DEUTSCHE BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 24/2015

The intraday interest rate – what's that?

Puriya Abbassi
(Deutsche Bundesbank)

Falko Fecht
(Frankfurt School of Finance and Management)

Johannes Tischer
(Deutsche Bundesbank and Johannes Gutenberg-Universität Mainz)

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

ISBN 978–3–95729–173–8 (Printversion)
ISBN 978–3–95729–174–5 (Internetversion)

Non-technical Summary

Research Question

Banks generally have an incentive to delay payments while managing their liquidity positions. From a systemic and financial stability perspective, this can create a gridlock and induce operational risks for payment systems as the bulk of transactions would be send in the last minutes of any given business day. Therefore, most central banks provide banks that participate in large-value real-time gross settlement systems with an intraday overdraft facility at a zero interest rate (or a rate much lower than the overnight rate). As a consequence banks should no longer have an incentive to delay payments within a day as liquidity is freely available during the day. In this paper, we use a novel and comprehensive dataset to study whether an intraday interest rate still prevails in the European secured money market, both before and during the financial crisis.

Contribution

Few empirical studies support the existence of an intraday term structure in the unsecured segment of interbank money markets. But intraday interest rates estimated on the basis of unsecured overnight loans do not necessarily indicate that liquidity is indeed pricier in the morning. They might as well be an artifact of banks with different credit risks and collateral constraints borrowing at different times during the day. We overcome this hurdle by using secured funding data provided by Eurex Repo, i.e. the leading market place for euro general collateral (GC) repos. Moreover, Eurex Repo use a collateral basket that is also accepted for the intraday overdraft facility in Eurosystem's TARGET2. Thus, by definition to the extent that banks satisfy their liquidity needs in this market they cannot be collateral constrained in using the Eurosystem's intraday credit line.

Results

Our results document that indeed before September 2007 there was virtually no intraday interest rate prevailing in the repo market. However, with the start of the subprime crisis, we find a significant intraday interest rate of up to 60 basis points (in absolute terms). With the start of the sovereign debt crisis in July 2010, the intraday rate increased even beyond the level it reached after the Lehman failure. The additional liquidity allotment through unconventional long-term refinancing operations (LTRO) with a maturity of one and three years did reduce but not eliminate it. In a further step, we consistently find a significant and strong relationship between the repo market's liquidity and the intraday interest rate suggesting that an important component of the intraday interest rate is a liquidity premium.

Nichttechnische Zusammenfassung

Forschungsfrage

Banken haben in der Regel im Rahmen ihrer Liquiditätssteuerung einen Anreiz, Zahlungen zu verzögern. Aus Finanzstabilitätsperspektive können die damit verbundenen operationellen Risiken innerhalb des Zahlungsverkehrssystems zu einem systemweiten Kollaps führen, wenn der Großteil der Transaktionen dann in den letzten Minuten eines jeden Geschäftstages versendet würde. Daher ermöglichen die meisten Zentralbanken den Banken, Innertagesüberziehungskredite zu einem Zinssatz von null Prozent (oder einer Rate, die viel niedriger als der Tagesgeldsatz ist). In der Konsequenz sollten dann die Banken auch keinen Anreiz mehr haben, Zahlungen innerhalb eines Tages zu verzögern, da Liquidität so über den Tag frei verfügbar wird. Zinssätze für Übernachtkredite zwischen Banken sollten dann auch nicht mehr systematisch im Laufe des Tages variieren. In diesem Papier verwenden wir einen neuen und umfassenden Datensatz, um zu analysieren, ob im Eurosystem dennoch ein Innertageszinssatz vorliegt und wodurch dieser erklärt werden kann.

Beitrag

Einige empirische Studien finden Hinweise auf die Existenz eines Innertageszinses im unbesicherten Segment des Geldmarktes. Allerdings muss ein auf Basis von unbesicherten Übernachtkreditkontrakten geschätzter Innertageszinssatz nicht notwendigerweise bedeuten, dass Liquidität am Morgen tatsächlich teuerer ist. Er kann vielmehr ein Ausdruck von unterschiedlichem Kontrahentenrisisko oder Mangel an Sicherheiten sein. Wir überwinden dieses Problem, indem wir Transaktionsdaten für den besicherten Interbankgeldmarkt nutzen, die uns von Eurex Repo, einem Abwickler von Repo-Geschäften, bereitgestellt wurden. Diese Daten ermöglichen es uns, bei der Schätzung des Innertageszinssatz für das Kontrahentenausfallrisiko und die potenziellen Stigma-Effekte zu kontrollieren. Darüber hinaus eignen sich GC Pooling Repos deswegen für unsere Analyse, weil sie den gleichen Sicherheitenkorb voraussetzen wie sie auch das Europäische System der Zentralbanken (ESZB) für den Innertagesüberziehungskredit in TARGET2 verwendet. Daher können Banken, die am GC pooling Repomarkt handeln, per Definition keinen Sicherheitenengpass haben.

Ergebnisse

Unsere Ergebnisse dokumentieren, dass vor September 2007 kein Innertageszins am Repomarkt vorlag. Doch mit dem Beginn der Finanzkrise finden wir eine deutliche Innertagesverzinsung von bis zu 60 Basispunkten. Mit dem Beginn der Staatsschuldenkrise im Juli 2010 erhöhte sich der Innertageszinssatz sogar auf über das Niveau nach der Lehman-Pleite. Die zusätzliche Liquiditätszuteilung mittels unkonventioneller langfristiger Refinanzierungsgeschäfte (LTRO) mit einer Laufzeit von ein und drei Jahren haben zwar zu einer deutlichen Verringerung geführt, den Innertageszins aber nicht beseitigt. In einem weiteren Schritt finden wir, dass ein erhöhter Innertageszins stark mit geringer Marktliquidität am Repomarkt korreliert. Dieses Ergebnis deutet daraufhin, dass eine Liquiditätsprämie einen wichtigen Bestandteil des Innertageszinssatz darstellt.

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The intraday interest rate - what's that?*

Puriya Abbassi[1], Falko Fecht[2] and Johannes Tischer[1,3]

[1]Deutsche Bundesbank
[2]Frankfurt School of Finance and Management
[3]Johannes Gutenberg-Universität Mainz

June 2015

Abstract

We study the intraday interest rate in a CCP-based GC pooling repo market and its key determinants. Since collateral used in this market is identical to collateral eligible for the daylight overdraft facility of the Eurosystem, any intraday rate in this market cannot be a result of collateral constraints keeping banks from using the overdraft for arbitrage. Nevertheless, we find that in the crisis period a statistically and economically significant intraday spread (up to 60 basis points) prevailed that was only somewhat mitigated by the ECB's unconventional monetary policy measures. Our results show that this spread was mainly determined by the market liquidity of the repo market, suggesting that the intraday spread is largely a liquidity premium.

Keywords: Intraday interest rate, central counterparty, overnight repos, central bank intervention, financial crisis

JEL Classification: E43, E50, G01, G10, G21

*We wish to thank Andre Ebner, Christoph Memmel, Alexander Müller, Marc Resinek, Florian Seifferer, Isabel Schnabel, Lars Stridde, Felix Thierfelder, Jun Yang, and Constantin Weiser. We would also like to thank Eurex Repo GmbH for providing us with the data for this project. Opinions expressed in this paper do not necessarily reflect the views of the Deutsche Bundesbank or its staff. Email: `puriya.abbassi@bundesbank.de` (Puriya Abbassi), `f.fecht@fs.de` (Falko Fecht) and `tischer@uni-mainz.de` (Johannes Tischer).

1 Introduction

Banks generally have an incentive to delay payments while managing their liquidity positions.[1] In doing so, they wait for incoming payments, reuse this incoming liquidity for their own outgoing payments and economize on their reserve holdings. Since transactions typically specify a particular day on which a payment has to be made, delaying a payment for a day or longer entails substantial costs for a bank. However, within a day there is usually no exact time at which a payment must be settled. Thus, banks could in principle try to save on liquidity holdings during the daytime by free-riding on the funds received through incoming payments. This also implies that large-value interbank overnight loans – which usually require immediate settlement – should be more expensive earlier in the day, as in-the-afternoon payments can be settled via incoming payments received throughout the day from other banks (see Angelini, 1998), hence suggesting an intraday interest rate. In this paper, we study the behavior and determinants of intraday interest rates in the European (secured) interbank money market, comparing both normal and crisis times.

This question is of particular interest from a systemic and financial stability perspective, as free-riding on funds received through incoming payments can create a gridlock and induces operational risks for payment systems, as the bulk of transactions would be sent in the last minutes of any given business day. Therefore, most central banks provide banks participating in large-value real-time gross settlement systems with an intraday overdraft facility at a zero interest rate (or a rate much lower than the overnight rate). As a consequence, banks should no longer have an incentive to delay payments within a day as liquidity is freely available intraday (see Kahn and Roberds, 2001, and Bech and Garratt, 2003). Consequently, interest rates on interbank overnight loans should no longer vary systematically during the day. In order to contain the resulting counterparty credit risk, central banks typically require banks to provide collateral against their overdrafts (see Martin, 2004). This, however, implies that banks lacking eligible collateral cannot use the overdraft facility and again have an incentive to delay their payments in order to reuse received fund flows (see Kahn and Roberds, 2001, and Bech and Garratt, 2003). If many banks face such collateral constraints, the overall liquidity again becomes scarce earlier in the day and overnight interbank loans can again be pricier in the morning compared to the afternoon, i.e. an intraday interest rate is charged. But even with sufficient collateral, banks might pay a premium in the morning for overnight loans to avoid market risk (see Angelini,

[1] Throughout the paper we use the term liquidity as referring to cash or funds, while illiquidity and market liquidity refer to the liquidity of a market.

2000). In particular, if markets are not perfectly liquid, banks short in liquidity in the morning face market risk when speculating on lower rates in the afternoon. Thus, any intraday interest rate might also simply reflect a market liquidity premium.

There are many papers which provide evidence on the existence of intraday interest rates in various unsecured interbank markets where central banks offer a collateralized intraday overdraft facility free of charge. Baglioni and Monticini (2008) find that in the tranquil pre-crisis period, a positive intraday interest rate can be found for interbank loans initiated on the Italian e-MID trading platform. For the recent financial crisis period, several authors find a substantially elevated intraday interest rate (see for example Baglioni and Monticini, 2008 and 2013, using Italian e-Mid data, Jurgilas and Zikas, 2014, using interbank loans extracted from the UK's large value payment system CHAPS). The authors generally view this as evidence that collateral constraints were more restrictive during the crisis, rendering the overdraft facility less effective in eliminating any positive intraday interest rate. However, none of those papers considers that variations in the market liquidity risk might also be a key driver of the intraday interest rate as proposed by Angelini (2000).

Moreover, intraday interest rates estimated on the basis of unsecured overnight loans do not necessarily indicate that liquidity is indeed pricier in the morning due to collateral constraints. They might as well be an artifact of banks with different credit risks and collateral constraints borrowing at different times throughout the day. In particular, banks with lower credit quality might be more eager to cover their liquidity needs earlier in the day. They have a higher probability of being rationed (Afonso, Kovner, and Schoar, 2011). Thus, accepting a higher rate in the morning rather than searching for a better deal later in the day is more attractive for them (Ashcraft and Duffie, 2007). As a consequence, the estimated intraday interest rate might simply reflect that risky and opaque banks borrow earlier, while safe banks can afford to wait. Given the overall increase in credit risk in the banking sector, these effects might also explain the significantly elevated intraday interest rate found for the crisis period.

For our analysis, we use a novel and comprehensive dataset on the CCP-based euro interbank repo market covering *all transactions* conducted from 2006 through 2012 to study whether an intraday interest rate also exists in the European secured money market. Our dataset is obtained from Eurex Repo GmbH, which is the leading marketplace for euro general collateral (GC) repos. GC pooling repos are typically used for secured funding (rather than security lending) and they are traded anonymously on an electronic platform. Thus, our data allows us to perfectly control for counterparty credit risk concerns or stigma effects when estimating the intraday interest rate. Moreover, GC pooling repos use a collateral basket that is also accepted for the intraday overdraft facility in Target2, i.e. the euro area payment system installed by the European System of Central Banks (ESCB). Thus, insofar as banks satisfy their liquidity needs in this market they cannot be collateral constrained in using the ESCB's intraday credit line: a bank that is short in overnight liquidity at the beginning of the day could either obtain funds through such a repo or draw on the overdraft facility and borrow overnight in the evening using a repo.[2] Therefore, any intraday interest rate in this repo market cannot result from banks being collateral-constrained in making use of the overdraft facility. To further account for differences in trading patterns across banks, we maintain the panel structure of our dataset and include further bank fixed effects when estimating the intraday interest rate. Differences in the trading pattern might, for instance, result from different banks facing different access to and pricing of unsecured interbank liquidity. Consequently, while some banks find it easier to borrow unsecured if they are unable to obtain funding in the repo market later during the day, others might pay a huge markup on unsecured loans and are therefore particularly eager to cover their liquidity needs early in the day even at a higher cost. Since the extent to which a particular bank is affected by such a market risk in the repo market varies over time, we also allow for time variation in the bank fixed effects. In sum, our data permits us to really exclude any effect from heterogeneity in credit quality, collateral constraints and trading patterns across banks. We thereby can assess the extent to which the intraday interest rate is indeed driven by market liquidity, as suggested by Angelini (2000), and can therefore be interpreted as an intraday liquidity premium in the repo market.

In a first step, we follow the approach by Baglioni and Monticini (2008) and derive an implicit intraday interest rate from the intraday term structure of the overnight market. Our results document that, before September 2007, there was indeed virtually no intraday interest rate prevailing in the repo market. However, with the start of the subprime crisis, we find a significant intraday interest rate. The additional liquidity allotment through unconventional long-term refinancing operations (LTROs) with a one-year maturity did reduce but not eliminate it. With the start of the sovereign debt crisis in July 2010, the intraday rate increased even beyond the level it reached after the Lehman failure. Again, the massive liquidity injection through the ESCB's LTRO with a three-year maturity mitigated but did not eliminate it. At times when calculated on a daily basis, the intraday interest rate reaches levels of up to 60 basis points, in absolute terms. Given that, by definition, all transactions in this repo market were backed by

[2]The haircuts applied by Eurex Repo and the ESCB are generally similar. If they differ, the haircuts applied by Eurex Repo are higher.

collateral that could also be used to obtain intraday liquidity from the ESCB's overdraft facility, our findings show that the intraday interest rate observed during the crisis was not a reflection of collateral constraints.

If collateral constraints were not the reason for the emergence of an intraday rate during the crisis, what then caused the intraday rate to occur? In a second step, we provide an answer to this question. To that end, we study whether the intraday rate is indeed a liquidity premium and reflects the contemporaneous market liquidity. We use a large set of market liquidity indicators (such as the Amihud ratio, Roll's bid-ask spread as well as the spread between buyer and seller initiated repos and the simple price volatility).[3] We consistently find a significant and strong relationship between the repo market's liquidity and the intraday interest rate, irrespective of the particular market liquidity measure we use. This confirms that an important component of the intraday interest rate is a liquidity premium. Interestingly, the LTROs mitigated the intraday rate and its sensitivity to the repo market liquidity; but after the lifespan of the liquidity providing operations both the intraday rate increases and its sensitivity to market liquidity rise again.

These results are robust to the inclusion of further explanatory variables that other studies found to be significant determinants. For instance, we control for (i) the daily liquidity needs proxied by the contemporary transaction volume in Target2, (ii) seasonal patterns like end-of-maintenance period and end-of-month effects, (iii) aggregate recourses to the marginal lending facility (the ECB's lender of last resort facility), (iv) the average credit risk premium in the unsecured interbank market using the Euribor-OIS spread.

A major concern might be that our results are due to a purely mechanical correlation between the intraday rate and some of the liquidity proxies measuring market liquidity on the respective day. For instance, if the intraday rate is high on a given day the Amihud ratio, which captures the overall rate change over the day relative to the transactions volume, is by definition also higher for that day. To mitigate this concern, we assess the extent to which the repo market liquidity calculated only for the afternoon affects the spread between the morning and afternoon rates paid for overnight repos. However, we also consistently find that the liquidity measures calculated for the afternoon have a significant effect on the intraday rate. This further supports the interpretation that the intraday rate is indeed largely a liquidity premium, i.e. that in

[3] Beaupain and Durre (2013) use similar measures to study the intraday market liquidity in the European money market. For an evaluation of these measures in assessing market liquidity, see Goyenko, Holden, and Trzcinka (2009).

anticipation of a less liquid market in the afternoon, banks try to cover their liquidity needs in the morning, even if this requires them to pay a spread.

As a final step, we try to shed some light on the determinants of the market liquidity, in particular on the role financial constraints of arbitrageurs might play. The existence of an intraday interest rate indicates that at least some banks have liquidity needs that they prefer to cover in the morning. They strive to avoid market risk presumably because their ability to replace borrowing in the secured market by borrowing unsecured is limited. This could generate a natural role for arbitrageurs. Banks that have better access to the unsecured interbank market, for instance, because they represent a better credit risk or are "too big to fail", are better suited to deal with the market risk in the repo market. Thus, they could act as arbitrageurs lending in the repo market early during the day to those banks that try to avoid market risk, use the collateral to borrow in the intraday overdraft facility and then repay this daytime liability by borrowing in the repo market later in the day when liquidity is cheaper. Our results point to a positive relationship between arbitrage activity and the intraday interest rate, presumably indicating that a higher premium is required to attract arbitrage activity. The view that financial constraints affect arbitrage activity, market liquidity and ultimately also the intraday rate in the GC pooling repo market is confirmed by some further tentative findings. The costs of arbitrage trades increase by the end of the year due to window dressing. Consistently, we find a significant decline in arbitrage activity at year-end. This is accompanied by a decline in market liquidity and an increase in the intraday rate which hints at a dampening effect of arbitrage on the intraday rate.

Our paper contributes to several strands of the literature. There is a vast amount of literature that studies the efficient pricing of intraday liquidity. Various theoretical contributions such as Angelini (1998), Martin (2004), Kahn and Roberds (2001), and Bech and Garratt (2003) show very robustly that, in real-time gross settlement systems (RTGS), banks' incentives to delay payments to recycle liquidity from incoming payments for outgoing payments bring about negative externalities in a large variety of different model set-ups. While those papers also indicate that a free-of-charge daylight overdraft facilities provided by the central bank eliminates this inefficiency, Martin (2004) shows that only collateralized overdrafts prevent inefficiencies arising from excessive risk-taking. Kahn and Roberds (2001) and Bech and Garratt (2003), however, argue that collateralization implies an opportunity cost of daylight overdrafts. Consequently, tighter collateral constraints increase the opportunity costs, raise the incentives to delay, and make liquidity pricier again during early hours. Our empirical analysis suggests, however, that an intraday rate does not only occur because of collateral constraints. It might rather result from imperfect market liquidity in money markets and actually reflect a liquidity premium. This suggests that the intraday rate is not necessarily a useful proxy for the tightness of collateral constraints. Nevertheless the intraday rate still serves as a good measure for the costs of immediacy.

Several papers attempt to assess empirically whether there is indeed an intraday interest rate and whether the intraday spread can serve as an indicator for intraday liquidity or collateral constraints. Using unsecured overnight loans, Baglioni and Monticini (2008, 2010, 2013) and Jurgilas and Zikes (2014) estimate a generally positive intraday interest rate that was, however, particularly elevated in crisis periods. They interpret this as an indication that collateral constraints were tighter during the crisis, encouraging banks to delay payments. However, using unsecured interbank transactions does not allow to isolate the pure intraday pricing patterns of liquidity. The estimated intraday interest rate might simply reflect differences in the intraday trading pattern of banks with different credit quality, collateral constraints and opportunity costs of obtaining liquidity in other markets. Our data and approach allow us to perfectly control for this. 1) Using secured transactions eliminates differences in counterparty risk. 2) Using transactions involving collateral eligible for the overdraft facility ensures all borrowing banks could also use the daylight overdraft to obtain the same liquidity. 3) Including bank fixed effects (time varying across the different subperiods) allows us to control for heterogeneity in the trading pattern and in the access to other short-term funding markets. Biais, Hombert, and Weill (2014) provides a theoretical framework showing that banks might indeed have very different trading patterns depending, for instance, on their risk management. Biais et al. (2014) argue that a bank's information aggregation technology determines how fast it responds to a liquidity shock and how frequently it trades. Of the papers estimating the intraday interest rate, Kraenzlin and Nellen (2010) is most closely related to ours. They use similar data on repo transactions but take a different approach. In particular, they do not control for differences in bank specific trading pattern using bank fixed effects. Their analysis is based on Swiss franc-denominated overnight Eurex Repo transaction data, which also uses collateral eligible for the Swiss National Bank's (SNB) intraday overdraft facility. But while here, too, any borrower should be able to use the overdraft facility in the morning rather than paying an intraday spread in the morning, they find an intraday rate prevailing in this market. In fact their results show that the intraday rate can largely be explained by the trading pattern of banks voluntarily refraining from using the overdraft facility. Those banks borrow largely in the morning and thereby "voluntarily" pay the intraday spread, even though they are by definition not collateral constrained in using the overdraft facility. Thus, the difference to our results indicates that not only heterogeneity in credit risk and collateral constraints but also differences in trading patterns matter. Controlling for this adequately, we do not find evidence for any intraday interest rate in tranquil periods. Only for crisis periods do we find a significant intraday pricing pattern of overnight repos during the day, which seems to be driven by reduced market liquidity.[4]

Since tension in money markets severely amplified the recent financial crisis also the resilience of repo funding markets is under scrutiny. Our paper also contributes to this debate. Gorton and Metrick (2012) and Copeland, Martin, and Walker (2014) document the demise of the decentralized repo market in the U.S. during the financial crisis. In contrast, using a data set comparable to ours covering also GC pooling repo transactions on Eurex Repo Mancini et al. (2014) provide evidence that this CCP-based repo market remained very resilient during the crisis. While our results do not question their conclusions, they nevertheless show that tensions in the financial system had an effect on market liquidity in crisis times and thereby contributed to an intraday liquidity premium.

Our paper obviously builds on key insights from the asset pricing literature, in particular the strand relating an asset's liquidity to its expected returns. Amihud and Mendelson (1986), for instance, show that a higher average illiquidity of an asset measured by its bid-ask-spread is associated with a higher expected return, i.e. a liquidity premium. Amihud (2002) finds that this only holds for the *expected* future market liquidity of an asset using the Amihud ratio as a liquidity measure, while an unexpected contemporaneous drop in market liquidity is rather associated with a drop in excess returns. Acharya and Pedersen (2005) analyze the liquidity premium in a CAPM context showing that the liquidity premium reflects the covariation of an asset's liquidity with market-wide liquidity factors. Our paper adds to this literature, showing that even in the market for liquidity, market liquidity varies and is associated with a liquidity premium even at an intraday horizon. Furthermore, our finding that a liquidity premium occurred only in times of economy wide liquidity dry-ups is also in keeping with Acharya and Pedersen (2005). It suggests that commonality between secured money market liquidity and the liquidity of the broader financial markets increased during the crisis, but is mitigated by the ESCB's LTROs. This is very much in line with Brunnermeier and Pedersen (2009) who show that funding liquidity risks and market liquidity risks in the broader financial market reinforce each other.

[4] Note, however, that in general the market liquidity of the repo market is in absolute terms higher than in other markets, as was shown in Mancini, Ranaldo, and Wrampelmeyer (2014). Our analysis uses variations in the repo market's liquidity and is not concerned with its overall level.

In addition, we even find tentative evidence that a high intraday rate and thus an increased liquidity premium are associated with higher opportunity costs of arbitrage.

These results have important policy implications. First, they suggest that the provision of an uncollateralized overdraft facility that is free of charge is not a sufficient condition to eliminate any positive intraday interest rate during crisis periods. An intraday liquidity premium might also simply emerge because of a reduction in market liquidity in the secured money market. Thus, reduced market liquidity in the repo market increases the market price for immediate funding liquidity. Furthermore, there seems to be a strong commonality in the market liquidity of the secured money market with broader financial markets, which suggests that severe liquidity dry-ups in other markets feed back into the market for liquidity and lead to an elevated liquidity premium in this market as well. This suggests that additional liquidity provision by central banks is needed to mitigate the crisis induced effects on money markets.

The remainder of the paper is structured as follows. In the next section, we will briefly describe the Eurex Repo trading platform and the related institutional details relevant for banks' liquidity management. Section 3 provides a description of our dataset and of our key variables. In Section 4, we estimate an intraday yield curve for the different subperiods. In Section 5, we focus only on the intraday yield spread between the morning and the afternoon and study its determinants in particular during the crisis period. Since we find that market liquidity is a key driver of the intraday spread, we try in Section 6 to further explore the determinants of the market liquidity, in particular the extent to which arbitrageurs' trading activity and funding costs affect market liquidity in the repo-market. Section 7 concludes.

2 GC Repo and the Institutional Environment

In the euro area, the Eurex Repo market plays a pivotal role in the collateralized segment of the European interbank money market. This CCP-based general collateral (GC) pooling market is increasingly used by banks for a substantial share of their inventory financing on an ongoing basis. All settled transactions must be backed by a harmonized collateral basket that coincides with those securities considered eligible collateral for the ESCB's daytime overdraft facility.[5] In the aftermath of the Lehman failure, the Eurosystem expanded its list of securities eligible for all its facilities from A- to BBB-, with effect from 15 October, 2008. In response, Eurex Clearing introduced a second basket (ECB extended basket) for repo trades to match this change in the

[5] These are the same criteria as those imposed on securities considered eligible for the Eurosystem's open market operations.

quality of the assets that can be pledged for a GC repo.[6] Given the broad range of eligible collateral and the specific arrangements of the market, banks tend to use the GC pooling repo market exclusively for funding purposes and turn to other European markets to obtain specific securities as collateral.[7]

Any bank involved in a transaction does not know its counterparty's identity. For each cash taker, Eurex Clearing becomes the credit provider and the credit taker for any cash provider. Trading fees incentivize banks to post anonymous bids on the electronic trading platform. A trade can then be initiated by the borrowing or lending party by accepting a posted offer. In this case, Eurex Clearing acts as the central counterparty to both parties (open offer, as opposed to a novation mechanism where the CCP steps in as counterparty after a trading agreement is already reached), thereby bearing the liability risk. Unlike the bilateral (OTC-based) repo market, this ensures that lending transactions are not hampered when reputation and counterparty risks change, for instance during periods of crisis. This explains why this market has grown to become the largest European collateralized CCP market in recent years (e.g. Deutsche Bundesbank Monthly Report, December 2013). Another argument for using this segment is the 0% risk weight of GC pooling transactions for the calculation of capital requirements, in particular so in times when equity capital is a scarce resource. During our sample period, market participation grew steadily. In September 2007, there were 19 banks active in the market with an outstanding volume of EUR 23.5 billion. By 2012, the number of participants had risen to 94 with an outstanding volume of EUR 70 billion. Also the Extended Basket introduced in October 2008 gained significant trading attendance over time and improved refinancing conditions for many banks (see ECB, 2012).[8]

For the clearing and settlement of each GC pooling transaction, Eurex Clearing uses the Eurosystem's payment and settlement system Target2 (for the cash leg) and Clearstream Banking Frankfurt's (CBF) settlement system CASCADE (for the collateral leg). Within CBF, which is the German central securities depository (CSD), collateral is automatically chosen from a pre-specified pool by a collateral management system (Xemac) and allocated to the lender's collateral account on a delivery-versus-payment basis.[9] Cash and security allocation only take

[6]For more details see http://www.ecb.europa.eu/press/pr/date/2008/html/pr081015.en.html and www.eurexrepo.com.

[7]The London stock exchange's bond trading unit MTS and ICAP's Broker Tec, for instance, are among the most commonly used European electronic platforms for these purposes.

[8]A list of participants is provided in the appendix.

[9]Banks that do not have an account with CBF can use collateral stored with the international central securities depository (ICSD) Clearstream Bank Luxembourg, which has a direct connection with CBF. For further details refer to www.eurexrepo.com.

place when a sufficient amount of cash and collateral is available. The fully automatic settlement procedure ensures that repo trades are settled in real time. Importantly, collateral received in a GC pooling transaction can be re-used to collateralize further GC pooling repos or transactions with the central bank, especially intraday overdrafts. This is important because it facilitates arbitrage trades dramatically as no additional collateral has to be put up, e.g. to fund lending transactions in the morning through the use of the overdraft facility. So far, this feature is only available to German banks, as re-using collateral is restricted to banks whose accounts are with the Deutsche Bundesbank. For any overnight loan, the repayment of the transaction is due the next morning, although no later than 9:20 a.m. CET (in CASCADE settlement cycle SDS1). Failure to comply with the obligations at SDS1 is considered as an "intraday transaction default" and sanctioned accordingly: service fee and GC repo overnight rate plus 50 basis points p.a., in relation to the value of the underlying transaction or the due cash amount, respectively.

3 Data and Key Variables

For our empirical exercise, we have obtained all GC pooling trades conducted in the period from January 1, 2006 through June 30, 2012. This data reports the information on the key terms of each loan, i.e. the unique identifier for the borrowing and lending bank, whether the lender or borrower initiated the transactions, the settlement date, the loan amount, the fixed interest rate, maturity date and the exact time stamp. For our analysis, we focus on overnight GC pooling repos. Panel A of Table 1 provides summary statistics of our dataset. On average, 49 trades are conducted between 9 borrowers and 9 lenders on a daily basis where the average daily trade volume amounts to EUR 7,930 million. We compute our implicit hourly rate on the basis of these collected trades.

As explained in the introduction, a non-zero intraday interest rate may be the result of various reasons. Our data, however, permits us to exclude any effect from heterogeneity in credit quality, collateral constraints and trading patterns across banks and thereby assess the extent to which the intraday interest rate is indeed driven by market liquidity as suggested by Angelini (2000), and can therefore be interpreted as an intraday liquidity premium in the repo market. To test this empirically, we compute four different liquidity measures that are widely used in the related literature (e.g. Beaupain and Durre (2013) or Mancini, Ranaldo, and Wrampelmeyer (2013)).

Our first measure captures the overall transaction costs in the GC repo market and follows the rationale of the implicit effective bid-ask spread as suggested by Roll (1984). This measure infers the effective bid-ask spread from the first order serial covariance (cov) of price changes observed over consecutive transactions (k) conducted throughout the day t. More specifically, the estimator is computed as follows:

$$Roll_t = 2 \cdot \sqrt{-Cov_t(\Delta r_k, \Delta r_{k-1})} \quad \text{if} \quad Cov_t(\Delta r_k, \Delta r_{k-1}) < 0 \tag{1}$$

and zero otherwise. A higher $Roll_t$ indicates a higher bid-ask spread and a more illiquid market.

As a second measure for the market liquidity in the GC repo market, we compute the Amihud ratio following Amihud (2002), which is the maximum price change in response to a given volume of transactions (in EUR billion here) on day t:

$$Amihud_t = \frac{r_t^{max} - r_t^{min}}{Vol_t} \tag{2}$$

A higher $Amihud_t$ indicates a more illiquid market.

Our third liquidity measure simply captures the market risk associated with the price volatility in the GC repo market. Thus, we compute the standard deviation of all observed interest rates during the day. As a fourth and final liquidity measure, we make use of specific information contained in our dataset indicating whether a particular trade was initiated by the seller (borrower) or buyer (lender). We calculate the spread between the average rate of seller initiated trades and the average rate of buyer initiated trades on a particular day (Aggressive Sell-Buy Spread, as the initiator is called "Aggressor"). This measure can also be seen as an alternative estimate of the maximum effective bid-ask-spread on the respective day. For both these measures, too, a larger value stands for a more illiquid market.

In using these four measures, we ensure that we take both spread (Roll, aggressive sell/buy, standard deviation) and depth proxies (Amihud) into account, as suggested by Beaupain and Durre (2013), and thus capture the different dimensions of market liquidity, tightness as well as depth and resilience according to Kyle (1985). Figure 3 depicts the development of the different market liquidity proxies over time. As the graphs vividly show, all measures indicate a lower level of market liquidity along with a higher volatility during both the subprime crisis and the sovereign debt crisis.

Some banks have high overnight borrowing costs in the unsecured market and are therefore particularly averse to any repo market risk. Consequently, they are unwilling to take on market risk by waiting until the afternoon to meet a liquidity need that arose in the morning. In fact, those banks might rather consider the morning and the afternoon repo market as segmented markets. As pointed out by Gromb and Vayanos (2002) and Brunnermeier and Pedersen (2009), the activity of arbitrageurs or market makers might be required to equilibrate prices across the two segments. However, their ability to provide liquidity and ensure an arbitrage-free pricing might be restrained. The extent to which they can increase their balance sheet and accumulate liquidity risks might be limited. Following this idea a high intraday spread might be a result of more restrained arbitrageurs or market makers in the repo market. In order to control for this, we include as a further explanatory variable the intermediated transaction volume, which supposedly reflects arbitrage activity between the morning and the afternoon session in the GC repo market. We compute this transaction volume as follows:

$$Intermediation_t = \frac{\sum_n min[buy_{n,t}^{morning}, sell_{n,t}^{afternoon}]}{Vol_t^{morning}} \tag{3}$$

More precisely, if a bank (n) lends the amount (i.e. buys the collateral) $buy_{n,t}^{morning}$ in the morning and borrows (i.e. sell the collateral) $sell_{n,t}^{afternoon}$ in the evening, the minimum of both numbers is the funding intermediated between the morning and the afternoon session in order to capture a positive intraday rate. The daily aggregate over all banks thus measures the proportion of a morning's trading volume that reflects arbitrage trades on the intraday rate. In order to take also exogenous shifts in banks' aggregate intraday trading pattern into account, we calculate for each trading day t the measure $TradingPattern_t$, which captures shifts between the two market segments:

$$TradingPattern_t = \frac{Vol_t^{morning}}{Vol_t^{afternoon}} \tag{4}$$

Panel B of Table 1 provides descriptive statistics of these two variables over our entire sample period.

4 Is there an intraday interest rate?

In order to assess whether there is an intraday yield curve in the repo market, we follow in this section the identification approach of Baglioni and Monticini (2008) and divide each day into 8 hourly time bands denoted by $h = 0, 1, \ldots, 7$, where the first starts at 8 a.m. and the last at 3 p.m. [10] Our implicit term structure is then computed as the difference of the overnight rate between different hourly time bands, i.e. 8 a.m. - 9 a.m. for a 1 hour loan, 8 a.m. - 10 a.m. for a 2 hours loan, ..., 8 a.m. - 3 p.m. for a 7 hours loan.[11] Let k count all transactions on day t

[10] Five trades that were conducted in the first 30 minutes after the market opened (7.30 a.m.) were deleted from the entire analysis as they were too few to form a meaningful first time band.

[11] Recall that the delivery date for an overnight loan is always 9:20 a.m. of the next morning of the initial settlement day.

with $k = 1, ...K$. For each transaction let i be the borrowing bank with $i = 1, ...I$, j the lending bank with $j = 1, ...J$, and h the hourly band with $h = 0, 1...7$. Define the interest rate $\hat{r}_{k,i,j,t,h}$ as a spread of the interest rate r of transaction k between the counterparties i and j in the hourly band h on day t to the volume-weighted daily average interest rate. That is:

$$\hat{r}_{k,i,j,t,h} = r_{k,i,j,t,h} - \sum_{k=1}^{K} \cdot \frac{r_{k,i,j,t,h} \cdot Vol_{k,i,j,t,h}}{Vol_t} \tag{5}$$

Our econometric analysis then takes the following form:

$$\hat{r}_{k,i,j,t,h} = c + \alpha_j + \alpha_i + \sum_{h=1}^{7} \beta_h x_h + \sum_{h=1}^{7} \delta'_h X_t x_h + \epsilon_{k,i,j,t,h} \tag{6}$$

where c denotes our constant term (i.e. our first hourly band 8 a.m. – 9 a.m.) and ϵ represents our i.i.d. error term. The index h refers to the hourly time band as of 9 a.m. and x_h is a binary variable that takes on the value 1 in time band h and zero otherwise. The coefficient of x_h then reflects the average difference between the overnight rates in time band h to the first time band. Or in other words it reflects the average rate for an intraday loan between 8 a.m. and the respective time band. X_t is a vector of controls for calendar effects (end of reserve maintenance period, end of year and end of month). To ensure that our estimated yield curve is not driven by bank specific characteristics such as banks with headquarters in countries of different time zones and different market participation due to differences in their risk management (Biais et al. (2014)), we also include borrower fixed effects α_i and lender fixed effects α_j.

During our complete sample period, we have a total of 97,798 observations (i.e. 48899 trades). For our estimations, however, we split our samples into the following five revealing subperiods. The period from January 1, 2006 through August 8, 2007 refers to the pre-crisis sample. We mark August 9, 2007 as the beginning of the financial crisis and, thus, the period from August 9, 2007 to June 22, 2009 as the financial crisis. On June 23, 2009 the Eurosystem extended its liquidity provision by an unconventional one-year longer-term refinancing operation (LTRO). Therefore, we define the third period so as to coincide with the lifetime of this first one-year LTRO, covering the period from June 23, 2009 to June 30, 2010. The period thereafter until December 20, 2011, is considered to be the period of the sovereign debt crisis. Our last subsample, which starts on December, 21 2011 and ends on June 30, 2012 accounts for the substantial liquidity injection in the longer-term bucket, i.e. the three-year LTROs in December 2011 and February 2012.

From an ex ante perspective, the price of intraday liquidity crucially depends on the opportunity cost (of pledging collateral) and the fees involved for central bank daylight overdrafts. In contrast to the U.S. system, the Eurosystem does not charge a fee for intraday overdrafts.

Yet for these overdrafts, banks in the euro area are required to provide securities that meet exactly the same eligibility criteria as needed for trades on Eurex pooling. This suggests that the daylight overdraft facility of the Eurosystem should be a perfect substitute for intraday liquidity from the GC repo market. If a bank borrows via the repo market in the morning, it must also have sufficient collateral to obtain liquidity alternatively from the daylight overdraft facility and borrow overnight in the repo market only in the afternoon. Thus, with no fees charged for central bank overdrafts, the intraday term structure in the GC repo market should be flat, indicating a zero intraday interest rate.[12]

The results of our estimations are shown in Table 2 Panel A. The constant term denotes the average deviation of the overnight rate in the first hourly time band, i.e. 8 a.m. – 9 a.m., from its volume-weighted daily interest rate. As a result, for each h the estimated coefficient reflects the estimate of the change of the deviation between the start of the day and the respective hourly band. Clustered standard errors on the bank level are presented in parentheses.

The first three columns show the estimates for the full sample period (1) excluding any fixed effect, (2) including only borrower and lender fixed effects and (3) including in addition also seasonal fixed effects as suggested by Owens and Wu (2014). The results indicate for all specifications a significantly positive intraday interest rate: the later the trading hour the lower the estimated rate. The inclusion of the fixed effects reduces the economic significance slightly, suggesting that the trading pattern of banks as well as seasonal effects play a role, but they do not substantially affect our results.

At first sight, these results might seem to confirm findings of previous studies which document a positive intraday rate based on unsecured interbank loans. However, our results go beyond this and show that an intraday rate also prevails in a market in which by definition collateral constraints cannot be the reason. Consequently, these results in fact contradict previous studies which view the intraday rate found in the unsecured market to be an indication for collateral constraints rendering the overdraft facility ineffective in eliminating incentives to delay payments.[13]

Consideration of the different subperiods separately provides further interesting insights. The estimates for the period before mid-2007 reported in columns 4 and 5 indicate an almost flat intraday term structure. This suggests that the Eurosystem's overdraft facility in this period was

[12]For the arbitrage arguments in the unsecured money market segment, see Martin (2004) and Baglioni and Monticini (2008).

[13]The intraday interest rates in unsecured markets found in other studies is generally higher than in the repo market. But, as Mancini et al. (2014) point out, the repo market is also generally more liquid than the other markets calling for a higher liquidity premium in unsecured markets.

in fact effective in eliminating any intraday rate in this market. So we do not find any evidence for the tranquil period that factors other than collateral constraints contributed to the intraday rate documented for the unsecured market.

For the periods associated with the subprime/Lehman crisis and the sovereign debt crisis, however, the intraday interest rate that we find for the repo market deviates significantly from zero, with a difference of more than 5 basis points between early morning and late afternoon hourly slots (see columns 6 & 7 and 10 & 11, respectively). Interestingly, with the conducting of both LTRO measures, the deviation diminishes to levels of around one basis point, yet remains statistically highly significant (see columns 8 & 9 and 12 & 13, respectively). Consequently, in particular for the crisis periods but also after the ECB's interventions, we find that factors other than collateral constraints contributed to a positive intraday rate. Figure 1 summarizes these findings graphically.

For a more detailed view on the daily variation of the intraday interest rate during our sample period, we also adopt the approach suggested by Van Hoose (1991) and Angelini (1998), dividing each trading day into a "morning session" and an "afternoon session" and then computing the difference between the quantity-weighted average overnight rate in the morning band and in the afternoon band. The daily value of this time series is depicted in Figure 1. This figure supports the previous finding: it shows that for the period before mid-2007 no significant deviation occured between morning and afternoon rates. During the period of the financial crisis and the sovereign debt crisis, however, the difference between the interest rates settled in the morning session and those in the afternoon session is on average positive, but highly volatile, and reaches levels of up to 60 basis points. In the period of the one- and three-year LTROs, the fluctuations of the intraday interest rate are substantially smaller, but the average intraday spread is still slightly positive. These findings not only document once again the existence of a non-zero intraday interest rate in the secured money market, particularly during both periods of market distress: they also highlight the substantial economic significance of the intraday rate.

By definition this intraday spread in the GC pooling repo market cannot be a reflection of collateral constraints but must be driven by other factors.[14] In the next section we therefore use

[14] It is important to note that although all the banks in our sample have, by definition, eligible collateral for the overdraft facility, if collateral constraints were to generate incentives to delay payments in the rest of the banking system, this should also lead to a positive intraday interest rate in the GC pooling market: collateral constrained banks that need reserves in the morning for time critical payments can neither borrow in the GC pooling market nor use the overdraft facility. However, when borrowing on an unsecured basis, they drive up the prices in the unsecured market; banks long in collateral (with an established lending relationship) lend to those banks and refinance themselves early in the day in the GC pooling market demanding overnight repos from liquidity-long banks. This would drive up the repo rate in the morning. Collateral-rich banks can, of course, use the overdraft

the time dimension of these deviations to analyze the determinants of the intraday rate.

5 What determines the intraday spread?

In the previous section we establish that the intraday interest rate prevails during crisis periods, even when we control for bank-specific time-invariant observable and unobservable heterogeneity. In this section we use the time dimension of the intraday interest rate to explore its determinants. To that aim, we set up the following econometric specification:

$$r_{k,t,h} \quad = \quad \alpha_t + \beta' X_t \cdot \text{afternoon} + \varepsilon_{k,t,h}. \tag{7}$$

We estimate at the transaction level k the contractual overnight rate $r_{k,t,h}$. For each day t we distinguish between the two bands $h = \{morning, afternoon\}$ whereby *morning* captures all trades before noon. We allow for daily fixed effects α_t to capture any shifts in the daily average interest rate due, for instance, to monetary policy or seasonal effects.[15]

Most important for identifying the key driver of the intraday rate is the interaction between the time varying vector X_t and the afternoon dummy $afternoon$. Besides seasonal fixed effects (reserve maintenance period and calendar controls), X_t also includes a set of time varying aggregate variables such as the intermediation ratio ($Intermediation_t$), the aggregate intraday trading pattern ($TradingPattern_t$), and one of our four market illiquidity indicators ($Roll_t$, $Amihud_t$, $Intraday\ Std.\ Dev_t$, $Aggr.\ Sell - Buy\ Spread_t$). Following Baglioni and Monticini (2013), we also use the spread between the three-month Euribor and OIS rate as a proxy for the tensions in the unsecured money market. Motivated by Kraenzlin and Nellen (2010), we control for the overall RTGS volumes as an indication of the daily aggregate liquidity needs. Furthermore, the vector X_t comprises three binary variables. One dummy accounts for the first one-year LTRO and therefore takes the value 1 during the period June 23, 2009 and June 30, 2010 and zero otherwise. The second dummy accounts for the three-year LTROs and has the value 1 for the period as from December 21, 2011 and zero otherwise. Third, we control for the crisis with a dummy that is 1 from August 9, 2007 on. Note that for brevity, we combine the two crisis periods and often also the two LTRO-periods in one dummy.

Table 3 Panel A reports the results of our baseline regression. Before studying the key

facility for arbitrage. This exposes them to market risk. The tighter the collateral constraints, the larger this exposure and the higher collateral rich banks' willingness to pay an intraday spread should be.

[15] For expositional reasons in this paper we present only results using the contractual rates and daily fixed effects. We also estimated all our panel regressions using the deviation from the volume weighted average daily rate as endogenous variable and obtained exactly the same results.

determinants of the intraday spread we first need to confirm that the simple spread between morning and afternoon rate paid on overnight repos also shows the same pattern as the hourly rates documented in the previous section. Column (1) indicates that for the pre-crisis period no positive intraday spread is indeed observed. In fact, during this period we rather find a negative intraday spread. However, during the crisis period, rates in the afternoon are significantly lower than in the morning. The unconventional LTROs both mitigated the intraday spread and increased the afternoon rates again, but could not fully offset the crisis impact.

Column (2) reports our first estimates including Amihud's (2002) ratio as a first market illiquidity measure. Controlling not only for seasonal effects, we again find that a positive intraday spread prevailed only in the crisis, and that it was partially mitigated by the two LTROs. This intraday spread was however also significantly determined by the contemporary market liquidity in the repo market. On days with a relatively low market liquidity, the afternoon rate was particularly low relative to the morning rate. One might have the notion that this market liquidity measure only captures high demand of liquidity on a particular day, for instance due to a high transaction volume in the payment system. This might require a larger reallocation of liquidity and put a strain on market liquidity. Column (3), therefore, includes as a further control the TARGET transaction volume on the respective day (excluding GC pooling overnight repo transactions). While the results show that a higher payments volume was associated with higher demand for intraday liquidity and thus with a higher intraday spread, the effect of market liquidity on the intraday spread does not reflect the elevated need for liquidity due to larger transaction volumes. After including the Target2 volume the effect of our market liquidity measure on the intraday spread remains significant and of identical magnitude.

Next, we are interested in the time variation of the effect of repo market liquidity on the intraday spread varied over time – in particular, whether market liquidity was a more important determinant during the crisis and whether the ECB's interventions mitigated the influence of market liquidity on the intraday spread. Indeed, as our results in column (4) show, lower market liquidity did not reduce afternoon rates in the pre-crisis period. On the contrary, low market liquidity in the repo market actually increased further the afternoon rates that were higher anyway. In the crisis period, however, the intraday spread was particularly elevated in times of a less liquid repo market. This sensitivity was not significantly changed by the liquidity injections through the LTROs.

The Amihud (2002) ratio captures the price impact of a given transaction volume. In order to assess whether our findings also apply to other perspectives on market liquidity, we use in column

(5) Roll's (1984) liquidity measure, which is an estimate of the bid-ask spread and thus rather proxies transaction costs for small amounts. Furthermore, to better reflect the notion of market risk in column (6) we use as a third alternative liquidity measure the simple intraday volatility of the ON repo rate (measured by its intraday standard deviation). The results are very similar: for both alternative liquidity measures we find that, only in the crisis period, the intraday spread is larger the more illiquid the repo market is. In the pre-crisis phase, a more illiquid secured money market is rather associated with a higher afternoon rate. For both alternative market liquidity measures, we again find that the LTROs did not affect the market liquidity sensitivity of the intraday spread.

A major concern with this approach may be, however, that the market liquidity measures are more or less mechanically correlated with the intraday spread. When the intraday rate is relatively high, this implies a stronger decline in the repo rate in the course of the day, which also means that for a given transaction volume the Amihud (2002) ratio is larger, thus indicating a more illiquid financial market. A similar argument can be made for the Roll (1984) measure and the simple price volatility. Thus, as a first step, to rule out that our results are driven by such a mechanical effect we consider a fourth liquidity measure that is not affected by this effect: since our data also provides information on whether a particular trade was initiated by the seller (borrower) or buyer (lender), we can calculate the spread between trades initiated by the seller and initiated by the buyer ($Aggr.\ Sell - Buy\ Spread_t$). Obviously, this measure also proxies the bid-ask-spread and thus captures rather the transaction costs of small amounts. Column (7) of Table 3 Panel A reports the result of our estimates using this alternative market liquidity measure. Again, the results are very consistent: only in the crisis period is a more illiquid repo market associated with a higher intraday spread, while no significant effect of market liquidity on the intraday interest rate can be found for the pre-crisis period. This is a first indication suggesting that our general results are not driven by mechanical correlations.

In order to further confirm that our results are not affected by the pure mechanical relation between the intraday spread and our daily measures of market liquidity, we next calculate the liquidity measures that are susceptible to a mechanical correlation for the afternoon only and rerun the previous estimates. This approach does not only allow us to check the robustness of the results, it offers a way to better assess whether the intraday spread is actually a liquidity premium. Following Amihud (2002), a contemporaneous unexpected drop in market liquidity should lead to a drop in returns, i.e a decrease in the rate. Only an anticipated future decline in market liquidity should be associated with a liquidity premium, i.e. a higher asset return.

Assuming that, in the morning session, market participants can already form expectations about the market liquidity in the afternoon which are on average correct, any intraday spread that we find to be associated with the market liquidity in the afternoon session can indeed be viewed as a liquidity premium.

Table 3 Panel B reports the estimates for the baseline regressions using the afternoon market liquidity according to the Amihud ratio, Roll's liquidity measure and the simple afternoon repo rate volatility. The estimates are similar across the three liquidity measures and consistent with our baseline result. We find an intraday spread only for the crisis period. With the exception of Roll's liquidity measure we also find for the different liquidity measures that a higher market illiquidity in the afternoon is associated with a higher intraday spread. Looking at the different subperiods separately reveals that this sensitivity of the intraday spread to the market liquidity is only due to the crisis period. Only in that period is a lower afternoon market liquidity also associated with a significantly lower afternoon rate. We do not find such a relationship for the pre-crisis period. In sum, these findings confirm our interpretation that market illiquidity indeed leads to a higher intraday spread and that this intraday spread can be seen as an intraday liquidity premium.

Of course a number of concerns that our results are due to unobserved variables are appropriate. To take those concerns into account, we perform a number of further robustness checks including a number of additional control variables. We run those robustness checks with our market liquidity measure calculated on the daily basis. But to account for concerns about a mechanical correlation we focus on the aggressive-sell-aggressive-buy spread, which is least likely affected by the mechanical interaction. Table 3 Panel C reports the first set of results from our robustness checks.

From November 24, 2008 onwards, our data comprises repo transactions in both baskets, the narrow and the extended basket. However, any security eligible for either basket is also accepted as collateral for the ECB's overdraft facility. Nevertheless, one might reasonably think that due to the lower collateral quality, lower market liquidity, different market participants or other factors the intraday spread should generally be higher in the extended basket and more sensitive to the LTROs. For this reason, we include a dummy variable indicating transactions in the extended basket, interact that with our afternoon dummy and allow for a different impact of the different LTROs on the intraday spread in the extended basket.[16] Furthermore, for a bank

[16]Since the extended basket was only introduced within the crisis, we cannot test whether the spread in the extended basket was also more responsive to the crisis.

that does not receive sufficient funds in the repo market – or does not at a reasonable price – in the afternoon the alternative funding option might be the unsecured market. Thus, there should be a relationship between the unsecured funding market and the aversion of market liquidity risk in the repo market that might be particularly strong in times of a high credit risk mark-up in the unsecured market. To control for this we include the EURIBOR-OIS spread as an aggregate proxy for the pricing of counterparty credit risk in the unsecured market in our estimations. A further alternative source of funding is, of course, the marginal lending facility (the discount window) at which banks can receive any amount of funding against the same collateral used in the repo market but usually at a higher rate. When anticipating that, by the end of the day, banks have to take recourse to the MLF at a mark-up (due to liquidity hoarding by some banks or a market squeeze), market participants might try to preserve liquidity early in the day and pay a mark-up in the repo market. This could be well correlated with a relatively illiquid repo market. To proxy for this effect, we include in our regression the aggregate MLF recourses by all euro-area banks by the end of the day.

Column (1) in Table 3 Panel C reports the results of our estimates including these three further controls with the aggressive-sell-aggressive-buy spread as market liquidity indicator. The rate seems to be, on average, somewhat higher in the extended basket, which is intuitive given the higher collateral risk. The afternoon rate is not significantly higher in the extended basket, which implies that the intraday rate, too, is, in sum, somewhat higher in the extended basket. At the same time, the LTROs were particularly effective in mitigating the intraday spread in this market segment. As one would expect on days with a high EURIBOR-OIS spread, we find a larger intraday spread, suggesting that the illiquidity from the unsecured money market indeed spilled over to the repo market. Higher recourse to the MLF was actually related to a higher afternoon rate, which suggests that high recourse to the MLF by the end of the day was not anticipated by banks in the morning, but that banks bid up the repo rate in the afternoon before taking recourse to the MLF. Most importantly, though, as column (1) also shows, the repo market liquidity remains a significant determinant for the intraday spread even after the inclusion of these additional covariates.

Although bank specific constant effects did not seem to play a role in the estimation of the intraday interest rate, banks' aggregate trading pattern might. Some banks, such as those with headquarters in Asia or with other strong ties to this time zone, might need to cover their euro liquidity needs early on in the day, while others with stronger relations to the U.S. might rather experience liquidity shocks later in the afternoon.[17] This suggests that the morning session and the afternoon session might be segmented markets. However, banks that operate over the entire trading day of the repo market could serve as arbitrageurs between these two segments and use the overdraft facility to provide additional liquidity in the morning market, while absorbing liquidity in the afternoon market to repay the overdraft. As pointed out by Gromb and Vayanos (2002) and Brunnermeier and Pedersen (2009), the ability of arbitrageurs or market makers to provide liquidity to the market and equilibrate prices across segments might be restrained. The extent to which they can increase their balance sheet and accumulate liquidity risks might be limited. Following this idea, it is reasonable to assume that a lower market liquidity and a higher intraday spread might both be a result of more restrained arbitrageurs or market makers in the repo market. In order to test for this, we include in column (2) as a further control the intermediated transaction volume that supposedly reflects arbitrage activity in this market (see equation 3 for a detailed definition). Surprisingly, we find that a high supposed arbitrage transaction volume is actually associated with a higher intraday spread. This might point to reversed causality. Obviously the considered arbitrage is particularly attractive if the intraday spread is relatively high.[18] We explore this finding in greater depth in the next section. To control also for aggregate intraday shifts in the trading volume that might affect the need for arbitrage activity we add in column (3) the ratio of aggregate morning transaction volume relative to the total afternoon transaction volume. Indeed, a relatively high trading volume in the morning also contributes to a higher intraday spread. Most important, however, is that the inclusion of those further control variables does not mitigate the significant effect of the market liquidity on the intraday spread.

The particular sensitivity of the intraday rate to market liquidity in the crisis period could result from the fact that a greater need for liquidity reallocation in the banking system (for instance, due to a higher Target2 transaction volume) put a particular strain on repo market liquidity because other money markets had largely dried up and liquidity reallocation was increasingly taking place via the CCP-based repo market (e.g. ECB, 2010). At the same time, a higher transaction volume in the payment system might also increase the intraday spread. Specification (4) takes this concern into account. Here we allow for an effect of the daily Target2 transaction volume that varies across the different subperiods when estimating the influence

[17]Following Biais et al. (2014) a further reason for the infrequent market presence of some banks might result from the time needed to aggregate and process information within a large financial institution.

[18]Also trading costs could play a role as arbitrage is, of course, only rewarding if the gains from arbitrage cover the trading costs. Thus, arbitrage activity might only start if the intraday spread is high enough.

of repo market liquidity on the intraday spread for the different subperiods. Interestingly, we find that a higher Target2 volume was associated with a higher intraday spread only in the crisis period. However, even when including all these further controls and the time varying effect of liquidity needs (measured by the Target2 volume), we still find that a reduced market liquidity increases the intraday spread significantly, but only in the crisis period. Columns (5)-(7) report the results of the same regression including all controls but using the three alternative market liquidity measures. The results for these measures likewise indicate that a reduced market liquidity brought about a higher intraday spread only during the crisis period and that this higher sensitivity was not significantly mitigated by the LTROs.

Finally, we further account for potential effects that Eurex' introduction of the extended collateral basket in October 2008 had. This extension contributed to a significant growth in repo volumes. Yet, one might have the notion that, compared to the narrow basket, the liquidity of the extended basket is generally lower (or more volatile in its liquidity). This might have decreased overall market liquidity at the same time as liquidity risks increased due to the unraveling financial crisis. Additionally, the intraday spread might have increased due to a higher average collateral risk in the repo market after the introduction of this segment. In order to take these concerns into account, we also estimate the final regression of Table 3 Panel C but allowing in addition also for a different sensitivity of the intraday spread in the extended basket to changes in market liquidity. The results reported in Table 3 Panel D indicate that the effect of a decline in overall repo market liquidity was much stronger for the intraday spread in the extended basket. Whereas, during the day, the rate in the extended basket – particularly in the crisis – was much higher in the extended basket, it was significantly lower in the afternoon. Yet for the narrow basket, too, a significant effect prevailed, but again only for the crisis period. Comparing the results across columns, we note that these findings are robust for the four different liquidity measures.

6 What affects market liquidity?

Our results so far reveal the existence of an intraday interest rate and establish a strong relationship between this intraday rate on any given day and the market liquidity of the repo market on the same day. To some extent, therefore, the intraday rate seems to reflect a liquidity premium. However, as discussed in the previous section, this liquidity premium provides some arbitrage opportunity, but is at the same time also a return that is necessary for arbitrageurs to step in and improve market liquidity. The necessary rate of return for arbitrageurs is, in turn, determined by their willingness and ability to enter into positions, i.e. given their funding constraints and the sensitivity of their funding costs. In this section, we also wish to provide some tentative conclusions on what determines market liquidity in the repo market and whether arbitrage trades may play a role in this context.

The starting point of this part of our analysis is the observation that repo market activity (or interbank money market activity in general) is significantly affected by banks' attempts to dress up their balance sheets (window dressing) at the end of the year as part of the annual balance sheet auditing procedure and report publications.[19] The corollary to this stylized fact is that the opportunity costs of exploiting an arbitrage opportunity in the GC pooling repo market should be higher at the end of a year for the following reason: Suppose a trader opens a position in the morning while expecting to close it at a favorable rate in the evening by entering an offsetting transaction. If that position cannot be closed, however, a net exposure from the morning trade remains on the balance sheet. Carrying a net exposure results in a balance sheet extension, which is particularly costly at the end of the year. We therefore consider this end-of-year impact on the funding constraints of arbitrageurs to be a valid "exogenous shock" to derive repercussions on the "causal" relationships between arbitrage activity, the repo market liquidity and the intraday spread.

In a first step, we study the arbitrage activity on the last day of the year. We do this by regressing our variable $Intermediation_t$ on an end-of-year dummy that takes the value 1 on the last trading day of any given year and zero otherwise. We include further time dummies to account for different crisis periods and monetary policy interventions as the opportunity costs of acting as an intermediary may change over these subperiods. In the next step, we study whether market liquidity is also lower at the end of the year by regressing the different market liquidity variables on the end-of-year dummy (Table 4 Panel A). Finally, we again estimate the interest rate at the transaction level while using only daily fixed effects and the afternoon dummy measuring trades that occurred in the second half of the day and an interaction of the afternoon dummy with our end-of-year dummy (Table 4 Panel B). This allows us to see whether, at the end of the year – when arbitrage trades are presumably more expensive –, the liquidity premium is elevated compared to other days. Since our previous analysis shows that the intraday rate is only positive during the crisis period, we also allow for different intraday rates for the different

[19] Owens and Wu (2014) provide empirical evidence on the window-dressing effect for the repo market in the U.S. Ebner, Fecht, and Schulz (2014) provide a discussion of the impact of settlement netting on trading activity at financial reporting dates in the euro area.

subperiods to ensure that our end-of-year dummy does not only pick up this crisis effect.[20]

Table 4 Panel A reports the results for these three steps of our analysis. They show that the intermediation activity of arbitrageurs is indeed significantly lower in times of elevated opportunity costs of arbitrage trades (see columns 1 and 2). This correlates with muted market liquidity at the year-end; see our regressions for the market liquidity measures (with the exception of the simple price volatility). We also find that the intraday interest rate is significantly elevated on average at the year-end, also when considering the afternoon bin (see Table 4 Panel B). That is, an increase in the intraday interest rate and thus in the liquidity premium is associated with higher opportunity costs of arbitrage.

While this conclusion is suggestive and indicative, it has important policy implications: reporting requirements of, for instance, banks' equity and leverage ratios at the end of the year correlate with arbitrage activities, market liquidity and the liquidity premium in the repo market; any change in the required equity and leverage ratio – which banks have to fulfill – are thus likely to have a similar effect on the market.[21]

7 Conclusion

In this paper we use transaction-level data on the Eurex Repo market to study the existence of an intraday interest rate in the secured segment of the euro-area money market. Any collateral used in this repo market is also eligible for operations with the European System of Central Banks, in particular the intraday overdraft facility. Thus, we can rule out that banks, insofar as they trade in this market, are collateral constrained, so that any intraday rate observed in this market cannot be a reflection of collateral constraints.

For the tranquil pre-crisis period, we do not find any intraday interest rate. But for the crisis period, we find an intraday interest rate of up to 60 basis points. The introduction of the first one-year and three-year LTRO proves successful in decreasing intraday interest rates. Even after controlling for a variety of other factors, we find that a key determinant of the intraday rate during the crisis was the repo market liquidity. This suggests that the intraday rate is largely a liquidity premium.

These findings have important implications. They show that even an uncollateralized, free-of-

[20] As can be seen, the results still hold after including control variables.

[21] Recall that our dataset does not contain any information on the identity of the involved parties, which would allow to study this point in further detail by, e.g., using supervisory and regulatory data.

charge daylight overdraft facility provided by a central bank cannot eliminate an intraday interest rate and an incentive to delay payments in real-time gross settlement (RTGS) systems. Thus, the costs of immediacy are also determined by money market liquidity. Evaporating market liquidity in the repo market increases the market price for immediate funding liquidity. Furthermore, our results indicate that intraday interest rates estimated using unsecured transactions do not only reflect collateral constraints. In particular, the sharp increase during the crisis in the unsecured market was apparently also driven by an elevated market liquidity premium.

References

Acharya, V. V. and L. H. Pedersen (2005). Asset pricing with liquidity risk. *Journal of Financial Economics 77*(2), 375 – 410.

Afonso, G., A. Kovner, and A. Schoar (2011, 08). Stressed, not frozen: The federal funds market in the financial crisis. *Journal of Finance 66*(4), 1109–1139.

Amihud, Y. (2002). Illiquidity and stock returns: Cross-section and time-series effects. *Journal of Financial Markets 5*(1), 31 – 56.

Amihud, Y. and H. Mendelson (1986). Asset pricing and the bid-ask spread. *Journal of Financial Economics 17*(2), 223 – 249.

Angelini, P. (1998). An analysis of competitive externalities in gross settlement systems. *Journal of Banking & Finance 22*(1), 1–18.

Angelini, P. (2000). Are banks risk averse? Intraday timing of operations in the interbank market. *Journal of Money, Credit and Banking 32*(1), 54–73.

Ashcraft, A. B. and D. Duffie (2007). Systemic illiquidity in the federal funds market. *The American Economic Review 97*(2), pp. 221–225.

Baglioni, A. and A. Monticini (2008). The intraday price of money: Evidence from the e-MID interbank market. *Journal of Money, Credit and Banking 40*(7), 1533–1540.

Baglioni, A. and A. Monticini (2010). The intraday interest rate under a liquidity crisis: The case of August 2007. *Economics Letters 107*(2), 198–200.

Baglioni, A. and A. Monticini (2013). Why does the interest rate decline over the day? Evidence from the liquidity crisis. *Journal of Financial Services Research 44*(2), 175–186.

Beaupain, R. and A. Durre (2013). Central bank reserves and interbank market liquidity in the euro area. *Journal of Financial Intermediation 22*(2), 259–284.

Bech, M. L. and R. Garratt (2003). The intraday liquidity management game. *Journal of Economic Theory 109*(2), 198–219.

Biais, B., J. Hombert, and P.-O. Weill (2014). Equilibrium pricing and trading volume under preference uncertainty. *The Review of Economic Studies*, 1–37.

Brunnermeier, M. K. and L. H. Pedersen (2009). Market liquidity and funding liquidity. *Review of Financial Studies 22*(6), 2201–2238.

Copeland, A., A. Martin, and M. Walker (2014). Repo runs: Evidence from the tri-party repo market. *Journal of Finance 69*, 2343 – 2380.

Ebner, A., F. Fecht, and A. Schulz (2014). Repo market microstructure in the case of GC Pooling. Technical report, mimeo.

Gorton, G. and A. Metrick (2012). Securitized banking and the run on repo. *Journal of Financial Economics 104*(3), 425–451.

Goyenko, R. Y., C. W. Holden, and C. A. Trzcinka (2009). Do liquidity measures measure liquidity? *Journal of Financial Economics 92*(2), 153–181.

Gromb, D. and D. Vayanos (2002). Equilibrium and welfare in markets with financially constrained arbitrageurs. *Journal of Financial Economics 66*(2-3), 361–407.

Jurgilas, M. and F. Zikes (2014). Implicit intraday interest rate in the UK unsecured overnight money market. *Journal of Financial Intermediation 23*(2), 232–254.

Kahn, C. M. and W. Roberds (2001). Real-time gross settlement and the costs of immediacy. *Journal of Monetary Economics 47*(2), 299–319.

Kraenzlin, S. and T. Nellen (2010). Daytime is money. *Journal of Money, Credit and Banking 42*(8), 1689–1702.

Kyle, A. S. (1985). Continuous auctions and insider trading. *Econometrica 53*(6), 1315–1336.

Mancini, L., A. Ranaldo, and J. Wrampelmeyer (2014). The euro interbank repo market. Swiss Finance Institute Research Paper 13-71, Swiss Finance Institute.

Martin, A. (2004). Optimal pricing of intraday liquidity. *Journal of Monetary Economics 51*(2), 401–424.

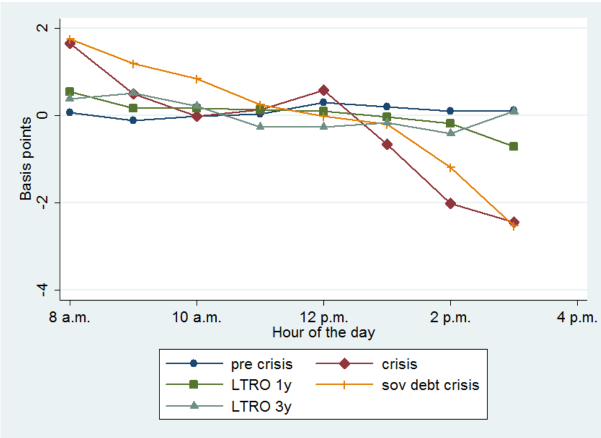
Owens, E. L. and J. S. Wu (2014). Quarter-end repo borrowing dynamics and bank risk opacity. Working Paper FR 11-15, Simon School of Business.

Roll, R. (1984). A simple implicit measure of the effective bid-ask spread in an efficient market. *Journal of Finance 39*(4), 1127–39.

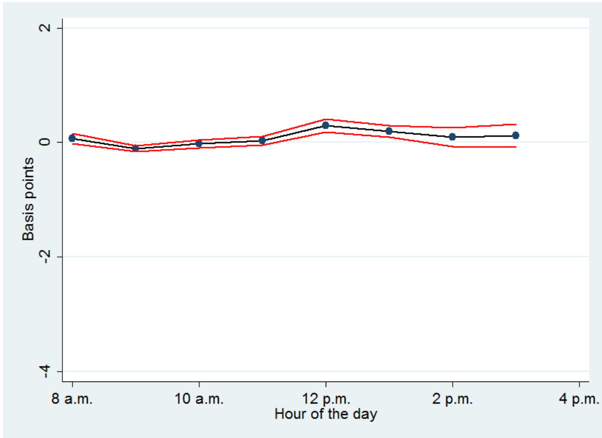
Van Hoose, D. D. (1991). Bank behavior, interest rate determination, and monetary policy in a financial system with an intraday federal funds market. *Journal of Banking & Finance 15*(2), 343–365.

Figures

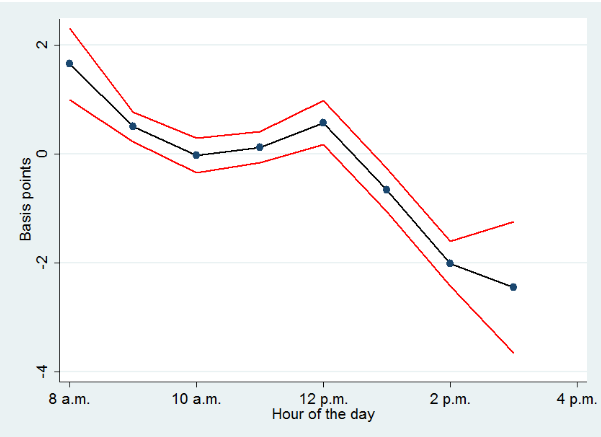
Figure 1: Intraday term structure



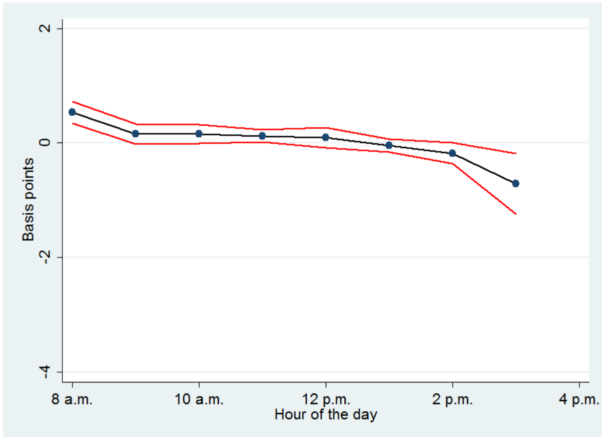
(a) Combined



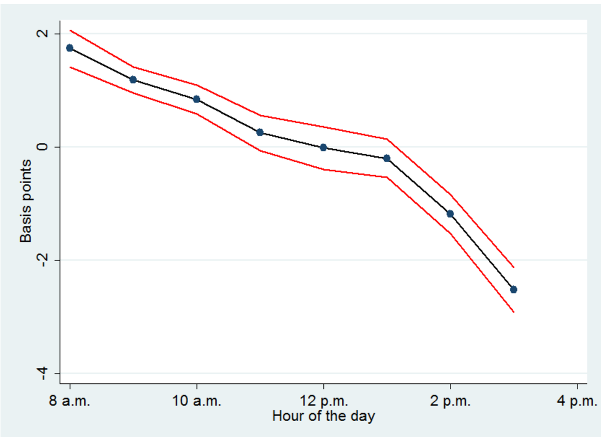
(b) Pre-crisis period



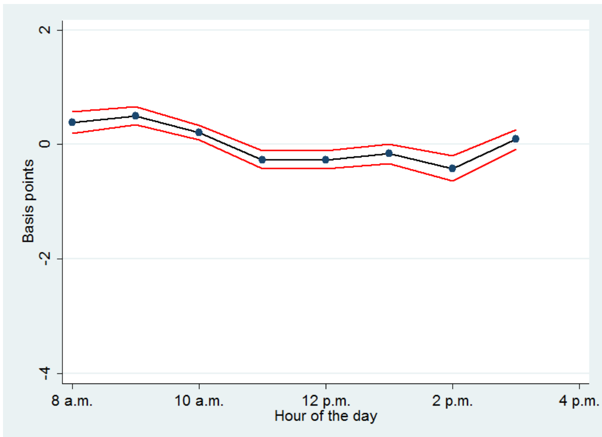
(c) Financial crisis period



(d) 1-year LTRO period



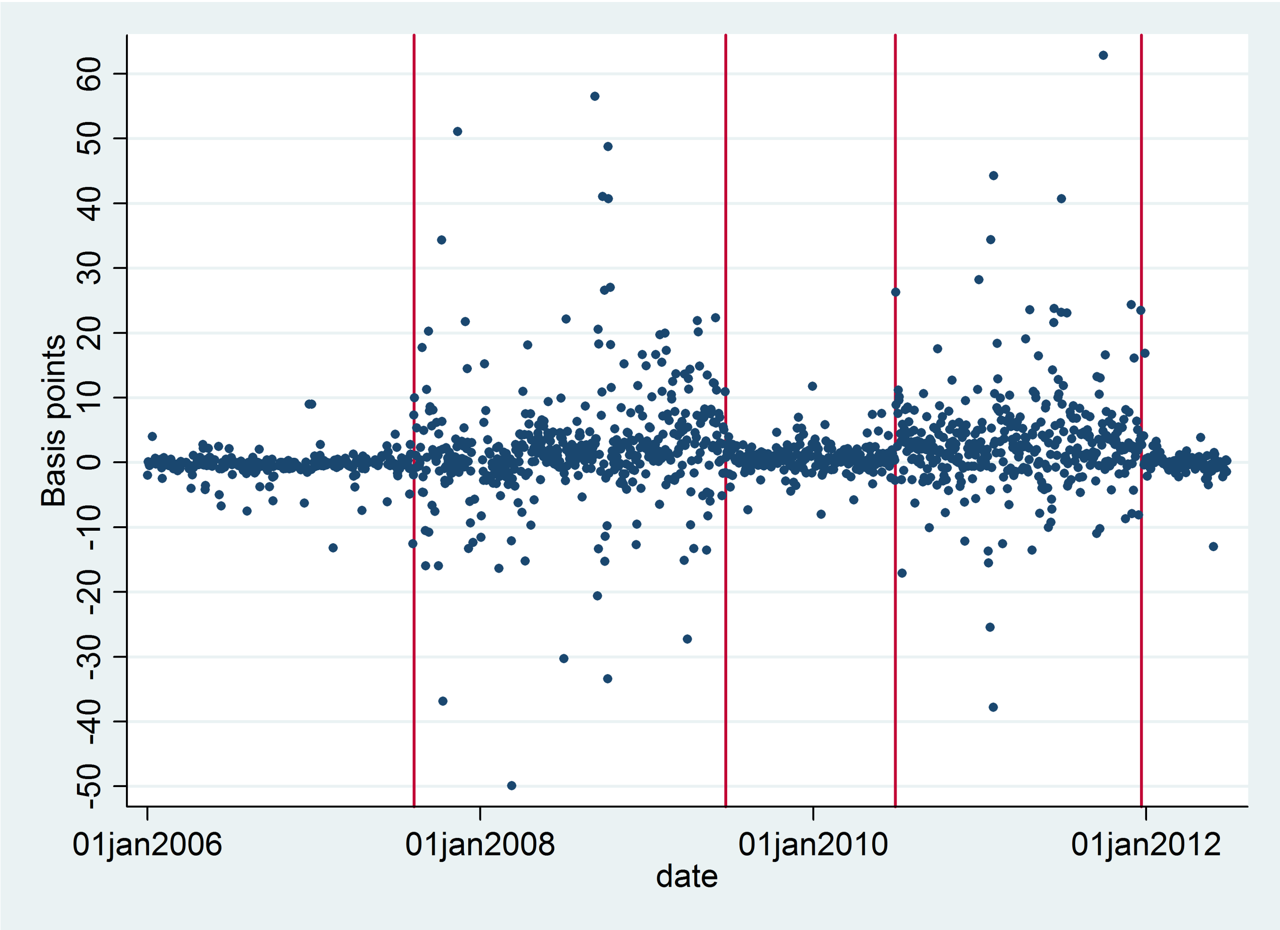
(e) Sovereign debt crisis period



(f) 3-year LTRO period

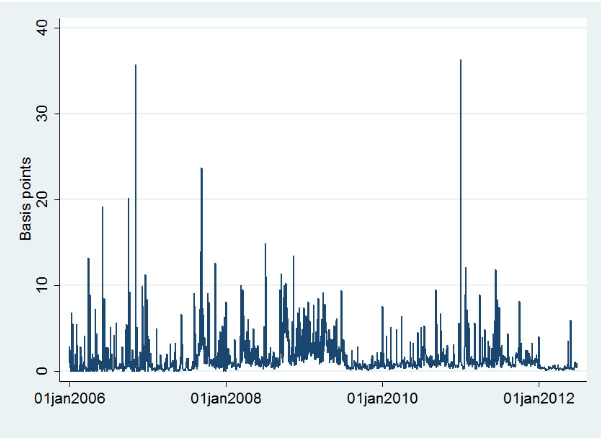
Notes: This figure shows the estimated intraday term structure (in basis points) for different periods from January 1, 2006 through June 30, 2012. The estimation refers to Equation (6) with reserve maintenance and calender controls as well as lender fixed effects and borrower fixed effects. In each subfigure, the solid black line represents the hourly band's deviation of the interest rate from its volume-weighted daily interest rate. We have multiplied the spread by 100 so that the unit of the y-axis is measured in basis points. The solid red lines in subfigure (b) through (f) denotes the 95th confidence band width. 'Pre crisis' period refers to January 1, 2006 through August 8, 2007. The 'Financial crisis' sample ranges from August 9, 2007 to June 22, 2009. '1-year LTRO' covers the period from June 23, 2009 until June 30, 2010. The period thereafter until 20 December 2011 is considered as the period of the 'sovereign debt crisis'. '3-year LTRO' refers to the subsample that starts on December, 21 2011 and ends in June 30, 2012.

Figure 2:
Daily spread between morning and afternoon rates

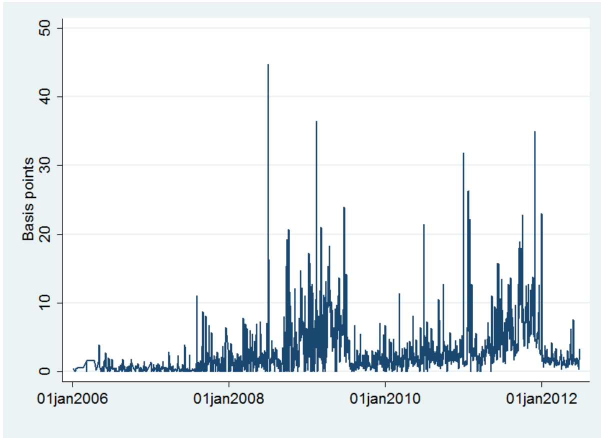


Notes: This figure plots the daily spread between the quantity-weighted average morning band and afternoon band rate for our complete sample starting in January 01, 2006 until June 30, 2012. We multiply this spread by 100 to reflect the spread in basis points. The vertical lines refer to the start of the financial crisis (first), the 1-year LTRO (second), the sovereign debt crisis (third), and the 3-year LTRO, respectively.

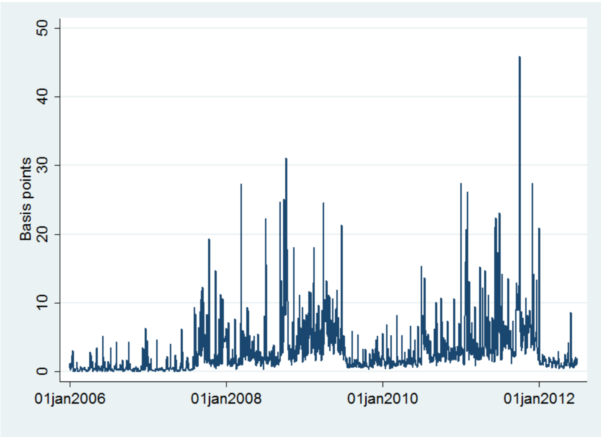
Figure 3:
Various market liquidity measures



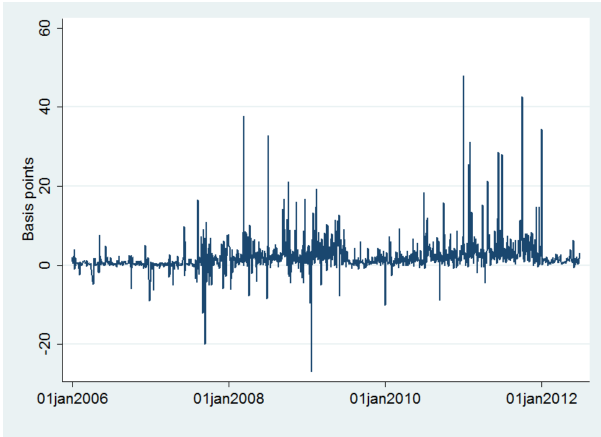
(a) Amihud ratio



(b) Roll's spread



(c) Intraday standard deviation



(d) Aggressive sell-buy spread

Notes: This figure plots the daily series of the four liquidity measures for our sample period from January 01, 2006 through June 30, 2012. We compute in subfigure (a) the Amihud ratio following Amihud (2002), which is the maximum price change in reaction to a given volume of transactions (in EUR billion here) on day *t*. We excluded 12 June, 2006 because the Amihud ratio has a severe outlier (>500) on that day. In subfigure (b), our measure captures the overall transaction costs in the GC repo market and follows the rationale of the implicit effective bid-ask spread as suggested by Roll (1984). This measure infers the effective bid-ask spread from the first order serial covariance (*cov*) of price changes observed over consecutive transactions (k) conducted throughout the day *t*. The figure in (c) captures the market risk associated with the price volatility in the GC repo market. Here, we compute the standard deviation of all observed interest rates during the day. In (d), we calculate the spread between the average rate of seller initiated trades and the average rate of buyer initiated trades on a particular day (aggressive-sell-aggressive-buy-spread). This measure can also be seen as an alternative estimate of the maximum effective bid-ask-spread on the respective day. For all measures, a larger value indicates more illiquidity. We calculate these measures using the interest rate in basis points. Further details regarding the computation refer to Section 3.

Tables

Table 1: Summary statistics of the GC pooling repo market

Panel (a): Variables describing the dataset	Mean	St.D.	Min	Max	N
no. transactions	48.70	25.73	1	155	1655
no. borrower	8.72	6.05	1	27	1655
no. lender	9.04	5.66	1	32	1655
daily trade volume (mio)	7929.97	5770.99	1	38352	1655
rate (bp)	193.04	155.78	22.93	508.57	1655
intraday rate morning - afternoon (bp)	1.43	6.47	-49.91	62.83	1655
intraday rate morning - afternoon (absolute, bp)	3.35	5.72	0	62.83	1655

Panel (b): Variables used in the regressions	Mean	St.D.	Min	Max	N
rate difference to daily mean (bp)	-0.08	6.27	-92.86	88.91	97792
extended basket	0.19	0.40	0	1	97792
afternoon	0.43	0.49	0	1	97792
Aggr. Sell-Buy Spread	2.30	4.04	-26.93	47.86	1539
Amihud Ratio (bps/bn EUR)	1.67	2.41	0	36.25	1654
Roll's Bid-Ask Spread	3.05	3.97	0	44.67	1487
Intraday Std.Dev. (bps)	3.12	3.93	0	45.83	1627
Net-RTGS (in bn. EUR)	661.16	168.05	297.67	1140.61	1654
Marginal lending facility (mio)	1132.87	2823.69	0	28707	1653
Euribor-OIS Spread (bps)	43.97	36.24	3.05	206.9	1652
Intermediation Ratio	0.03	0.06	0	0.87	1654
Trading Pattern (mio EUR/mio EUR)	13.80	140.28	0	4030	1513
Amihud Ratio afternoon (bps)	3.52	6.22	0	76.92	1513
Roll's Bid-Ask Spread afternoon (bps)	3.91	4.68	0	37.26	1046
Intraday Std.Dev. Afternoon (bps)	3.09	3.77	0	56.66	1342

Notes: This table reflects the summary statistics on the key variables we use for our analysis. The data covers all overnight transactions conducted during the sample from January 2006 through June 2012. This yields a total of 1655 observed trading days within our sample. The individual number of observations varies because of data availability problems. Additionally, we have excluded two outlier days (June 12, 2006 for the normal and November 20, 2006 for the afternoon liquidity measures) in our data set. The Euribor-OIS spread denotes the difference between the 3-month Euribor rate and the correspondingly dated overnight indexed swap (OIS).

Table 2:
Intraday term structure for all banks

Dependent Variable: $\hat{r}_{k,i,j,t,h}$													
	full sample Jan 06 - Jun 12			pre-crisis Jan 06 - Aug 07		financial crisis Aug 07 - Jun 09		1y-LTRO Jun 09 - Jun 10		sovereign debt crisis Jul 10 - Dec 11		3y-LTRO Jan 12 - Jun 12	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
8 - 9 a.m.	1.5224***	1.4070***	1.3147***	0.0563	0.0681	1.3563***	1.6528***	0.7457***	0.5357***	2.1169***	1.7386***	0.4807***	0.3837***
	(0.174)	(0.118)	(0.108)	(0.051)	(0.047)	(0.283)	(0.336)	(0.126)	(0.096)	(0.165)	(0.167)	(0.087)	(0.097)
9 - 10 a.m.	-0.5293***	-0.4223***	-0.5381***	-0.2351***	-0.1674***	-0.9758***	-1.1529***	-0.5696***	-0.3778***	-0.4349*	-0.5547**	0.1527	0.1195
	(0.145)	(0.125)	(0.116)	(0.053)	(0.055)	(0.247)	(0.268)	(0.132)	(0.092)	(0.225)	(0.225)	(0.150)	(0.117)
10 - 11 a.m.	-1.0273***	-0.9693***	-0.8651***	-0.1442***	-0.0926*	-1.2009***	-1.6761***	-0.6019***	-0.3799***	-1.4290***	-0.8979***	-0.0167	-0.1769
	(0.152)	(0.168)	(0.153)	(0.050)	(0.051)	(0.369)	(0.431)	(0.117)	(0.071)	(0.239)	(0.234)	(0.221)	(0.118)
11 a.m. - 12 p.m.	-1.5183***	-1.3926***	-1.1657***	0.0614	-0.0350	-1.3011***	-1.5284***	-0.6927***	-0.4102***	-2.1122***	-1.4889***	-0.7988***	-0.6511***
	(0.155)	(0.142)	(0.145)	(0.059)	(0.054)	(0.298)	(0.341)	(0.143)	(0.116)	(0.270)	(0.264)	(0.154)	(0.123)
12 - 1 p.m.	-1.5439***	-1.4434***	-1.1816***	0.371)***	0.2291***	-1.1101***	-1.0755***	-0.5387***	-0.4470***	-2.4162***	-1.7577***	-0.7350***	-0.6516***
	(0.131)	(0.150)	(0.143)	(0.070)	(0.061)	(0.271)	(0.331)	(0.146)	(0.125)	(0.267)	(0.301)	(0.117)	(0.131)
1 - 2 p.m.	-1.9963***	-1.7717***	-1.5645***	0.3299**	0.1023	-2.0901***	-2.3152***	-0.8502***	-0.5770***	-2.5486***	-1.9390***	-0.6591***	-0.5468***
	(0.148)	(0.142)	(0.136)	(0.125)	(0.088)	(0.341)	(0.411)	(0.131)	(0.104)	(0.274)	(0.289)	(0.121)	(0.124)
2 - 3 p.m.	-2.6564***	-2.4950***	-2.3716***	0.4456	0.0250	-3.0665***	-3.6622***	-1.0665***	-0.7163***	-3.4625***	-2.9228***	-0.9367***	-0.8026***
	(0.179)	(0.200)	(0.167)	(0.332)	(0.105)	(0.521)	(0.473)	(0.178)	(0.168)	(0.237)	(0.245)	(0.159)	(0.163)
3 - 4 p.m.	-3.8048***	-3.6590***	-3.1129***	0.0996	0.0464	-3.6936***	-4.1032***	-1.7686***	-1.2488***	-5.3522***	-4.2571***	-0.5679***	-0.2934**
	(0.393)	(0.333)	(0.262)	(0.109)	(0.117)	(0.847)	(0.798)	(0.363)	(0.337)	(0.295)	(0.190)	(0.153)	(0.142)
Seasonal Controls	no	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Borrower/Lender FE	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	97,792	97,792	97,792	4,434	4,434	19,848	19,848	13,784	13,784	45,202	45,202	14,524	14,524
R-squared	0.036	0.108	0.125	0.066	0.230	0.073	0.106	0.134	0.157	0.166	0.200	0.158	0.299
adjusted R-squared	0.036	0.106	0.123	0.057	0.217	0.070	0.102	0.129	0.151	0.163	0.197	0.151	0.291

Notes: This table shows the estimation results of Equation (6) for the different subsamples that we have defined. The dependent variable is $\hat{r}_{k,i,j,t,h}$, the difference between the overnight rate on transaction k and the daily volume weighted average overnight rate. To account for the hourly time bands, we have included hour-dummies, where for each hour we define an individual binary variable. Since overnight repos are traded between 8 a.m. and 4 p.m., we have 7 different dummies and a constant that considers the time slot for the bin from 8 a.m. to 9 a.m. The other variables are interpreted relative to the constant. Seasonal and reserve maintenance period (RMP) dummies are included to account for the term structure on end of reserve maintenance period, end of month and end of year days, respectively. While each estimation except column (1) includes borrower and lender fixed effects, the first column of each estimation refers to the specification without seasonal fixed effects. Robust standard errors are clustered at the bank level and shown in parentheses. ***,**, and * denote statistical significance at p<0.01, p<0.05, and p<0.1.

Table 3 Panel A:
Market liquidity as a determinant of the intraday interest rate

	Dependent Variable: $r_{k,t,h}$						
		Liquidity measures:					
		Amihud ratio			Roll's spread	Intraday st. dev.	Aggr. Sell-Buy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
afternoon*liquidity		-0.738***	-0.737***				
		(0.172)	(0.174)				
afternoon*liquidity*pre-crisis				0.463**	0.798**	0.886***	-0.102
				(0.218)	(0.361)	(0.306)	(0.209)
afternoon*liquidity*crisis				-0.795***	-0.218***	-0.790***	-0.645***
				(0.169)	(0.0518)	(0.0819)	(0.204)
afternoon*liquidity*LTRO				0.264	0.100	0.135	0.157
				(0.295)	(0.113)	(0.130)	(0.105)
afternoon*RTGS			-0.007***	-0.007***	-0.005***	-0.0002	-0.004***
			(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
afternoon	0.573***	1.574***	4.311***	2.993***	2.245***	-0.184	2.490***
	(0.133)	(0.305)	(0.574)	(0.460)	(0.452)	(0.498)	(0.450)
afternoon*crisis	-3.655***	-3.111***	-0.994**	0.471	-0.594	1.464***	0.143
	(0.348)	(0.298)	(0.434)	(0.454)	(0.470)	(0.434)	(0.450)
afternoon*LTRO1y	2.398***	1.764***	1.744***	1.433***	1.558***	-0.758*	0.560
	(0.264)	(0.230)	(0.227)	(0.300)	(0.271)	(0.390)	(0.353)
afternoon*LTRO3y	2.764***	1.874***	2.279***	2.078***	2.328***	-0.510	1.312***
	(0.237)	(0.198)	(0.218)	(0.229)	(0.269)	(0.374)	(0.306)
afternoon*end rmp		0.169	0.0912	-0.00466	-1.066*	1.314**	-0.0620
		(0.507)	(0.507)	(0.531)	(0.602)	(0.559)	(0.593)
afternoon*end month		-3.356***	-2.059**	-2.007**	-2.950***	0.0137	-1.323*
		(0.905)	(0.868)	(0.864)	(0.997)	(0.645)	(0.759)
afternoon*end year		-9.251**	-9.893**	-10.62**	-12.17***	-6.414	-1.551
		(4.092)	(4.063)	(4.385)	(4.306)	(4.268)	(4.671)
Constant	117.8***	117.8***	117.8***	117.8***	116.0***	117.7***	116.3***
	(0.172)	(0.172)	(0.172)	(0.172)	(0.174)	(0.172)	(0.171)
Daily Fixed Effects	yes	yes	yes	yes	yes	yes	yes
Observations	48,896	48,896	48,896	48,896	48,426	48,869	48,503
within R-squared	0.0378	0.0547	0.0565	0.0573	0.053	0.1036	0.0846
between R-squared	0.0553	0.0091	0.0193	0.0198	0.0357	0.0185	0.0274

Notes: This table shows the results on the determinants of the intraday interest rate. The underlying economic idea is to understand why there is a non-zero intraday interest rate. The specification is defined in Equation (7). The dependent variable is the overnight rate on the transaction level. We measure the liquidity of the GC pooling repo market using four different variables: (i) the Amihud ratio following Amihud (2002), (ii) the implicit effective bid-ask spread as suggested by Roll (1984), (iii) the standard deviation of all observed interest rates during the day, and (iv) the spread between the average rate of seller initiated trades and the average rate of buyer initiated trades on a particular day (aggressive-sell-aggressive-buy-spread). 'crisis' is a binary variable that takes the value one during the sample from August 9, 2007 to June 30, 2012 and zero otherwise. Similarly, we have computed the dummy 'LTRO 1y' (controlling for the complete lifespan of the one-year LTRO starting in June 23, 2009 and ending on June 30, 2010) and the 'LTRO 3y' dummy (which equals one for the period from December 21, 2011 to June 30, 2012 and zero otherwise). Robust standard errors are clustered at the bank level and shown in parentheses. ***,**, and * denote statistical significance at $p<0.01$, $p<0.05$, and $p<0.1$. For further details, please refer to Tables 1 - 2.

Table 3 Panel B:
The influence of the afternoon liquidity on the intraday rate

	Dependent Variable: $r_{k,t,h}$								
	Liquidity measures:								
	Amihud Ratio			Roll's spread			Intraday st. dev.		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
afternoon*liquidity	-0.254***	-0.253***		-0.0460	-0.0316		-0.474***	-0.458***	
	(0.0582)	(0.0587)		(0.0393)	(0.0388)		(0.0942)	(0.0964)	
afternoon*liquidity*pre-crisis			0.0132			-0.0928			0.327
			(0.0260)			(0.787)			(0.372)
afternoon*liquidity*crisis			-0.277***			-0.0449			-0.474***
			(0.0605)			(0.0385)			(0.0950)
afternoon*liquidity*LTRO			0.0994			0.0796			0.126
			(0.0974)			(0.0819)			(0.122)
afternoon*RTGS		-0.00648***	-0.00661***		-0.00652***	-0.00656***		-0.00378***	-0.00386***
		(0.00112)	(0.00112)		(0.00110)	(0.00109)		(0.00110)	(0.00109)
afternoon	1.183***	3.901***	3.528***	4.079***	6.748***	6.810***	1.186***	2.786***	2.358***
	(0.239)	(0.558)	(0.499)	(1.041)	(1.114)	(1.427)	(0.241)	(0.511)	(0.497)
afternoon*crisis	-3.015***	-0.916*	-0.351	-6.675***	-4.533***	-4.493***	-1.856***	-0.716*	-0.152
	(0.342)	(0.461)	(0.465)	(1.087)	(1.204)	(1.418)	(0.350)	(0.425)	(0.414)
afternoon*LTRO1y	1.975***	1.955***	1.669***	2.372***	2.360***	2.105***	1.049***	1.083***	0.787***
	(0.244)	(0.235)	(0.274)	(0.261)	(0.252)	(0.266)	(0.282)	(0.287)	(0.272)
afternoon*LTRO3y	2.103***	2.506***	2.339***	2.851***	3.264***	3.069***	1.294***	1.582***	1.354***
	(0.235)	(0.243)	(0.255)	(0.236)	(0.220)	(0.252)	(0.253)	(0.290)	(0.282)
afternoon*end RMP	0.289	0.209	0.212	-1.086*	-1.186*	-1.227**	0.771	0.666	0.633
	(0.522)	(0.521)	(0.517)	(0.600)	(0.601)	(0.599)	(0.510)	(0.511)	(0.516)
afternoon*end month	-3.754***	-2.466**	-2.396**	-4.351***	-3.099***	-3.104***	-2.832***	-2.132**	-2.114**
	(1.020)	(0.989)	(0.991)	(1.041)	(1.048)	(1.046)	(0.974)	(0.954)	(0.949)
afternoon*end year	-11.06***	-11.70***	-12.10***	-13.27***	-13.76***	-15.48***	-10.41**	-10.85***	-11.80***
	(3.801)	(3.783)	(3.928)	(4.644)	(4.652)	(5.254)	(3.989)	(3.981)	(4.315)
Constant	114.6***	114.6***	114.6***	90.51***	90.51***	90.51***	109.2***	109.2***	109.2***
	(0.173)	(0.173)	(0.173)	(0.185)	(0.186)	(0.185)	(0.176)	(0.176)	(0.176)
Daily Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	48,219	48,219	48,219	43,597	43,597	43,597	47,135	47,135	47,135
within R-squared	0.0537	0.0554	0.056	0.0474	0.0489	0.049	0.0613	0.0618	0.062
between R-squared	0.0053	0.016	0.0162	0.0473	0.018	0.0167	0.006	0.0122	0.0127

Notes: This table reports the estimates for the baseline regressions as presented in Table 3 Panel Ausing the afternoon market liquidity according to the Amihud ratio, Roll's liquidity measure, and the simple afternoon repo rate volatility. This serves to rule out that the results from Panel A are only due to mechanical correlations between market liquidity and the intraday rate. 'crisis' is a binary variable that takes the value one during the sample from August 9, 2007 to June 30, 2012 and zero otherwise. Similarly, we have computed the dummy 'LTRO 1y' (controlling for the complete lifespan of the one-year LTRO starting in June 23, 2009 and ending on June 30, 2010) and the 'LTRO 3y' dummy (which equals one for the period from December 21, 2011 to June 30, 2012 and zero otherwise). Robust standard errors are clustered at the bank level and shown in parentheses. ***,**, and * denote statistical significance at p<0.01, p<0.05, and p<0.1. For further details, please refer to Tables 1 - 3 Panel A.

Table 3 Panel C:
Further determinants of the intraday interest rate

	Dependent Variable: $r_{k,t,h}$						
	Liquidity measures:						
	Aggr. Sell-Buy				Amihud Ratio	Roll's spread	Intraday st. dev.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
afternoon*liquidity	-0.645***	-0.627***	-0.627***				
	(0.0784)	(0.0797)	(0.0797)				
afternoon*liquidity*pre-crisis				-0.0269	0.545***	0.768**	0.858***
				(0.216)	(0.181)	(0.365)	(0.315)
afternoon*liquidity*crisis				-0.637***	-0.851***	-0.194***	-0.815***
				(0.0810)	(0.164)	(0.0476)	(0.0813)
afternoon*liquidity*LTRO				0.119	0.225	0.0493	0.0553
				(0.107)	(0.296)	(0.114)	(0.127)
afternoon*Intermediation Ratio		-9.546***	-9.563***	-9.779***	-13.71***	-12.88***	-7.173***
		(1.688)	(1.688)	(1.628)	(1.611)	(1.557)	(1.688)
afternoon*RTGS	-0.00349***	-0.00287***	-0.00288***				
	(0.000904)	(0.000901)	(0.000899)				
afternoon*RTGS*pre-crisis				0.00288	0.00574*	0.00566	-0.00432
				(0.00298)	(0.00305)	(0.00426)	(0.00269)
afternoon*RTGS*crisis				-0.00356***	-0.00667***	-0.00480***	0.000705
				(0.00123)	(0.00138)	(0.00134)	(0.00127)
afternoon*RTGS*LTRO				0.00230	0.00528**	0.00518**	-0.00254
				(0.00205)	(0.00249)	(0.00260)	(0.00201)
afternoon*Trading Pattern			-0.00200***	-0.00198***	-0.00158***	-0.00187***	-0.00181***
			(0.000655)	(0.000657)	(0.000539)	(0.000597)	(0.000569)
afternoon*MLF	8.25e-05*	9.85e-05**	9.83e-05**	9.46e-05*	6.08e-05	3.56e-05	0.000156***
	(4.89e-05)	(4.87e-05)	(4.87e-05)	(4.86e-05)	(4.67e-05)	(4.43e-05)	(5.33e-05)
afternoon*Euribor-OIS Spread	-0.00716**	-0.00971***	-0.00967***	-0.00945***	-0.00172	-0.00157	0.00643**
	(0.00292)	(0.00291)	(0.00290)	(0.00287)	(0.00298)	(0.00346)	(0.00285)
Extended Basket Dummy	7.157***	7.104***	7.105***	7.094***	7.274***	7.054***	7.060***
	(0.428)	(0.428)	(0.427)	(0.425)	(0.460)	(0.434)	(0.406)
afternoon*Extended Basket	-0.00903	0.0979	0.0962	0.118	-0.298	0.165	0.226
	(0.342)	(0.346)	(0.346)	(0.342)	(0.396)	(0.374)	(0.322)
Extended Basket*LTRO1y	-4.702***	-4.680***	-4.680***	-4.662***	-4.840***	-4.599***	-4.620***
	(0.442)	(0.434)	(0.434)	(0.429)	(0.463)	(0.436)	(0.413)
afternoon*Extended Basket*LTRO1y	1.817***	1.770***	1.772***	1.728***	2.131***	1.631***	1.647***
	(0.468)	(0.469)	(0.469)	(0.470)	(0.500)	(0.482)	(0.474)
Extended Basket*LTRO3y	-4.839***	-4.773***	-4.774***	-4.770***	-4.970***	-4.776***	-4.728***
	(0.457)	(0.461)	(0.460)	(0.460)	(0.485)	(0.473)	(0.441)
afternoon*Extended Basket*LTRO3y	-0.225	-0.328	-0.327	-0.330	0.149	-0.295	-0.432
	(0.476)	(0.476)	(0.475)	(0.473)	(0.501)	(0.501)	(0.468)
afternoon	2.435***	2.241***	2.317***	-0.343	-2.251*	-2.006	1.688
	(0.395)	(0.395)	(0.392)	(1.277)	(1.301)	(1.761)	(1.049)
Constant	115.1***	115.1***	112.6***	112.6***	113.5***	112.5***	113.5***
	(0.0929)	(0.0946)	(0.0944)	(0.0946)	(0.0897)	(0.0967)	(0.0958)
Period Dummies	yes	yes	yes	yes	yes	yes	yes
Seasonal/RMP Dummies	yes	yes	yes	yes	yes	yes	yes
Daily Fixed Effects	yes	yes	yes	yes	yes	yes	yes
Observations	48,492	48,492	47,980	47,980	48,209	47,941	48,206
within R-squared	0.2024	0.2043	0.2048	0.2051	0.1807	0.1744	0.2254
between R-squared	0.0467	0.0396	0.0415	0.0387	0.0524	0.0604	0.0315

Notes: This table extends the regressions presented in Table 3 Panel A with further control variables. MLF refers to the marginal lending facility, i.e. Eurosystem's lender of last resort facility. 'RTGS' captures the liquidity flows settled via the payment and settlement system Target2 net of GC pooling volume. 'Intermediation' reflects the intermediated transaction volume that supposedly reflects arbitrage activity between the morning and the afternoon session in the GC pooling market, which we compute as follows: $Intermediation_t = \sum_n min[buy_{n,t}^{morning}, sell_{n,t}^{afternoon}]/Vol_t^{morning}$. 'Trading pattern' is determined as the ratio between the aggregated transaction volume in the morning and the afternoon. Robust standard errors are clustered at the bank level and shown in parentheses. ***,**, and * denote statistical significance at p<0.01, p<0.05, and p<0.1. For further details, please refer to Tables 1 through 3 Panel B.

Table 3 Panel D:
The influence of liquidity on intraday rates in the two baskets

	Dependent Variable: $r_{k,t,h}$			
	Liquidity measures:			
	Aggr. Sell-Buy	Amihud Ratio	Roll's spread	Intraday st. dev.
	(1)	(2)	(3)	(4)
afternoon*liquidity*pre-crisis	0.0511	0.492***	0.777**	0.823**
	(0.231)	(0.176)	(0.366)	(0.327)
afternoon*liquidity*crisis	-0.477***	-0.608***	-0.0773	-0.639***
	(0.0848)	(0.173)	(0.0478)	(0.0745)
afternoon*liquidity*LTRO	0.0463	-0.123	-0.0807	-0.110
	(0.118)	(0.301)	(0.121)	(0.115)
liquidity*Ext Basket*crisis	0.897***	2.239***	1.146***	1.258***
	(0.164)	(0.499)	(0.0485)	(0.130)
afternoon*liquidity*Ext Basket*crisis	-0.744***	-1.628***	-0.397***	-0.780***
	(0.201)	(0.589)	(0.0920)	(0.162)
liquidity*Ext Basket*LTRO	0.0507	1.768	0.117	0.174
	(0.195)	(1.127)	(0.276)	(0.205)
afternoon*liquidity*Ext Basket*LTRO	0.548**	0.547	0.233	0.507**
	(0.246)	(1.023)	(0.241)	(0.239)
afternoon*Intermediation Ratio	-9.608***	-13.15***	-12.89***	-6.853***
	(1.566)	(1.630)	(1.513)	(1.572)
afternoon*RTGS*pre-crisis	0.00187	0.00444	0.00466	-0.00657**
	(0.00290)	(0.00291)	(0.00409)	(0.00255)
afternoon*RTGS*crisis	-0.00405***	-0.00642***	-0.00449***	0.00104
	(0.00131)	(0.00135)	(0.00129)	(0.00128)
afternoon*RTGS*LTRO	0.00242	0.00531**	0.00511**	-0.00322
	(0.00206)	(0.00245)	(0.00243)	(0.00194)
afternoon*Trading Pattern	-0.00189***	-0.00158***	-0.00174***	-0.00169***
	(0.000634)	(0.000545)	(0.000567)	(0.000546)
afternoon*MLF	8.20e-05*	4.02e-05	1.32e-05	0.000122**
	(4.47e-05)	(4.49e-05)	(4.35e-05)	(4.83e-05)
afternoon*Euribor-OIS Spread	-0.00747**	-0.00351	0.00234	0.00884***
	(0.00284)	(0.00327)	(0.00348)	(0.00287)
Extended Basket Dummy	3.304***	3.698***	0.424	-0.318
	(0.722)	(0.749)	(0.321)	(0.673)
afternoon*Extended Basket	3.218***	2.247***	2.085***	4.700***
	(0.832)	(0.840)	(0.448)	(0.869)
Extended Basket*LTRO1y	-2.387***	-4.911***	-0.652	0.0876
	(0.768)	(1.193)	(0.554)	(0.712)
afternoon*Extended Basket*LTRO1y	-1.248	-0.284	-0.806	-2.785***
	(1.009)	(1.149)	(0.648)	(0.942)
Extended Basket*LTRO3y	-2.745***	-3.320***	-0.860	0.164
	(0.714)	(0.904)	(0.611)	(0.689)
afternoon*Extended Basket*LTRO3y	-2.841***	-1.882*	-1.677**	-4.224***
	(0.856)	(0.965)	(0.688)	(0.885)
afternoon	0.0299	-1.673	-1.620	2.608***
	(1.254)	(1.228)	(1.684)	(0.983)
Constant	112.6***	113.5***	112.4***	113.5***
	(0.0905)	(0.0909)	(0.0836)	(0.0889)
Period Dummies	yes	yes	yes	yes
Seasonal/RMP Dummies	yes	yes	yes	yes
Daily Fixed Effects	yes	yes	yes	yes
Observations	47,980	48,209	47,941	48,206
within R-squared	0.2411	0.208	0.2379	0.2949
between R-squared	0.054	0.061	0.033	0.039

Notes: This table extends the regressions presented in Table 3 Panel C by allowing for a different sensitivity of the intraday spread in the extended basket to changes in market liquidity. This addresses potential concerns that with the introduction of the extended basket a probably less liquid market segment (or more volatile segment in its liquidity) was introduced more or less simultaneously with the beginning of the financial crisis when also liquidity risks increased. Robust standard errors are clustered at the bank level and shown in parentheses. ***,**, and * denote statistical significance at p<0.01, p<0.05, and p<0.1. For further details, please refer to Tables 1 through 3 Panel C.

Table 4 Panel A:
Determinants of market liquidity

Dependent Variable:	Intermediation		Amihud Ratio		Roll's spread		Intraday st. dev.		Aggr- Sell-Buy	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
end year	-0.0159*	-0.0136***	8.970*	9.667*	13.94**	17.90***	10.09**	11.96***	10.45	13.93
	(0.00928)	(0.00355)	(4.827)	(5.729)	(5.454)	(5.485)	(4.134)	(4.191)	(10.68)	(12.32)
RTGS		8.37e-05***		-0.00029		0.00842***		0.00665***		0.00487***
		(1.83e-05)		(0.00073)		(0.00118)		(0.00137)		(0.00149)
Marginal lending facility		1.97e-06***		5.27e-05*		0.00012*		0.00025***		0.00018***
		(6.33e-07)		(2.94e-05)		(6.49e-05)		(6.09e-05)		(4.48e-05)
Euribor-OIS Spread		-0.00034***		0.0103***		0.0137***		0.00199		-0.0151***
		(7.27e-05)		(0.00227)		(0.00478)		(0.00476)		(0.00424)
crisis		0.0191***		0.354		0.130		1.714***		2.181***
		(0.00718)		(0.288)		(0.419)		(0.461)		(0.528)
LTRO1y		-0.0198***		-0.881***		-1.807***		-2.961***		-2.433***
		(0.00455)		(0.116)		(0.220)		(0.219)		(0.247)
LTRO3y		0.0107		-1.713***		-3.047***		-4.140***		-2.453***
		(0.00661)		(0.125)		(0.246)		(0.266)		(0.269)
Constant	0.0260***	-0.0287***	1.639***	1.330***	3.014***	-3.117***	3.086***	-2.213***	2.265***	-1.686***
	(0.00144)	(0.00754)	(0.0553)	(0.347)	(0.100)	(0.513)	(0.0959)	(0.582)	(0.0960)	(0.632)
Daily Fixed Effects	no	no	no	no	no	no	no	no	no	no
Observations	1,654	1,651	1,654	1,651	1,487	1,486	1,627	1,624	1,539	1,537
R-squared	0.000	0.095	0.050	0.136	0.033	0.246	0.020	0.312	0.022	0.153
adjusted R-squared	-0.000337	0.0911	0.0494	0.132	0.0325	0.243	0.0196	0.309	0.0211	0.149

Notes: The aim of this table is to provide some tentative conclusions on the relationship between arbitrage trades and market liquidity in the repo market. The results refer to the regression of 'Intermediation' on an end-of-year dummy that takes the value one on the last trading day of any given year and zero otherwise. In columns (3) through (10), we further study whether market liquidity is lower at the year-end. All regressions cover the sample period from January 01, 2006 through June 30, 2012. Robust standard errors are shown in parentheses. ***,**, and * denote statistical significance at $p<0.01$, $p<0.05$, and $p<0.1$. For further details, refer to Table 1 through 3.

Table 4 Panel B:
Intraday interest rate at the year-end

	Dependent Variable: $r_{k,t,h}$		
	(1)	(2)	(3)
afternoon*end year	-16.20***	-17.71***	-17.11***
	(3.429)	(3.495)	(5.363)
afternoon*RTGS			-0.00967***
			(0.00144)
afternoon*MLF			-1.40e-05
			(5.35e-05)
afternoon*Euribor-OIS Spread			0.000548
			(0.00434)
afternoon*crisis		-3.689***	-0.550
		(0.290)	(0.517)
afternoon*LTRO1y		2.399***	2.377***
		(0.237)	(0.261)
afternoon*LTRO3y		2.915***	3.538***
		(0.233)	(0.285)
afternoon	-2.166***	0.616***	4.758***
	(0.206)	(0.0978)	(0.688)
Constant	117.8***	117.7***	117.7***
	(0.183)	(0.180)	(0.180)
Daily Fixed Effects	yes	yes	yes
Observations	48,896	48,896	48,896
within R-squared	0.0312	0.0413	0.0461
between R-squared	0.2088	0.0467	0.0761

Notes: This tables complements Panel A of this table and shows the intraday interest rate at the year-end. For any further information, refer to Table 1 through 4 Panel A.

Table 5:
GC pooling participants

Participant	Country	Participant	Country	Participant	Country
Aareal Bank AG	D / IRL	Dexia Bank Belgium S.A.	B	Maple Bank GmbH	D
ABN Amro Bank N.V.	NL	Donner & Reuschel	D	Mediterranean Bank plc	MT
Banco Bilbao Vizcaya Argentaria S.A.	E	Dutch State Treasury Agency	NL	Mitsubishi UFJ Securities International PLC	GB
Banco Cooperativo Espanol	E	Düesseldorfer Hypothekenbank AG	D	M.M. Warburg & Co KGaA	D
Banco de Investimento Global S.A.	PT	DZ Bank AG	D	Morgan Stanley & Co International PLC	GB
Banco Popular Espanol	E	European Financial Stability Facility S.A.	L	Morgan Stanley Bank AG	D
B. Metzler seel. Sohn & Co. KGaA	D	European Investment Bank	L	NATIXIS	F
Bankhaus Lampe KG	D	FMS Wertmanagement	D	Norddeutsche Landesbank	D
Bankia wg Caja de Ahorros y Monte de Piedad de Madrid	E	Fortis Bank S.A.	B	Norddeutsche Landesbank Luxembourg	L
Banque Centrale du Luxembourg	L	Hamburger Sparkasse AG	D	Nordea Bank Finland PLC	FI
Banque LBLux S.A.	L	Hauck & Aufhäuser Privatbankiers KGaA	D	NRW.Bank	D
Banque Privee Edmond de Rothschild	L	HSBC France S.A.	F	Oldenburgischer Landesbank AG	D
Barclays Capital Plc. Ltd.	GB	HSBC Trinkaus & Burkhardt	D	Raiffeisen Bank International AG	A
Bayerische Landesbank AG	D	HSH Nordbank AG	D	Raiffeisen-Landesbank Steiermark	A
BHF Bank AG	D	HYPO NOE Gruppe Bank AG	A	Raiffeisenlandesbank Voralberg	A
BNP Paribas S.A.	GB	IKB Deutsche Industriebank AG	D	Raiffeisenverband Salzburg	A
BRD Finanzagentur	D	ING Bank N.V.	NL	Royal Bank of Scotland PLC	GB
Bremer Landesbank	D	ING-DiBa AG	D	SEB AG	D
Caceis Bank Luxembourg S.A.	L	Jefferies International Limited	GB	Societe Generale S.A.	F
Credit Agricole Corporate and Investment Bank	F	J.P. Morgan AG	D	Sparkasse Schwarz AG	A
Citigroup Global Markets Ltd.	GB	KA Finanz AG	A	Stadtsparkasse Duesseldorf	D
Clearstream Banking S.A.	L	KAS Bank N.V.	NL	UniCredit Bank AG	D
Commerzbank AG	D	KBL European Private Bankers S.A.	L	UniCredit Bank Austria AG	A
Confederation Espanola de Cajas de Ahorros	E	KfW Bankengruppe	D	UniCredit Bank Luxembourg	L
COREALCREDIT Bank AG	D	Kommunalkredit Austria AG	A	Valartis Bank	CH
Credit Suisse Securities (Europe) Ltd.	GB	Land Rheinland-Pfalz	D	Vorarlberger Landes- und Hypothekenbank AG	A
Danske Bank A/S	DK	Landesbank Baden-Württemberg	D	VTB Bank (Deutschland) AG	D
Degussa Bank GmbH	D	Landesbank Berlin AG	D	Westdeutsche Immobilienbank AG	D
Deka Bank Deutsche Girozentrale	D	Landesbank Hessen-Thüringen	D	WestLB AG	D
Deutsche Bank AG	D	Landesbank Saar	D	WGZ-Bank AG	D
Deutsche Postbank AG	D	Landwirtschaftliche Rentenbank	D		

Notes: This table reflects the list of participants as at the end of our sample, i.e. June 2012. For more details, please refer to www.eurexrepo.com.