recourses dropped							

Table 2: Summary statistics on MRO bidding data and the repo rate

This table provides descriptive statistics on the bid-quantity schedules that we observe in the Eurosystem's main refinancing operations (MROs) in the period January 5, 2005 to October 8, 2008. The **willingness-to-pay** is computed as the quantity-weighted average MRO interest rate across all successful bids. As the **LOLR interest rate**, we report the statistics for the Eurosystem's marginal lending interest rate that prevailed immediately before the auctions. **Distance** is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** refers to the volatility by means of the one-month standard deviation of the daily one-week repo rate. On September 30, 2008 the observed willingness-to-pay exceeded once the LOLR rate by 25 basis points. This observation has been excluded from our sample.

	Mean	Std.	Min.	Max.	Obs.
No. of bids	1.71	1.14	1.00	10	118225
Willingness-to-pay (in %)	3.15	0.90	2.05	5.25	63408
distance (in %)	0.86	0.12	0.00	1.00	63408
LOLR interest rate (in %)	4.00	0.85	3.00	5.25	63408
Uncertainty (in %)	0.04	0.04	0.00	0.15	63408

Table 3: LOLR recourse on auction day

This table shows the propensity to draw on the LOLR facility on the repo auction day in the period from January 5, 2005 to October 8, 2008. **Distance** is a variable that measures each bank's individual stress level to seek funding in the interbank money market. It is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** denotes the interest rate volatility for a one-week collateralized money market loan. We compute the volatility by means of the one-month standard deviation of the daily one-week repo rate. D_{LTRO} is a binary variable that equals 1 on any auction day preceding the conduct of an LTRO and zero otherwise. In the same vein, we include the dummy variable D_{sLTRO} to control for any effect stemming from Eurosystem's **supplementary** LTROs during the financial crisis. Each column of the table represents a different model specification. **Model 1** and **2** stem from a pooled estimation and are different in that they consider a linear and an additional quadratic 'distance' term, respectively. In **Model 3-7**, we employ a random effects estimation. **Model 3** adopts the specification of Model 2. **Model 4** extends Model 3 by the repo rate volatility and its interaction term with the 'distance' term. **Model 5** expands Model 4 by the LTRO dummy to account for alternative refinancing operations. We substitute our LTRO variable in **Model 6** with the dummy that accounts for supplementary LTROs instead. **Model 7** employs our third model but controls for monthly time-varying fixed effects. Following this structure, **Model 8-14** re-estimate the models 1-7 while only considering LOLR recourses that exceed the amount of € millions (**significant recourses**).

LOLR recourse on auction day														
	all recources							significant recources						
	pooled		random effects					pooled		random effects				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
distance	-1.513***	-10.48***	-12.76***	-13.13***	-14.01***	-14.06***	-9.654***	-2.244***	-11.20***	-13.87***	-15.35***	-16.39***	-16.25***	-11.15***
	(0.365)	(1.357)	(1.728)	(2.999)	(3.015)	(3.028)	(2.676)	(0.409)	(1.461)	(1.890)	(3.293)	(3.319)	(3.321)	(2.951)
distance^2		6.642***	7.953***	6.995***	7.139***	7.914***	5.661***		6.864***	8.337***	8.048***	8.227***	8.872***	6.080**
		(1.046)	(1.270)	(1.860)	(1.857)	(1.874)	(2.097)		(1.163)	(1.420)	(2.083)	(2.081)	(2.100)	(2.399)
uncertainty				-11.04	-11.52	-8.873					-14.32	-14.89	-12.89	
				(8.887)	(8.972)	(9.094)					(9.618)	(9.741)	(9.807)	
dummy (LTRO)					-0.622***							-0.694***		
					(0.140)							(0.173)		
distance x uncertainty				5.859	5.102	4.282					11.03	10.24	10.20	
				(11.66)	(11.75)	(11.80)					(12.77)	(12.91)	(12.89)	
dummy (sLTRO)						0.874***							0.818***	
						(0.197)							(0.238)	
cons	-3.858***	-1.160***	-2.679***	-1.437	-0.598	-1.444	-3.495***	-3.654***	-1.121**	-2.425***	-0.754	0.199	-0.715	-3.003***
	(0.307)	(0.428)	(0.613)	(1.294)	(1.316)	(1.317)	(1.023)	(0.339)	(0.440)	(0.644)	(1.381)	(1.414)	(1.401)	(1.141)
lnsig2u			1.655***	1.657***	1.662***	1.664***	1.665***			1.645***	1.651***	1.661***	1.659***	1.650***
			(0.166)	(0.167)	(0.167)	(0.167)	(0.167)			(0.189)	(0.190)	(0.191)	(0.191)	(0.190)
Time FE	No	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes
Obs.	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408
No. banks	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055

Table 4: LOLR Recourse on the same day when previous auction's repo matures

This table reflects the results for our second specification, capturing the utility to use the LOLR facility on the day when the previous auction's repo matures. For this purpose, we consider euro area recourses that we observe in the period from January 5, 2005 to October 8, 2008. **Distance** is a variable that measures each bank's individual stress level to seek funding in the interbank money market. It is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** denotes the interest rate volatility for a one-week collateralized money market loan. We compute the volatility by means of the one-month standard deviation of the daily one-week repo rate. D_{LTRO} is a binary variable that equals 1 on any auction day preceding the conduct of an LTRO and zero otherwise. In the same vein, we include the dummy variable D_{sLTRO} to control for any effect stemming from Eurosystem's **supplementary** LTROs during the financial crisis. Each column of the table represents a different model specification. **Model 1** and **2** stem from a pooled estimation and are different in that they consider a linear and an additional quadratic 'distance' term, respectively. In **Model 3-7**, we employ a random effects estimation. **Model 3** adopts the specification of Model 2. **Model 4** extends Model 3 by the repo rate volatility and its interaction term with the 'distance' term. **Model 5** expands Model 4 by the LTRO dummy to account for alternative refinancing operations. We substitute our LTRO variable in **Model 6** with the dummy that accounts for supplementary LTROs instead. **Model 7** employs our third model but controls for monthly time-varying fixed effects. Following this structure, **Model 8-14** re-estimate the models 1-7 while only considering LOLR recourses that exceed the amount of € millions (**significant recourses**).

LOLR Recourse on the same day when previous auction's repo matures

	all recources							significant recources						
	pooled		random effects					pooled		random effects				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
distance	-1.659***	-9.440***	-10.79***	-13.39***	-13.23***	-13.21***	-16.28***	-2.399***	-9.641***	-10.41***	-10.20**	-10.03**	-10.36**	Not converged
	(0.503)	(1.868)	(2.197)	(3.589)	(3.599)	(3.594)	(3.821)	(0.592)	(2.138)	(2.426)	(4.363)	(4.391)	(4.374)	
distance^2		5.773***	6.789***	7.571***	7.737***	7.387***	9.149***		5.547***	6.236***	5.049*	5.463*	5.214*	
		(1.439)	(1.653)	(2.257)	(2.271)	(2.272)	(2.964)		(1.692)	(1.883)	(2.808)	(2.842)	(2.825)	
uncertainty				-14.56	-14.52	-15.05					-8.725	-8.691	-8.432	
				(11.41)	(11.38)	(11.37)					(13.36)	(13.31)	(13.42)	
dummy (LTRO)					0.362**							0.676***		
					(0.163)							(0.200)		
distance x uncertainty				15.49	16.31	15.86					3.015	4.710	2.878	
				(14.78)	(14.77)	(14.74)					(18.16)	(18.12)	(18.18)	
dummy (sLTRO)						-0.269							0.183	
						(0.376)							(0.381)	
cons	-4.417***	-2.076***	-3.467***	-1.721	-2.133	-1.717	-1.220	-4.311***	-2.251***	-3.345***	-2.407	-3.161*	-2.402	
	(0.421)	(0.592)	(0.745)	(1.562)	(1.571)	(1.556)	(1.653)	(0.488)	(0.653)	(0.785)	(1.816)	(1.828)	(1.820)	
lnsig2u			1.238***	1.230***	1.230***	1.233***	1.247***			0.895***	0.877***	0.877***	0.875***	
			(0.187)	(0.187)	(0.187)	(0.187)	(0.187)			(0.229)	(0.229)	(0.229)	(0.229)	
Time FE	No	No	No	No	No	No	Yes	No	No	No	No	No	No	
Obs.	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	
No. banks	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	

Table 5: LOLR recourse between two consecutive auction days

In this table, we present the empirical results for the propensity that a financial institution will use its recourse to the LOLR facility between two consecutive auction days. The period over which we run our estimations covers January 5, 2005 through October 8, 2008. **Distance** is a variable that measures each bank's individual stress level to seek funding in the interbank money market. It is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** denotes the interest rate volatility for a one-week collateralized money market loan. We compute the volatility by means of the one-month standard deviation of the daily one-week repo rate. D_{LTRO} is a binary variable that equals 1 on any auction day preceding the conduct of an LTRO and zero otherwise. In the same vein, we include the dummy variable D_{sLTRO} to control for any effect stemming from Eurosystem's **supplementary** LTROs during the financial crisis. Each column of the table represents a different model specification. **Model 1** and **2** stem from a pooled estimation and are different in that they consider a linear and an additional quadratic 'distance' term, respectively. In **Model 3-7**, we employ a random effects estimation. **Model 3** adopts the specification of Model 2. **Model 4** extends Model 3 by the repo rate volatility and its interaction term with the 'distance' term. **Model 5** expands Model 4 by the LTRO dummy to account for alternative refinancing operations. We substitute our LTRO variable in **Model 6** with the dummy that accounts for supplementary LTROs instead. **Model 7** employs our third model but controls for monthly time-varying fixed effects. Following this structure, **Model 8-14** re-estimate the models 1-7 while only considering LOLR recourses that exceed the amount of € millions (**significant recourses**).

LOLR recourse between two consecutive auction days

	all recources							significant recources						
	pooled		random effects					pooled		random effects				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
distance	-2.085***	-11.44***	-14.30***	-18.55***	-18.36***	-18.67***	-14.97***	-3.369***	-12.61***	-15.07***	-17.96***	-17.76***	-18.19***	-16.18***
	(0.364)	(1.319)	(1.842)	(2.989)	(2.996)	(3.002)	(2.652)	(0.409)	(1.454)	(1.957)	(3.540)	(3.553)	(3.557)	(2.872)
distance^2		7.125***	8.927***	10.40***	10.62***	10.51***	10.52***		7.471***	8.963***	9.459***	9.828***	9.661***	10.95***
		(1.042)	(1.372)	(1.883)	(1.894)	(1.897)	(2.108)		(1.206)	(1.510)	(2.291)	(2.312)	(2.307)	(2.385)
uncertainty				-21.68**	-21.62**	-21.50**					-18.22*	-18.21*	-18.05*	
				(8.969)	(8.954)	(8.996)					(10.19)	(10.16)	(10.23)	
dummy (LTRO)					0.455***							0.655***		
					(0.129)							(0.164)		
distance x uncertainty				23.78**	24.83**	23.67**					15.45	17.09	15.47	
				(11.65)	(11.65)	(11.67)					(13.87)	(13.86)	(13.88)	
dummy (sLTRO)						0.130							0.239	
						(0.264)							(0.318)	
cons	-3.505***	-0.824**	-2.521***	0.146	-0.378	0.154	-3.090***	-3.020***	-0.666	-2.235***	-0.127	-0.862	-0.0990	-2.825***
	(0.302)	(0.401)	(0.652)	(1.283)	(1.290)	(1.285)	(0.969)	(0.328)	(0.408)	(0.661)	(1.450)	(1.459)	(1.454)	(1.063)
lnsig2u			1.775***	1.765***	1.765***	1.764***	1.781***			1.689***	1.755***	1.751***	1.754***	1.726***
			(0.187)	(0.186)	(0.187)	(0.186)	(0.189)			(0.206)	(0.217)	(0.217)	(0.217)	(0.213)
Time FE	No	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes
Obs.	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408	63408
No. banks	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055	1055

Table 6: LOLR recourse on auction day (robustness check)

In this table we show our estimation results for the propensity to draw on the LOLR facility on the repo auction day in the period from January 5, 2005 to October 8, 2008. In contrast to Table 3, the findings presented here refer to a **fixed effects estimation**. **Distance** is a variable that measures each bank's individual stress level to seek funding in the interbank money market. It is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** denotes the interest rate volatility for a one-week collateralized money market loan. We compute the volatility by means of the one-month standard deviation of the daily one-week repo rate. D_{LTRO} is a binary variable that equals 1 on any auction day preceding the conduct of an LTRO and zero otherwise. In the same vein, we include the dummy variable D_{sLTRO} to control for any effect stemming from Eurosystem's **supplementary** LTROs during the financial crisis. Each column of the table represents a different model specification. **Model 1** and **2** are different in that they consider a linear and an additional quadratic 'distance' term, respectively. **Model 3** enriches Model 2 by the repo rate volatility and its interaction term with the 'distance' term. **Model 4** expands Model 3 by the LTRO dummy to account for alternative refinancing operations. We substitute our LTRO variable in **Model 5** with the dummy that accounts for supplementary LTROs instead. **Model 6** employs our third model but controls for monthly time-varying fixed effects. Following this structure, **Model 7-12** re-estimate the models 1-6 while only considering LOLR recourses that exceed the amount of € millions (**significant recourses**).

LOLR recourse on auction day												
fixed effects												
	all recources						significant recources					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
distance	-1.868***	-12.40***	-12.75***	-13.69***	-13.72***	-8.013***	-2.694***	-13.91***	-15.58***	-16.90***	-16.70***	-9.675***
	(0.394)	(1.829)	(3.217)	(3.260)	(3.265)	(2.762)	(0.439)	(2.117)	(3.715)	(3.794)	(3.773)	(3.268)
distance^2		7.621***	6.593***	6.786***	7.523***	4.423**		8.282***	8.037***	8.398***	8.985***	4.905*
		(1.327)	(1.971)	(1.983)	(1.998)	(2.159)		(1.555)	(2.325)	(2.353)	(2.362)	(2.612)
uncertainty			-11.39	-11.97	-9.257				-15.04	-15.95	-13.93	
			(9.394)	(9.509)	(9.616)				(10.15)	(10.31)	(10.34)	
dummy (LTRO)				-0.616***						-0.694***		
				(0.139)						(0.173)		
distance x uncertainty			5.891	5.312	4.323				11.46	11.16	11.00	
			(12.28)	(12.41)	(12.45)				(13.44)	(13.61)	(13.56)	
dummy (sLTRO)					0.900***						0.845***	
					(0.198)						(0.239)	
Time FE	No	No	No	No	No	Yes	No	No	No	No	No	Yes
Obs.	12475	12475	12475	12475	12475	12475	10295	10295	10295	10295	10295	10295
No. banks	110	110	110	110	110	110	89	89	89	89	89	89

Table 7: LOLR Recourse on the same day when previous auction's repo matures (robustness check)

The results presented in this table replicate the estimation presented in Table 4, yet are based on a **fixed effects estimation**. Our period under consideration remains from January 5, 2005 to October 8, 2008. **Distance** is a variable that measures each bank's individual stress level to seek funding in the interbank money market. It is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** denotes the interest rate volatility for a one-week collateralized money market loan. We compute the volatility by means of the one-month standard deviation of the daily one-week repo rate. D_{LTRO} is a binary variable that equals 1 on any auction day preceding the conduct of an LTRO and zero otherwise. In the same vein, we include the dummy variable D_{sLTRO} to control for any effect stemming from Eurosystem's **supplementary** LTROs during the financial crisis. Each column of the table represents a different model specification. **Model 1** and **2** are different in that they consider a linear and an additional quadratic 'distance' term, respectively. **Model 3** enriches Model 2 by the repo rate volatility and its interaction term with the 'distance' term. **Model 4** expands Model 3 by the LTRO dummy to account for alternative refinancing operations. We substitute our LTRO variable in **Model 5** with the dummy that accounts for supplementary LTROs instead. **Model 6** employs our third model but controls for monthly time-varying fixed effects. Following this structure, **Model 7-12** re-estimate the models 1-6 while only considering LOLR recourses that exceed the amount of € millions (**significant recourses**).

LOLR Recourse on the same day when previous auction's repo matures												
fixed effects												
	all recources						significant recources					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
distance	-1.484***	-10.67***	-13.05***	-12.89***	-12.83***	-16.01***	-2.028***	-10.18***	-9.604**	-9.398**	-9.664**	-11.99**
	(0.549)	(2.304)	(3.865)	(3.868)	(3.859)	(4.402)	(0.637)	(2.647)	(4.724)	(4.742)	(4.738)	(4.943)
distance^2		6.820***	7.604***	7.762***	7.390***	9.169***		6.257***	5.037*	5.405*	5.093*	5.175
		(1.722)	(2.387)	(2.398)	(2.394)	(3.311)		(2.032)	(3.003)	(3.031)	(3.020)	(4.111)
uncertainty			-12.45	-12.44	-13.05				-5.692	-5.631	-5.582	
			(12.19)	(12.17)	(12.12)				(14.31)	(14.28)	(14.34)	
dummy (LTRO)				0.365**						0.682***		
				(0.163)						(0.201)		
distance x uncertainty			13.54	14.39	14.02				0.307	1.858	0.241	
			(15.68)	(15.67)	(15.61)				(19.23)	(19.23)	(19.24)	
dummy (sLTRO)					-0.337						0.0672	
					(0.377)						(0.384)	
Time FE	No	No	No	No	No	Yes	No	No	No	No	No	Yes
Obs.	10265	10265	10265	10265	10265	10265	8720	10265	10265	10265	10265	10265
No. banks	88	88	88	88	88	88	74	74	74	74	74	84

Table 8: LOLR recourse between two consecutive auction days (robustness check)

The results presented in this table follow the same specification as in Table 5 but employ a **fixed effects estimation**. The period over which we run these estimations remains January 5, 2005 through October 8, 2008. **Distance** is a variable that measures each bank's individual stress level to seek funding in the interbank money market. It is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids. **Uncertainty** denotes the interest rate volatility for a one-week collateralized money market loan. We compute the volatility by means of the one-month standard deviation of the daily one-week repo rate. D_{LTRO} is a binary variable that equals 1 on any auction day preceding the conduct of an LTRO and zero otherwise. In the same vein, we include the dummy variable D_{sLTRO} to control for any effect stemming from Eurosystem's **supplementary** LTROs during the financial crisis. Each column of the table represents a different model specification. **Model 1** and **2** are different in that they consider a linear and an additional quadratic 'distance' term, respectively. **Model 3** enriches Model 2 by the repo rate volatility and its interaction term with the 'distance' term. **Model 4** expands Model 3 by the LTRO dummy to account for alternative refinancing operations. We substitute our LTRO variable in **Model 5** with the dummy that accounts for supplementary LTROs instead. **Model 6** employs our third model but controls for monthly time-varying fixed effects. Following this structure, **Model 7-12** re-estimate the models 1-6 while only considering LOLR recourses that exceed the amount of € millions (**significant recourses**).

LOLR recourse between two consecutive auction days												
fixed effects												
	all recources						significant recources					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
distance	-2.170***	-14.39***	-18.10***	-17.88***	-18.23***	-14.70***	-3.391***	-14.76***	-17.10***	-16.80***	-17.34***	-14.80***
	(0.416)	(2.005)	(3.252)	(3.253)	(3.267)	(2.927)	(0.460)	(2.176)	(3.938)	(3.942)	(3.964)	(3.233)
distance^2		9.040***	10.37***	10.57***	10.49***	10.43***		8.817***	8.945***	9.230***	9.140***	10.01***
		(1.474)	(2.025)	(2.032)	(2.040)	(2.287)		(1.657)	(2.502)	(2.518)	(2.524)	(2.628)
uncertainty			-18.48*	-18.43*	-18.28*				-17.66	-17.51	-17.56	
			(9.625)	(9.608)	(9.654)				(11.20)	(11.17)	(11.24)	
dummy (LTRO)				0.464***						0.645***		
				(0.129)						(0.164)		
distance x uncertainty			20.53*	21.59*	20.41				15.04	16.42	15.11	
			(12.41)	(12.41)	(12.43)				(15.12)	(15.11)	(15.14)	
dummy (sLTRO)					0.131						0.214	
					(0.265)						(0.320)	
Time FE	No	No	No	No	No	Yes	No	No	No	No	No	Yes
Obs.	11056	11056	11056	11056	11056	11056	8410	11056	11056	11056	11056	11056
No. banks	96	96	96	96	96	96	72	72	72	72	72	72

B Figures

Figure 1: Specification for our empirical analysis

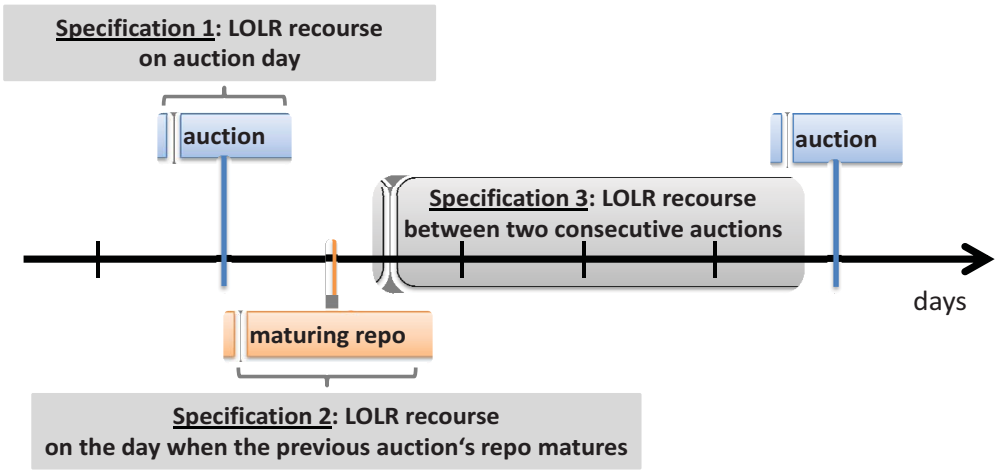
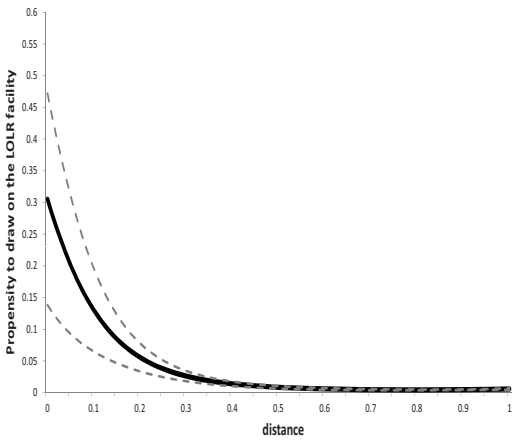
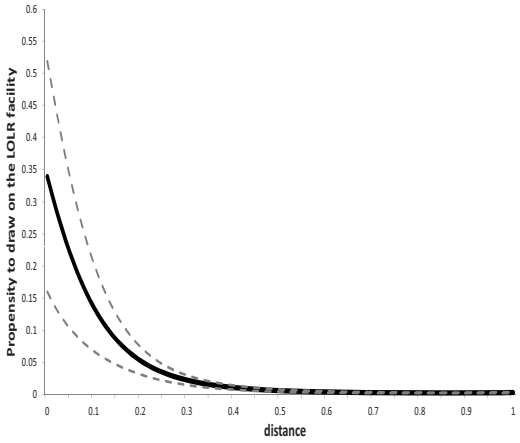


Figure 2: Predictive margin of different states of *distance* for days subsequent to an MRO (specification 3)



(a) All LOLR recourses between two consecutive auctions



(b) LOLR recourses beyond 1 € million of value and between two consecutive auctions

Notes: These predictive margins are determined on the basis of Model 2 and consider only LOLR recourses between two consecutive auctions (specification 3). The dotted lines denote the 95% confidence interval and the solid line reflects the predictive margin of different states of *distance*. **distance** is computed as the difference between the marginal lending rate and the quantity-weighted average MRO rate across all successful bids.