

Mind the Gap: Disentangling Credit and Liquidity in Risk Spreads

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ABSTRACT

Widening interest rate spreads observed during the recent financial crisis could represent deteriorating liquidity or greater credit risk. I construct new microstructure measures of market liquidity and credit and find that market liquidity effects explain more than two-thirds of the widening of one- and three-month euro LIBOR-OIS spreads and of intra-euro-area sovereign debt spreads over the sample period, which covers the first half of the financial crisis. My new market liquidity measure uses the yield spread between bonds of differing liquidity that are all guaranteed by the German government; my new credit risk measure is an indicator of credit tiering in the interbank money market. Previous literature finds that risk spreads are largely attributable to default risk, but I ascribe this difference in results in part to omitting the effects of liquidity risk, which my new market liquidity measure captures. Additionally, I find evidence that liquidity risk, measured as the covariance of returns with market liquidity, is priced in fixed income markets.

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The 2007-2009 financial crisis was marked by an unusual widening of risk spreads and increased volatility in financial asset prices. One example is the spread between term interbank borrowing rates and overnight indexed swap (OIS) rates of comparable maturity. Euro LIBOR-OIS spreads rose from 4 basis points to more than 150 basis points in the fall of 2008 at the one- and three-month maturities, reaching their widest levels since the inception of the OIS market. Intra euro-area government bond yield spreads also widened dramatically. For instance, the ten-year Italian government bond yield spread over its German counterpart rose from 20 basis points in the summer of 2007 to a peak of over 160 basis points, reaching its highest level since the inception of the euro.

The rise in risk spreads could represent increased compensation demanded by risk-averse investors against the likelihood of default. Alternatively, it could represent a premium demanded by investors to induce them to hold comparatively illiquid assets. Decomposing interest rate spreads into default and market liquidity components is important for investors' portfolio allocation decisions—investors with the longest investment horizons should prefer to hold higher yielding assets if these elevated yields represent compensation for poor liquidity, but not if they represent a greater risk of default. Amihud and Mendelson (1986) and Longstaff (2005) both propose models with different types of investors, in which the longer-horizon investors hold less liquid assets and receive a premium for doing so. The default-versus-liquidity decomposition is also important for policymakers—if rising spreads primarily represent the effects of poor market liquidity, then policy actions to improve market functioning could help to dampen spread

widening. For example, an exchange of more liquid bonds for their less liquid counterparts via a securities lending facility could promote more orderly market functioning. On the other hand, if the widening largely represents a heightened risk of default, then only actions aimed at improving the solvency of the banks/governments in question will ultimately succeed.

This paper makes three contributions in decomposing risk spreads into liquidity and credit components. The first contribution is to construct new measures of market liquidity and credit. My new market liquidity measure is the yield spread between German federal government bonds and KfW (Kreditanstalt für Wiederaufbau) agency bonds. I construct this variable with high-frequency data from MTS, the largest euro-area electronic bond trading platform. KfW bonds are German agency bonds that are less liquid than their federal government counterparts, but that are also fully guaranteed against default by the German federal government and so have an identical risk profile. The yield spread between these two bonds is a pure measure of the German government bond market liquidity premium demanded by investors. *Market* liquidity, rather than *funding* liquidity (reflecting investor's or institution's demand for precautionary reserves) is considered in this paper.

My credit measure is a time-varying indicator of credit tiering, defined as the spread between actual unsecured interbank borrowing rates paid by banks that are good credit risks versus those that are bad credit risks. I construct this variable with high-frequency data from e-MID, an electronic interbank deposit trading platform that provides a unique identifier for the borrowing bank in each transaction. In unsecured interbank transactions, participants are exposed to the credit risk of their counterparty. In contrast, in asset markets, credit risk reflects

the creditworthiness of an asset's issuer rather than the trading counterparty. The e-MID platform is identity transparent in that participants have full information about all available borrowing and lending orders, and can choose to participate in any open order based on the combination of the rate posted and the counterparty's identity. So the fact that different banks pay different prices to borrow at the same point in time can only reflect differences in counterparty credit risk.

My second contribution is to use these credit and liquidity measures to explain interest rate spread widening and to provide empirical evidence for general equilibrium relations between asset market liquidity and money market rates. Over the sample, my credit and liquidity measures are nearly orthogonal to one another. Econometrically, this allows me to cleanly identify their separate effects on interest rate spreads. I find that both credit and liquidity effects are important in explaining the widening of money market spreads, but that my market liquidity measure explains a greater share. This result supports the idea that asset market liquidity directly affects money markets, providing empirical evidence for models such as Brunnermeier and Pedersen (2009) and Bolton, Santos, and Sheinkman (2010). My measure of market liquidity explains 68 percent of the widening of sovereign bond spreads over my sample period. The importance of liquidity in bond spreads is perhaps surprising because previous empirical work has generally found a much smaller role for liquidity (see for example, Beber, Brandt and Kavajecz (2006); Longstaff, Mithal and Neis (2005), McAndrews, Sarkar and Wang (2008), and Taylor and Williams (2009); discussed later in this paper).

My third contribution is to investigate the pricing of liquidity *risk* in bond markets. I construct a measure of liquidity risk, defined as the covariance between a bond's return and a measure of bond market liquidity, drawing on the theoretical models of Acharya and Pedersen (2005), and Pastor and Stambaugh (2003). Liquidity *risk* represents the possibility that liquidity will dry up in the future at exactly the time when investors' marginal utility is at its highest.² A bond could have low transactions costs today, but still have high liquidity risk. The latter channel is missed by traditional liquidity measures. I posit that my measures of credit and liquidity improve upon existing measures, which have found a lesser role for liquidity. Notably, my market liquidity measure reflects the cost of transacting today as well as compensation for the risk that transactions costs in less liquid markets may rise further in the future. Moreover, it is not contaminated by any effects from credit, and vice versa.

The plan for the remainder of this paper is as follows. In Section I, I introduce the datasets that I use to construct my new liquidity and credit measures and the particular interest rate spreads that I will parse into these two components. In Section II, I detail my construction of new liquidity and credit measures, and describe how they are distinct from one another. In Sections III and IV, I discuss the determinants of the interbank and sovereign debt market spreads, respectively. In Section V, I discuss the effect of liquidity risk on interest rate spreads. Section VI concludes.

² This is the risk that bid-ask spreads will rise due to factors such as the exit of market makers, an increase in risk aversion, or a higher ratio of informed to noise traders.

I. Data

A. *The e-MID Data*

To construct a new measure of private credit risk, I use unsecured interbank transaction data from the e-MID interbank trading platform.³ This platform is an electronic limit order book that allows banks to post offers (to borrow or lend) that other banks can then choose to accept. My dataset shows the rates on each individual e-MID transaction from January 1, 2007 through April 30, 2008, including the time stamp, currency, rate, maturity, volume, and codes identifying the banks posting/accepting the offer. There are 150 banks in the sample. The sample period spans the first half of the recent financial crisis period.

Two important features of the platform are, first, that the platform does not offset any counterparty credit risk, and second, that search costs are identical for all platform participants as each has access to all offers posted. The e-MID platform is identity-transparent; a participant can view offers posted by all other counterparties at any point in time, and knows the identity of its counterparty before agreeing to a trade. Trades are not necessarily executed in price-time priority. The counterparty to a limit order to borrow (a bank lending funds via a market order) knows precisely which counterparty it is dealing with, and can in principle perfectly price the risk of not being repaid.⁴ Thus, differing limit order borrowing rates that are transacted upon at the same point in time reflect the perceived credit differential between the two institutions alone.

³ MID is an acronym for Mercato Interbancario dei Depositi (Interbank Deposit Market). Transactions on this platform comprise roughly 20 percent of all unsecured euro-denominated interbank transactions.

⁴ Not surprisingly, given this trading structure, the vast majority of limit orders posted on e-MID are offers to borrow funds; 76 percent of lending in euros is conducted by market order rather than by limit order.

B. *The MTS Data*

To construct a new measure of market liquidity and intra-euro-area government bond spreads, I use data from the MTS bond trading platform.⁵ The MTS platform is a traditional electronic limit order book that allows dealers to post offers to buy or sell government securities that other dealers can then choose to accept. The counterparty's identity is not known until the transaction has been agreed to (this contrasts with the identity-transparent set-up of the e-MID platform).⁶ Also, these bonds are settled delivery versus payment.⁷ Thus, counterparty credit risk on the system is negligible. The bond issuer's default risk is the sole credit risk that should be reflected in prices. My dataset shows all MTS quotes and transactions prices from April 1, 2007 through March 30, 2008, along with their associated volumes. The data cover seven euro-area government debt markets: Belgium, France, Germany, Greece, Italy, Portugal, and Spain, and also German KfW agency bonds. I limit the sample to plain vanilla bonds with amounts outstanding greater than € billion that were issued within two years of the observation date. These bonds are denoted as "benchmark" bonds on the MTS system, and appeal to a broad investor base. I form three maturity buckets, which I refer to as the two-, five-, and ten-year maturities. Appendix I provides additional detail on the data that are used in this paper.

⁵ MTS is the largest inter-dealer platform for secondary market transactions in the European government bond market with an estimated 80 percent of electronic inter-dealer transactions (Euroweek special report, May 2007). MTS is an acronym for Mercato dei Titoli di Stato (Market for Government Bonds).

⁶ This makes the risk to selling via limit order or market order symmetric in the bond market. In fact, the data show that the share of limit orders to buy versus limit orders to sell is nearly equal.

⁷ In case of a failure to deliver, the worst case scenario is that the buyer will lose the bond's capital gain if the bond has appreciated between the time of purchase and settlement.

C. *Interest Rate Spreads*

I aim to parse two interest rate spreads into liquidity and credit risk components using my proposed measures of liquidity and credit: (1) LIBOR-OIS spreads, which reflect risk premia in interbank money markets, and (2) intra-euro-area government bond spreads.

Starting out with the money markets, the spread between LIBOR and overnight indexed swaps (OIS) should reflect an interbank credit and liquidity differential. LIBOR rates should typically be the average expected overnight interbank interest rate over the term of the loan, plus a term premium. However, as argued by Taylor and Williams (2009) and McAndrews, Sarkar and Wang (2008), the rate can be pushed up as the lender demands compensation for taking on default risk, due to poor market liquidity, or because of other factors, especially at times of market stress. An overnight indexed swap (OIS) rate reflects the expected average overnight rate over the term of the contract, plus a pure term premium, but default risk and liquidity premia in OIS are negligible (Brunnermeier, 2009).

A term LIBOR rate reflects the interbank credit risk of a loan for that term. The OIS rate, on the other hand, reflects a sequence of refreshed overnight bank credit risks (rather than term credit risk to a single counterparty as is reflect in a term LIBOR rate), as counterparties agree to exchange the difference between a fixed interest rate and the realized compounded overnight interbank rate on an agreed-upon notional principal.⁸ The EONIA rate to which the OIS contract is linked reflects the interbank credit risk of lending only overnight, no matter how long the term of the swap. Thus, the credit risk differential between term LIBOR and EONIA rates (thus OIS

⁸ The overnight index rate is EONIA (euro overnight index average).

rates) reflects an incremental term credit risk. The notional principal is not exchanged, the contract is collateralized, and only the offsetting fixed for floating rate payments are made at maturity of the contract. Credit exposure is only to the net interest payment, which is far smaller than the underlying notional amount. Likewise, the capital requirement for the purpose of banks' capital ratios on an OIS contract is based on the net interest payment, not the notional principal.

LIBOR has a liquidity component, but the liquidity component of the OIS rate should be negligible for a number of reasons. First, market liquidity premia in the cash bond market will drive LIBOR rates higher via the repo market, since unsecured funding is a close substitute to repo funding. OIS are not a proxy for repo funding and should only be affected by cash bond market liquidity to the extent that it affects the overnight unsecured funding rate. Also, an OIS is a derivative in net zero supply. As such, it is unclear which side of the transaction would demand a liquidity premium; the payer of the fixed rate or the receiver of the fixed rate. Empirically, the depth of the OIS market far exceeds that of the interbank cash market. According to a 2006 ECB money market study, a €20 billion transaction has a minimal price effect in the euro OIS market.⁹ In contrast, out of 154,115 unsecured funding transactions in my sample, the size of the largest term funding transaction is only €1 billion. The LIBOR- OIS spread has received considerable attention in the press and from policymakers since many private lending rates are tied to term interbank rates and so a widening spread means an

⁹ The ECB study also notes that the euro OIS market comprises roughly half the volume of all euro OTC derivatives (a much larger share than standard interest rate swaps).

effectively less accommodative stance of monetary policy.¹⁰ However, the relative magnitudes of the effects of credit and liquidity in the spread between LIBOR and OIS rates are unclear.

In the government bond market, I consider the *spread* of each country's sovereign bond yield relative to that of Germany, to control for the common component in euro-area government bond yields. The correlations of yield *levels* of euro-area government bonds rose around the time of monetary union and have been quite high since then (Ehrmann, Fratzscher, Gürkaynak and Swanson (2007)), largely due to the common piece of these yields that reflects the state of euro-area monetary policy. Widening euro-area government bond yield spreads sparked a debate during the crisis over whether investors were demanding compensation for the increased likelihood of default or withdrawal from the monetary union, or a liquidity premium for the decreased transactability in these markets, unrelated to default risk.

The large amount of variation in credit and liquidity captured over the crisis sample period means that the parameters are better identified than they would be using even longer samples of pre-crisis data. The top panel of *Figure 1* shows euro LIBOR-OIS spreads at one- and three-month maturities. These spreads rise sharply in August 2007 and exhibit great volatility thereafter. The bottom panel of *Figure 1* shows two sovereign yield spreads: the ten-year Spanish and Italian government bond yield spreads over German government bonds. Sovereign spreads did not widen as dramatically as the money market spreads at the onset of the

¹⁰ Swap rates, forward rate agreements, interest rate futures contracts, and many mortgage rates are tied to Euribor. Euribor is compiled by the European Banking Federation, whereas euro LIBOR is compiled by the British Bankers Association. Euribor and euro LIBOR are both survey rates of interbank unsecured euro lending, and are thus very closely linked. A TED spread (or a “euro TED” spread) can itself be decomposed into LIBOR-OIS and OIS-Treasury. The additional OIS-Treasury spread will vary due to Treasury market specialness, and so this effect is stripped out by using OIS as the benchmark.

credit crisis, but rose more notably in the spring of 2008. This may reflect a shift in the perceived credit risk from the interbank market around August 2007 to the sovereign markets as the economic downturn deepened and governments assumed more private bank obligations. The sample period saw several bank-specific recapitalizations, a number of which were funding injections by governments.¹¹ Beginning in August 2007, U.S. and European central banks took many operational measures to target general funding and market liquidity pressures.¹²

[Figure 1]

II. New Measures of Credit and Liquidity

In sub-Sections A and B, I describe the construction of my new measures of liquidity and credit, respectively, which will then be used to decompose LIBOR-OIS spreads and intra-euro area government bond spreads. The interaction between the liquidity and credit variables shows an extremely low correlation over my sample period, which I discuss in sub-Section C.

A. A Measure of Market Liquidity: KfW Spread

First, to form the liquidity measure, I compare two securities with identical credit profiles: German federal government bonds and KfW agency bonds. German federal government bonds are highly liquid benchmark euro-area securities, backed by the full faith and

¹¹ Some of the most widely cited events over the sample are the U.K. government's guarantee of all deposits of Northern Rock on September 18, 2007, German state-owned bank WestLB's €3 billion injection from the state of North Rhine Westphalia on February 8, 2008, the German government's €1.5 billion injection of funds to IKB Deutsche Industriebank on February 14, 2008, and the Federal Reserve-brokered purchase of Bear Stearns by J.P. Morgan on March 16, 2008 and its agreement to lend up to \$30 billion to cover losses.

¹² These measures include massive overnight funds injections, loosening the terms of standard funds injections (such as accepting a broader range of collateral), relaxing the terms of emergency lending facilities (such as widening the base of eligible counterparties), and introducing new dollar swap, term funds lending, and securities lending facilities. See Brunnermeier (2008) for a detailed account of liquidity and credit events over this period.

credit of the German government. Their less liquid counterparts are bonds issued by KfW, a German government-owned development bank, founded in 1948 with the initial aim of facilitating post-war reconstruction. The key feature of the KfW agency bonds, which my liquidity measure exploits, is that the German federal government *explicitly* guarantees all of KfW's current and future obligations.¹³ Also, there is no tax differential as Germany does not have a class of tax-exempt bonds such as in the U.S.

The yield spread between ordinary German government bonds and KfW bonds at specific maturities identifies the premium that investors are willing to pay for the comparative liquidity of the federal government bonds, distinct from any credit differential. *Figure 2* illustrates this yield spread divergence over the sample period. The KfW liquidity measure widens most substantially toward the end of the sample period, reaching a peak of nearly 60 basis points around the collapse of Bear Stearns in March 2008. Over the sample period the average spread of two-, five-, and ten-year KfW yields over their German federal counterparts are 16, 18, and 22 basis points, respectively. A hold-to-maturity investor should be willing to pay a larger liquidity risk premium for a long-horizon security than a short-horizon security, *ceteris paribus*.

[Figure 2]

¹³ The KfW website links directly to the law stating its explicit government guarantee in both English and German, "The Federal Government guarantees all of the obligations of the Institution in respect of loans extended to and debt securities issued by the Institution . . ." This contrasts with the frequently debated relationship between the U.S. Treasury and Fannie Mae or Freddie Mac (where no guarantee is explicit, even after they were placed under conservatorship of the Treasury in September 2008). If KfW fails to make any payment of principal or interest, the Federal Republic is liable for that payment as and when it becomes due and payable. The Federal Republic's obligation under this statutory guarantee ranks equally, without any preference, with all of its other present and future unsecured and unsubordinated indebtedness. German government bonds and KfW bonds are, however, not fungible; the securities are distinct. For instance, a KfW security may not be delivered into a federal government bond futures contract.

The KfW spread is a clean measure of liquidity—there is no question of any differential in credit risk. The KfW spread is also a comprehensive market liquidity measure in that the spread reflects compensation demanded by the investor for present and anticipated transactions costs and for the risk of liquidity deterioration – in fact it reflects anything outside of credit risk. This measure can model the effects of market liquidity in the interbank market more precisely than can traditional measures of liquidity such as the volumes or bid-ask spreads computed from interbank rates. Disagreement or uncertainty about credit risk in an asymmetric information environment such as the unsecured interbank deposit market, where the counterparty’s credit is what is effectively traded, may influence transactions prices and thus traditional measures of liquidity. In contrast, the sovereign debt market represents an environment in which there is negligible counterparty risk reflected in transactions prices that are agreed to before the identity of the counterparty is known.

The KfW liquidity measure draws from Longstaff (2004) who argued that the spread between Refcorp (Resolution Funding Corporation) and U.S. Treasury bonds is a measure of Treasury market liquidity. KfW bonds are less liquid than German federal government bonds, but the bonds are traded sufficiently such that high frequency observations are available, so this liquidity instrument can be used to estimate the liquidity components of other spreads. This application is motivated by the work of researchers such as Chordia, Sarkar, and Subrahmanyam (2005), who argue that common factors drive a large share of liquidity across stock and bond markets. In using the KfW spread to identify the impact of market liquidity on intra-euro-area

yield spreads and on money market risk spreads, I assume that it is proportional to the liquidity premium in these other markets.

1. Liquidity Measure Interpretation

Market liquidity seems to be the most natural interpretation of the spread between KfW bonds and their German federal government counterparts, since this is the only substantive difference between them. Indeed, two assets with identical cash flows in all states of the world could be priced differently due to differences in market liquidity. Standard market microstructure measures show empirical evidence that the KfW market is relatively less liquid.¹⁴ In part, the liquidity differential may owe to the active futures market for German two-, five-, and ten-year government bonds, enhancing the liquidity of the underlying cash market.¹⁵ Bond liquidity premia can also be due to the ease with which a security can be used as collateral in funding markets, and indeed repo funding rates are higher for KfW than for German federal government bonds. However, the causality of the relationship is not clear here—it seems natural to argue that the greater liquidity of federal government bonds causes the repo funding rate secured by this collateral to be lower (Brunnermeier and Pedersen, 2009). Repo specialness tends to occur in issues that are expected to be liquid. Nonetheless, while the KfW spread widens considerably over the sample, the repo differential stays relatively small.

¹⁴ Transaction volumes of federal bonds are six times as large as those of KfW bonds, and bid-ask spreads are three times as large in KfW bonds as compared to the federal bonds. Also, KfW is the 5th largest European debt issuer, after the governments of Germany, France, Italy, and the U.K.

¹⁵ No euro-area government bond markets (outside of Germany) have futures contracts associated with them. French, Italian, and Spanish futures contracts were initiated, but ceased trading due to lack of interest.

The KfW spread could be thought of more generally as reflecting any factors that prevent investors from exploiting what would be an arbitrage opportunity if the underlying assets were held to maturity. Investors might choose to leave these opportunities unexploited because they have short horizons and may be concerned that frictions (e.g. transactions costs, forced hedge fund liquidations, or irrational investor behavior) could make the mispricing even more extreme, as in the model of Shleifer and Vishny (1997). Arbitrageurs with limited capital may be reluctant to bet on an anomaly in pricing that may get worse before it gets better.

B. A Private Credit Measure

Now I construct a new measure of credit risk in the interbank funding market with e-MID money market transactions, which I later use to decompose one- and three-month LIBOR-OIS spreads.

1. Credit Measure Motivation

The levels of banks' credit risk premia are unobservable, but the dispersion in borrowing rates paid across banks, which is observable, should reflect credit risk tiering as it controls for the common component in rates (such as market-wide liquidity and the riskfree rate) that is unrelated to credit. To use credit tiering as a proxy for the overall level of credit risk, I assume that there is multiplicative relationship between the two. More formally, suppose that the *spread* between the interest rate that bank j has to pay on day t and the hypothetical risk-free interest rate is $b_j r_t$: b_j is a bank fixed effect and r_t is a time fixed effect. Normalize the average b_j to one and let

the cross-sectional dispersion (standard deviation) of b_j be θ . Then the average credit premium on any day is r_t and the dispersion of rates across banks on any day is θr_t . The average credit premium is proportional to the dispersion in rates. Thus credit tiering each day across institutions is a measure of average interbank credit risk.

The intuition behind the multiplicative relationship between the change in the overall credit quality and each bank's credit premium is similar to that of a structural credit model. As the default risk of good credit institutions worsens, that of poor credit institutions worsens proportionately more, and so an increase in the spread of rates paid between good and bad institutions measures a change in the average level of credit risk.¹⁶ For instance, the Merton (1974) model predicts that the credit risk premium is approximately proportional to volatility, and I treat dispersion as a proxy for volatility. A common shock to credit will have a greater effect on the risk-neutral likelihood of default for institutions close to the default boundary than those that are clearly solvent. In contrast, a shock to market-wide liquidity will have the same effect on all interbank rates, and so the dispersion will be left unchanged. Market liquidity is a market or asset-wide phenomenon, whereas credit differentials are ascribed to an individual or an institution.

One simple first-pass approach to measure the dispersion in rates is to compute the intradaily standard deviation of transacted overnight rates, which is shown in *Figure 3* along

¹⁶ A simple example illustrates the model's multiplicative assumption. Suppose $r_t = 1$ on a day with low credit risk and $r_t = 5$ on a day with high credit risk, and suppose $b_j = 0.5$ for the best credit bank and $b_j = 1.5$ for the worst credit bank. Then credit tiering on a good credit day would be $r_{low}b_{worst} - r_{low}b_{best} = 1$ and credit tiering on a bad credit day would be $r_{high}b_{worst} - r_{high}b_{best} = 5$.

with a time series of the number of transactions on each day on the e-MID platform. The dispersion of rates rises considerably following August 2007, despite a fairly stable number of transactions.¹⁷ A natural explanation for the rise in credit tiering is that the banks with highest perceived exposure to subprime mortgage-backed securities or other risky securitized products were perceived as weakening credit risks at this time, while other banks were not. However, intraday rate volatility could increase the intraday standard deviation even when rates paid by banks of different credit risk remain unchanged. So an ideal credit measure would reflect the difference in rates paid by the very best and the very worst credit institutions at each point in time. In the following section, I construct a credit measure that improves on the simple standard deviation approach.

[Figure 3]

2. Bank Credit Risk Premia Estimation

A priori, I cannot tell which banks are good/bad credit risks in order to calculate the dispersion across the quality of borrowers. I do have a unique identifier for each bank in the sample, but it is generic and does not reveal the bank's actual identity. Thus, I first estimate banks' credit quality, using all overnight limit order borrowing rates in the sample to run the following pooled regression:

¹⁷ ECB reserve maintenance period end dates are dropped; these have very high intraday standard deviation, but for reasons that are mainly due to banks' strategies for meeting reserve requirements. The total number of transactions is relatively low on four days in the sample: April 15, 2007 and April 15, 2008 (Independence Day – Italy), August 15, 2007 (Assumption Day), and November 1, 2007 (All Saints' Day).

$$r_{i,j,t} = \alpha + \sum_{t=1}^T \beta_{1,t} D_t + \sum_{j=1}^{n-1} \beta_{2,j} B_j + \varepsilon_{i,j,t} \quad (1)$$

where $r_{i,j,t}$ denotes the rate paid by borrower j in its i^{th} transaction on day t , D_t denotes the dummy for day t and B_j denotes the dummy for borrower j . *Limit order to borrow* rates alone reflect credit risk since the lending bank, which is exposed to counterparty risk, agrees to the rate knowing the identity of the borrower.¹⁸ Restricting my sample to these rates also avoids any bid-ask bounce effect since only one side of the quote is considered. The time dummy controls for any effect that is common to all rates, including market liquidity effects.¹⁹ The bank dummy coefficient, $\beta_{2,j}$, estimates the average credit quality of each institution.²⁰

Credit rationing among banks could influence interbank rates. The weakest banks may not be able to borrow from other banks at any rate and so could, in principle, drop out of the sample at the time of a financial crisis, biasing the measured interbank rates downwards. While this is possible, there are three reasons why it is likely to be a small effect. First, I consider only overnight borrowing. Credit rationing is presumably much less severe at the overnight maturity than for longer terms. Second, credit rationing would most likely take the form of the borrowing

¹⁸ There is no way to insure against the default of interbank deposits. In principal, a CDS contract could be entered into each day with the counterparty's debt as the reference obligation, but transactions costs would be prohibitive. In practice, these loans are not resold. Novation requests, or third party risk assumption for a transaction, occurred during the crisis. But, this was motivated by risk reduction of outstanding obligations, not to insure new transactions.

¹⁹ Controlling for the day effect in equation (1) is important as the overall level of rates changed over the sample – in fact, the ECB raised its policy rate by 25 basis points on March 14 and June 13, 2007. Another way to isolate the credit component of overnight rates is to subtract the daily GC repo rate from the left-hand side of Equation (1). However, this approach confounds the credit component with repo market seasonality.

²⁰ The range of these estimates is 0.26; the average rate paid by the best banks is 26 basis points below the average rate paid by the worst banks. The mean and median values of the bank coefficient dummies are -3.03 and -3.04, respectively, indicating little skew in the distribution.

limit of a bank being reduced rather than that bank being shut out of borrowing altogether. Finally, even at the worst point of the financial crisis, very few banks drop out of the sample.

3. Credit Tiering Measure Construction

To form my daily measure of credit tiering, I first group banks into credit deciles according to their $\beta_{2,j}$ coefficient estimates; the highest coefficient estimates represent the banks that on average paid the highest rates, interpreted as banks perceived to be the worst credit risks.²¹ Then, on each day, I compute the average borrowing rate paid within each decile. My time-varying measure of credit tiering is the difference between the average rate paid by the banks in the highest decile on day t , $\bar{r}_{t,H}$, and that paid by banks in the lowest decile, $\bar{r}_{t,L}$.

$$credit_t = \bar{r}_{t,H} - \bar{r}_{t,L}$$

Figure 4 shows a time series of the e-MID credit tiering measure in overnight funding markets. Credit tiering was highest in August 2007 and rose again around the year-turn. It might seem surprising that credit tiering peaked so early in the financial crisis. The ECB began large-scale special banking operations at the start of the crisis that may have helped to restore the perceived creditworthiness of the worst credit institutions, although of course raising moral hazard concerns.

[Figure 4]

²¹ The cross-sectional ranking of banks is fixed over the sample. The deciles are each of equal size by number of limit order borrowing transactions, to ensure that transactions represent each decile on each day, but the total number of transactions in each bin may vary. The number of banks in each decile ranges from 10 to 25.

To check whether my proposed credit measure identifies the difference between rates paid by good and bad credit institutions, I consider the propensity to borrow via limit order versus market order for different credit categories. On the e-MID system, the bank's identity is shown to participants along side of the posted rate for a limit order, and the decision to transact is based on this information. Particularly good credit banks should want to borrow via limit order, so that their identity is factored into the counterparty's decision to lend at a particular rate; the lending bank will know that that the borrower is low risk and will thus agree to a relatively low rate. It turns out that 93 percent of borrowing by banks in the best credit decile is conducted via a limit order whereas only 47 percent of borrowing by banks in the lowest credit decile is conducted via limit order. This suggests that the grouping of banks by decile has indeed separated the good credit risk banks from the bad credit risk banks.

C. Market Liquidity and Credit as Distinct Variables

The two variables of primary concern in this paper are market liquidity and credit risk, which are measured distinctly from one another; the liquidity variable includes no credit effects and the credit variable does not reflect any market liquidity effects. It is not a necessary condition that credit and liquidity are entirely uncorrelated, but that there are shocks to credit that do not affect liquidity and vice versa. For example, a reduction in the number of trading counterparties might affect liquidity but not credit, and news about the likelihood of default of an issuer might affect credit but not liquidity. The identifying assumption is that the interest rate spreads, the credit tiering measure, and the KfW spread are all driven by two (possibly

correlated) factors, "credit" and "liquidity," such that the loading of credit tiering on liquidity is zero and the loading of the KfW spread on credit is zero.

The sample-period correlation between my measured indicators of liquidity and credit is 0.07. The absence of multicollinearity between these credit and liquidity measures in this sample gives me the necessary power to identify the largely separate and indeed orthogonal components of interest rate spreads. Some events over the sample period likely affected both credit and liquidity, and at first glance, it may seem surprising that there is not a strong positive correlation between the two. However, it is reasonable to believe that European banks' perceived creditworthiness actually improved in the fall of 2007 and early 2008 as governments insured banks' private obligations, while poor market functioning continued to plague bond and money markets. It is possible that *shocks* to credit and liquidity are correlated while the *levels* of the two remain uncorrelated. For instance, one variable could recover more quickly to shocks than the other. Indeed, over an earlier sample period, Beber, Brandt and Kavajecz (2006) found a negative relationship between measures of credit and liquidity.

Market liquidity is the concept of liquidity that I measure in this paper—the premium demanded for buying or selling a large volume of an asset, such as a government bond, with immediacy. The market liquidity of an asset is quite separate from the default risk of the issuer. A different concept of liquidity is *funding* liquidity: an institution's precautionary demand for term funding so as to have liquid assets on its balance sheet. However, in interbank funding markets, the precautionary demand for funding is closely tied to banks' creditworthiness. Credit and *funding* liquidity are particularly hard to disentangle and I do not attempt to do so; my

measure of private credit risk incorporates both default risk and associated funding liquidity in the interbank market.

III. The Determinants of LIBOR-OIS Spreads

I now use my new measures of credit and market liquidity to explain movements in money market and sovereign debt spreads. First, in the interbank term funding market, my empirical strategy is to regress one- and three-month LIBOR-OIS spreads onto the credit and market liquidity measures detailed above. I consider time-series regressions of the form

$$Spread_t = \alpha + \beta_1 credit_t + \beta_2 (KFW_t - yield_{t,DE}) + \varepsilon_t \quad (2)$$

run at the daily frequency where $Spread_t$ denotes the LIBOR-OIS spread on day t , $credit_t$ is the interbank credit-tiering variable on that day as defined from Equation (1) and $KFW_t - yield_{t,DE}$ is the average KfW spread as a measure of market liquidity.²² A separate regression is run for the one- and three-month LIBOR-OIS spreads.

The results for both the univariate and bivariate cases of equation (2) are shown on the left side of *Table I*. The credit tiering measure is positive and highly statistically significant, with or without controlling for liquidity. The liquidity measure is also significant, and indeed even more so. A one percentage point increase in credit dispersion (meaning that on a given day the best decile banks pay 100 basis points less than the worst decile banks) leads to a 95 basis

²² One transmission mechanism which links asset markets to funding markets is the repo market, where bonds are used as collateral in cash borrowing transactions. Any maturity of bond can be submitted as general collateral, and so I use a simple average of the two-year, five-year, and ten-year yields to proxy the effect of bond market liquidity on funding markets. The results are virtually identical when using the two-year, five-year, and ten-year spreads since these series are nearly proportional to one another.

point increase in the one-month LIBOR-OIS spread and a 132 basis point increase in the three-month LIBOR-OIS spread. A one percentage point increase in the KfW spread accounts for a 99 basis point increase in the one-month LIBOR-OIS spread and a 203 basis point increase in the three-month LIBOR-OIS spread. The R-squared values are 0.47 and 0.69 in the one-and three-month bivariate regressions, indicating that these two variables alone explain a substantial share of LIBOR-OIS spreads.²³ Of the 77 basis point increase in three-month LIBOR-OIS spread over my sample period, 53 basis points can be explained by liquidity. The average level of the three-month LIBOR-OIS spread is 39 basis points over my sample. The fitted value using the mean KfW spread shows that liquidity explains 81 percent of that spread's level.

Interest rate spreads must be stationary in very long samples, but in this short sample, the spreads do show persistence. In equation (3), the Durbin Watson statistic is 1.42 for the 1-month maturity and 0.83 for the three-month maturity, rejecting the null of no serial correlation in the error, but not showing extreme persistence. Nonetheless, to address the possibility that the results in levels reflect a spurious relationship between highly persistent variables, the regression is also run with variables and spreads that have been first differenced. The right side of *Table I* shows these results. The liquidity variable remains significantly positive in all cases, but the estimates are less precise than in levels, which is not surprising as differencing lowers the signal-to-noise ratio.

[Table I]

²³ The credit or liquidity measures could contain some classical measurement error and the unexplained component of the LIBOR-OIS spread could reflect omitted credit and/or liquidity effects. But, that would bias my coefficient estimates toward zero, meaning the true effects are even larger. Augmenting the regression with quadratic and cubic terms of both KfW and credit variables showed neither the quadratic nor cubic terms were significant.

Credit tiering explains a large amount of the widening of LIBOR-OIS spreads, but there is a separate and even larger effect for deteriorating market liquidity. The top panel of *Figure 5* shows the fitted share of the one-month LIBOR-OIS spread owing to liquidity, and the middle panel shows the effect of liquidity and credit jointly. This suggests that interbank credit risk explains most of the LIBOR-OIS spread around August 2007, at the beginning of the crisis, but that a more gradual deterioration in market liquidity and the risk of future market illiquidity surpassed the contribution of credit to spread widening by the end of the sample period.

[Figure 5]

The middle panel of *Figure 5* also shows that while credit and liquidity variables together explain much of the variation in the LIBOR-OIS spread, they do not capture the spike in this spread at the end of 2007. The discrete 62 basis point jump in the one-month LIBOR-OIS spread occurs on November 29, 2007, the first date on which a one-month deposit contract matures after the year end. The precise timing of this jump in the one-month spread (which is not evident in the three-month spread) suggests that interbank borrowers were willing to pay an extra premium to secure funds over the year turn for window dressing purposes. To control for this seasonal effect, I add a dummy to the time series regression in equation (2):

$$Spread_t = \alpha + \beta_1 credit_t + \beta_2 (KFW_t - yield_{t,DE}) + YE_t + \varepsilon_t \quad (3)$$

where YE_t is a dummy variable which is one for the days in which the one- and three- month contracts cover the year-end and is zero otherwise. The results are shown in *Table I*; the year-end effect, liquidity, and credit together explain nearly all of the variation in LIBOR-OIS

spreads. The bottom panel of *Figure 5* shows the fitted share of the one-month LIBOR-OIS spread owing to liquidity, credit, and the year-end effect.

Consider an extreme hypothetical counterfactual scenario in which all bonds are been made equally liquid. The KfW spread would then be zero (below its level even before August 2007). Judging from my regression results, this would lead the one- and three-month LIBOR-OIS spreads to be narrower at the end of April 2008 by 35 and 71 basis points respectively, and therefore quite close to the levels at which the spreads stood at the beginning of the sample period. Measures to improve market liquidity could narrow spreads independent of any credit effect.

A. *Other Analysis*

1. Lying About LIBOR?

One factor that could contribute to the unexplained share of results for equation (2) is the mismatch between LIBOR survey rates and rates from actual market transactions. The interbank credit tiering measure which is used to decompose the LIBOR-OIS spread is computed from transacted prices. LIBOR rates, on the other hand, are indicative rates collected by the BBA (British Bankers Association). The LIBOR survey is comprised of self-reported borrowing rates from 18 banks. These rates are not anonymous. As a result, the quoted rates may understate true

borrowing costs if banks understate their true unsecured borrowing costs to improve the perception of their creditworthiness to others.²⁴

A useful feature of the e-MID data is that it provides actual transactions rates on overnight and term borrowing (though the majority of e-MID transactions are at the overnight maturity). I calculate the average of euro transacted rates at overnight, one month, and three month maturities, where a proposal to borrow funds was accepted (for comparability with the LIBOR definition) over the period since August 1, 2007.²⁵ As shown in *Table II*, the average e-MID rate was only two, seven, and five basis points above the same-day LIBOR rate at the overnight, one-month and three-month maturities, respectively, over the recent period of financial market turmoil. It appears that at most LIBOR is only modestly understating true borrowing costs. Before August 1, 2007, the comparable spreads (also shown in *Table II*) were narrower, and thus the incentive to misreport may be lower when there is less dispersion in borrowing rates.

[Table II]

2. *Parameter Constancy*

To check whether the coefficient estimates are stable over the sample, I conduct a Chow test for a break on August 1, 2007, which seems a natural candidate break date since it is at the

²⁴ As a result of these concerns, ICAP set up an alternative anonymous survey rate called the New York Funding Rate (NYFR). Initially, NYFR was very close to LIBOR, consistent with my results, although the spread between these two rates widened sharply in August 2008, after my sample period ended.

²⁵ Euribor survey rates are taken from 43 banks at present, a broader set than euro LIBOR. Both of these are offer rates, but there is a difference in the survey questions. The Euribor survey requests that banks submit the rate at which other prime banks are likely able to borrow. In contrast, the LIBOR survey requests that banks submit the rate at which the contributing bank expects to borrow.

onset of the financial crisis. I reject the null of parameter constancy. The coefficient estimates for the period following August 1, 2007 are close to those for the entire sample period, while the coefficient estimates in the first part of the sample are not significantly different from zero. This may be explained in that the period before August 2007 was a short sample period with little variation in the right-hand-side variables, while the subsequent period had substantial variation in the explanatory variables. Most identification in parameter estimates is drawn from the latter part of the sample during the crisis period.

3. Comparison with Other Studies

I ascribe the importance of liquidity in interest rate spreads in my results in part to the fact that my liquidity measure captures the pricing of liquidity risk (which is explicitly tested in Section V). Also, my credit and liquidity measures are particularly clean measures that are distinct from the effects of one another. There is no credit differential whatsoever between KfW securities and German federal government bonds, and so the spread between these two should capture anything outside of credit, including liquidity risk. The interbank credit measure is identified entirely within the unsecured interbank market, on a platform where transactions are identical outside of the creditworthiness of the borrower. In contrast, credit risk measures employed by other researchers, such as the repo-LIBOR spread, are constructed with interest rates from two different markets. They could therefore be contaminated by factors specific to one of those two markets, such as changes in the supply of repo collateral.

I find that market liquidity accounts for more than half of the explained variance of spread levels in euro-denominated LIBOR-OIS spreads. Using roughly the same sample period, Taylor and Williams argue that credit explains most of the variation in dollar-denominated LIBOR-OIS spreads (dollar and euro money market spreads moved together closely over this period). Michaud and Upper (2008) find a significant role for liquidity in explaining money market spreads, but they use the bid-ask spreads on e-MID deposits as a measure of liquidity. It is difficult to disentangle counterparty credit risk from the bid-ask spread measured with e-MID transactions. On this platform, a counterparty's identity is known before a borrowing rate is agreed to and so the rate demanded will partly reflect the perceived likelihood of repayment. A study that has findings closer to mine is McAndrews, Sarkar and Wang (2008) who focus on liquidity risk and the extent to which measures taken by the Federal Reserve have reduced liquidity risk. They decompose LIBOR into its credit and liquidity components, estimating the credit component from bank CDS prices and recovery rates, and find that there is a substantial and time-varying liquidity component in LIBOR-OIS spreads.

Table III shows the correlation between my new measures of credit and liquidity with measures used by Taylor and Williams, and Michaud and Upper. The credit indicator that is most closely correlated (at 0.51) with my new credit dispersion measure is the yen LIBOR minus TIBOR spread. Taylor and Williams argue that this spread reflects credit because the Japanese banks were relatively unaffected by the financial market turmoil. It is indeed conceptually similar to my measure, since it is also a measure of credit tiering, which identifies the banks on the TIBOR panel as good credit risks and those on the LIBOR panel as bad. Transaction volume

is the traditional liquidity variable most closely correlated with the KfW spread, at 0.69, though this variable is related to credit quality as better quality banks transact in larger sizes. Indeed, most of the traditional liquidity indicators are more highly correlated with my proposed credit measure, as none of them is entirely distinct from the effects of credit. For instance, the interbank bid-ask spread, which in large part reflects the borrowing banks' credit risk, has a correlation of 0.9 with my credit tiering measure.

[Table III]

IV. The Determinants of Euro-area Sovereign Spreads

To parse the spreads of various euro-area government bond markets into liquidity and credit components, I measure liquidity with the KfW spread and I use sovereign CDS spreads as a proxy for sovereign default risk.

I decompose intra euro-area spreads by running a time series regression for each country-maturity pair as follows:

$$yield_{i,t} - yield_{DE,t} = \alpha_i + \beta_{1,t}(KfW_t - yield_{DE,t}) + \beta_{2,t}(CDS_{i,t} - CDS_{DE,t}) + \varepsilon_{i,t} \quad (4)$$

where $KfW_t - yield_{DE,t}$ is the yield spread of a KfW bond at the two-, five-, and ten-year maturities over the comparable-maturity German federal government yield, and $CDS_{i,t}$ is the comparable-maturity CDS spread on bond i at time t measuring the risk of sovereign default, after controlling for liquidity. Any effect of counterparty credit risk in CDS spreads should be differenced out since the spreads are all relative to German CDS spreads. The subscript DE

denotes Germany.²⁶ The coefficients β_1 and β_2 represent the effects of liquidity and credit, respectively. Note that separate coefficients are estimated for each country and each maturity.

I start with univariate regressions, nested versions of equation (4), first showing the effects of liquidity alone and then credit alone on euro-area sovereign yield spreads. Coefficient estimates reflecting only the effects of liquidity are shown on the left side of Panel A in *Table IV*. They are significant and positive for all 18 country-maturity pairs—as the KfW spread widens and liquidity deteriorates, yield spreads among euro-area sovereign bonds widen too. The economic magnitude of the coefficient estimates is quite large. The Italian-over-German ten-year spread coefficient shows that a one percentage point widening of the KfW spread implies a 104 basis point widening in the Italian-over-German sovereign spread. The coefficient estimates increase in maturity, ranging from a low of 0.21 for France at the two-year maturity to a high of 1.06 for Greece at the ten-year maturity, similar to the pattern across maturities found by Beber, Brandt and Kavajecz (2006) for traditional liquidity measures. The effect of CDS spreads alone on euro-area government spreads is shown on the right side of Panel A in *Table IV*. As expected, the coefficient estimates on CDS spreads are also positive and significant. Arbitrage arguments posit that movements in CDS spreads are proportional to movements in yield spreads, and thus CDS are explaining most of the variation in spreads by construction. However, the range of coefficient estimates, from 0.41 to 2.02, with R-squared values as low as 0.19, show that the relationship is far from perfect.

²⁶ Since the German yield is included in both sides of the regression, measurement error in German yields would increase the correlation. This should be a minimal concern, however, since German government bonds are the most liquid securities in the euro area and I am averaging across bonds which should reduce measurement error further.

[Table IV]

The multivariate results of equation (4) (*Panel B of Table IV*) show a striking breakdown in the relative contribution of credit versus liquidity on interest rate spreads over the sample period. The Italian-German ten-year spread widened by 30 basis points during the sample. Judging from the coefficient estimates in Panel B of *Table IV*, only 4 basis points of this is explained by worsening credit, while 26 basis points is explained by deteriorating liquidity. Over my sample, the average level of the Italian-German ten-year spread is 25 basis points. The fitted value using the mean KfW spread shows that liquidity explains 87 percent of the average level of this sovereign spread. The decomposition of other spread changes is similar, and on average across maturity-country pairs, liquidity contributes 68 percent of spread widening over my sample and 77 percent of the average level of spreads. In this sense, it appears that the priced odds of a credit event for euro-area governments has not varied significantly over this period. Perhaps this is due to a belief that the European Monetary Union would intervene to prevent a member's default or withdrawal.

Coefficient estimates in the multivariate case show that market liquidity continues to have a significant and positive relationship with intra-euro-area sovereign spreads, even after controlling for sovereign credit risk, in 17 out of 18 cases. Italian and Greek spreads show the most sensitivity to changes in the KfW spread across maturities, with coefficient estimates ranging from 0.5 to 0.9. The estimates of the coefficients on CDS spreads in this equation are generally significant and positive at the two- and five-year maturity. However, at the ten-year maturity, CDS spreads have no significant effect on sovereign bond spreads for four of the six

countries considered. For Greece, Italy and Portugal, the coefficients on CDS spreads are larger and more significant at short maturities than at longer maturities. These sovereign spreads were apparently particularly sensitive to news about the likelihood of default in the near term. Thus, while both liquidity and credit are collinear, and both appear to be related to sovereign bond spreads, liquidity has the stronger relationship to sovereign bond spreads, in that liquidity is more consistently significant. Also, the R-squared values in the univariate regression with only credit as a regressor are generally lower than those in the univariate regression with liquidity as the only regressor. And, these are in turn not far below the R-squared values from the multivariate regression, which range from 0.55 to 0.92.

V. Liquidity as a Risk Factor versus Liquidity as a Characteristic

A. *Liquidity as a Risk Factor*

The effect of liquidity on asset prices can take different forms. Investors may demand a premium for holding bonds that are less liquid at present, as considered in Amihud and Mendelson (1986), to compensate them for higher transactions costs, or they may demand a premium for the *risk* that bonds will become less liquid in the future. One form of liquidity risk that Acharya and Pederson (2005) and Vayanos (2004) argue might be important is the compensation that investors demand to hold a bond that has a low return at a time when liquidity is poor. If a measure of liquidity fails to capture the pricing of liquidity risk, then the importance of liquidity as a determinant in the widening of interest rate spreads may be understated. Traditional liquidity measures such as bid-ask spreads only measure transactions costs, and do

not capture liquidity risk. In order to investigate the pricing of liquidity risk in interest rate spreads, I adopt a two-step Fama MacBeth procedure to estimate the liquidity risk premium in the sovereign bond market.

In the first step, I define the following time-varying liquidity beta with a different time series regression for each country-maturity pair:

$$r_{i,t} - r_{DE,t} = \alpha_{i,t} + \beta_{i,t} \Delta(KfW_t - yield_{DE,t}) + \varepsilon_{i,t} \quad (5)$$

where $\Delta x_{i,t} = x_{i,t} - x_{i,t-1}$, $r_{i,t}$ denotes the return on holding the i th bond on day t , approximated as minus the yield change times the duration. As in the previous equations, the DE subscript refers to Germany and the KfW liquidity measure, $KfW_t - yield_{DE,t}$, measures bond market liquidity. The estimated betas identify the market liquidity *risk* for each country-maturity pair and how it changes over time. Intuitively, an investor would find an asset particularly risky if its relative returns were low at a time when benchmark bond liquidity also dried up. I estimate these betas at a daily frequency using a 60-day rolling average of returns and changes in liquidity.

In the second step, I run a pooled time-series and cross-sectional regression:

$$yield_{i,t} - yield_{DE,t} = \gamma_0 + \gamma_1 \beta_{i,t} + \gamma_2 (liq_{i,t} - liq_{DE,t}) + \gamma_3 (CDS_{i,t} - CDS_{DE,t}) + \varepsilon_{i,t} \quad (6)$$

where $\beta_{i,t}$ is the time-varying liquidity beta defined in equation (5) and $CDS_{i,t}$ is the sovereign CDS spread in country i at time t . The liquidity index for a benchmark bond in country i at time t , $liq_{i,t}$, combines bid-ask spreads and market depth and is defined in Appendix I. In this regression, γ_1 gives the market price of liquidity risk while γ_2 is the direct effect of liquidity on

yields.²⁷ Thus, the coefficients γ_1 and γ_2 can be thought of as liquidity entering as a factor and as a characteristic, respectively, in the terminology of Daniel and Titman (1997).²⁸ This regression is pooled across countries because the liquidity and credit variables are country specific (the credit tiering measure, which did not appear to be a significant determinant of spreads, is not included). A separate regression is run for each maturity category.

The addition of liquidity as a factor explains a larger share of euro-area sovereign bond spreads than does liquidity as a characteristic alone. The R-squared values for univariate regressions with only liquidity as a factor on the right-hand side (nested versions of Equation (6)) range from 0.12 to 0.22, shown in *Table V*. The coefficient estimate on the liquidity factor is negative and significant at the two- and five-year maturities, at -0.31 and -0.02, respectively, once controlling for the effects of credit and liquidity as a characteristic, though it is not significant at the ten-year maturity. A negative coefficient is consistent with the premium demanded by investors for the *risk* that bonds will become less liquid in the future—an asset with a high liquidity beta has a relatively high return when KfW liquidity deteriorates and is a good hedge because liquidity improves in bad times. Accordingly investors are willing to accept a lower yield to induce them to hold this bond. The coefficient estimates for liquidity and credit, γ_2 and γ_3 , are significant in all cases, indicating that liquidity is important as a characteristic as well. Less liquid assets should command a higher return, in equilibrium, as compensation for higher transactions costs, consistent with a negative coefficient on the liquidity index, γ_2 . The

²⁷ Returns could equivalently be put on the left-hand side of equation (6).

²⁸ The KfW spread cannot be used as a characteristic because it does not vary across countries.

magnitude of the coefficients on credit imply that a one percentage point increase in CDS spreads leads to a 53 to 80 basis point increase in yields, depending on the maturity.

[Table V]

The KfW spread is a more comprehensive measure of the effects of market liquidity than the more conventional measures of liquidity since it does not just reflect transactions costs or market depth, but the total effect of liquidity on prices. *Table VI* shows a cross-correlation matrix for the new and traditional liquidity and credit measures, including the liquidity beta. As might be expected, at the 2-year maturity, the sector where the effect of liquidity risk is strongest, the liquidity beta shows the strongest correlation with the KfW spread, at 0.39. Both of these measures reflect liquidity risk; a higher KfW spread represents deteriorating liquidity/high liquidity risk while a positive liquidity beta represents an asset that is a good hedge against this risk. The correlation between the liquidity beta and traditional measures of liquidity is quite low, ranging from 0.17 for the bid-ask spread to -0.09 for cumulative depth. This is also not surprising since the traditional liquidity measures do not capture the effects of liquidity risk.

[Table VI]

B. *Methodology or Sample Period?*

The result that sovereign yield spreads are driven primarily by market liquidity, contrasts with the findings of previous research. Beber, Brandt, and Kavajecz, using an earlier sample period from 2003 to 2004, found that market liquidity explains only 11 percent of the variance in sovereign spreads, although the share explained by liquidity is roughly twice as big in periods of

high uncertainty. Longstaff, Mithal and Neis (2005), also using traditional liquidity measures, find that corporate bond spreads are largely attributable to the default component. In contrast, I find that the KfW liquidity measure explains most of the variation in sovereign yield spreads.

This begs the question as to whether the difference in results stems from the use of a new liquidity measure or from a difference in the sample period. My sample period covers the first half of the financial crisis, whereas Beber, Brandt, and Kavajecz and Longstaff, Mithal and Neis use earlier sample periods. To disentangle these effects, I use the data over my sample period to run the same decomposition as in Equation (4), but now using the same liquidity measure as Beber, Brandt, and Kavajecz. Specifically, I run the following pooled regression on daily data:

$$yield_{i,t} - yield_{DE,t} = \alpha + \gamma_1(liq_{i,t} - liq_{DE,t}) + \gamma_2(CDS_{i,t} - CDS_{DE,t}) + \varepsilon_{i,t} \quad (7)$$

where $CDS_{i,t}$ is the sovereign CDS spread in country i at time t and, $liq_{i,t}$ is defined as the liquidity index (market depth divided by the bid-ask spread) for country i at time t . The regression is pooled across days and countries. A separate regression is run for each maturity bin.

The results of estimating Equation (7) are shown in *Table VII*, and can be compared to results for Equation (4), shown in Panel B of *Table IV*. Over my sample period, the traditional measure of liquidity had a much smaller role in euro-area yield spread widening than the KfW measure. Averaging across maturities and countries, the traditional liquidity measure explains only an average of 26 percent of the spread levels, compared with 77 percent when using the

KfW measure. This strongly suggests that the larger role for liquidity appears to stem from the methodology and not the sample period.

[Table VII]

C. *Feedback between Liquidity Risk and Credit Risk*

In a general equilibrium framework, shocks to bond market liquidity could affect not just bond yields but also money market spreads and funding market liquidity. Even though the levels of my credit and liquidity measures are only weakly correlated, the innovations may show a stronger correlation. One key intermediary in this relationship is the repo market. Poor liquidity in the bond market leads to increased haircuts in the repo funding market, as less liquid collateral is less valuable to the lenders in case of default. Higher effective repo rates raise the demand for term funding in the unsecured interbank market, since unsecured lending is a close substitute for secured lending. In turn, higher repo market haircuts make it more difficult for bond market traders to finance their positions, which can cause bond market liquidity to deteriorate, in an adverse feedback loop. Brunnermeier and Pedersen (2009) present a formal general equilibrium model of such feedback between market and funding liquidity.

To empirically investigate whether market liquidity Granger-causes credit risk, and vice-versa, I estimate a vector autoregression (VAR) of order one in the two-day averages of the KfW spread (as a measure of market liquidity) and the interbank credit tiering measure (reflecting funding and credit risk). The estimated VAR is:

$$\begin{pmatrix} \text{liq}_t \\ \text{credit}_t \end{pmatrix} = \mu + \Phi \begin{pmatrix} \text{liq}_{t-1} \\ \text{credit}_{t-1} \end{pmatrix} + \varepsilon_t$$

where liq_t and credit_t denote the KfW spread and interbank credit tiering measure, respectively. Results are shown in *Table VIII*. The lag of liquidity is significant and positive in the equation for credit. However, the lag of the credit measure is not significant in the equation for liquidity. Thus, I find Granger causality going from market liquidity to credit risk, though not vice versa. This result indicates that measures to stem spikes in market illiquidity may succeed in dampening otherwise heightened funding/credit crunches, and further motivates the use of bond market liquidity to explain interbank interest rate spreads.

[Table VIII]

VI. Conclusions

Beginning in August 2007, interest rate spreads across markets widened sharply, threatening the stability of the financial system and of the broader economy. There are two primary factors behind these movements: (1) a higher likelihood of default, and (2) deterioration in market liquidity, separate from default risk. Determining which component plays the larger role is important for policymakers and investors. If the chief component is default risk, only actions to improve the solvency of the issuer are likely to be successful. Whereas if the main driver is market liquidity, measures to improve market functioning are most appropriate.

Using microstructure datasets to construct new measures of both credit and liquidity, I decompose term LIBOR-OIS spreads and euro-area sovereign bond spreads into default risk and market liquidity components. The correlation between these new measures of credit and

liquidity, at 0.07, is remarkably low over this sample period, making it possible to disentangle their effects on interest rate spreads. The new liquidity measure is the spread between bonds issued by a German government agency, KfW (Kreditanstalt für Wiederaufbau), and their federal government counterparts. The beauty of this spread is that the two bonds being compared have identical credit risk but different liquidity. The new credit measure is the dispersion in rates paid between the best and the worst credit risk banks. This credit tiering measure is unaffected by any market-wide liquidity effects; also its identification stems entirely from within the interbank deposit market.

I find that both credit and liquidity effects are important in explaining the widening of spreads. However, I find that market liquidity can explain much more of the spread widening in the interbank market than other researchers, such as Taylor and Williams (2009), have concluded, and that it can explain more of the spread widening in the sovereign bond market than found by Beber, Brandt and Kavajecz (2006). Using a measure of bond market liquidity to decompose money market spreads, I also provide new empirical evidence for the general equilibrium relationship between these two markets. Over my sample period, the three-month LIBOR-OIS spread rose by 77 basis points, and I find that 53 basis points of which were due to liquidity. Similarly, for the Italy-Germany ten-year sovereign bond spread decomposition, I find that liquidity explains 26 of the 30 basis points of widening in that spread. The reason why I find a much larger effect of liquidity than others have shown is that my measure of liquidity does not just capture transactions costs, but also the pricing of liquidity risk—the compensation that

investors demand for the possibility that liquidity will worsen in the future at a time when they most want to transact.

These results have implications for policymakers and for the portfolio choices of investors. In particular, since I find that market liquidity explains a large share of the rising spreads, it means that measures to improve market functioning could be effective in bringing down risk spreads. This can help to avoid the risk of an adverse feedback loop between the liquidity of asset markets and the liquidity of funding markets, and in turn the state of the economy.

Appendix 1: Data

e-MID Interbank Platform and Transactions

Unsecured interbank market transactions are conducted over the counter, and can occur as a principal-to-principal transaction or via a broker. The e-MID euro interbank trading platform was founded by the Italian government in 1990, and was privatized and opened to international members in 1999. In 2001, e-MID also began to conduct dollar-denominated transactions, though they comprise a much smaller share of the platform's trading volume. Transactions range from overnight to one year in maturity. Over my sample period, overnight transactions account for 89 percent of the total. The average daily transaction volume for overnight euro loans is €18.8 billion. Trading on this platform occurs from 7:00 a.m. until 6:30 p.m. CET.

The e-MID funding market platform gives participants access to liquidity of more than one counterparty at a time, as a third-party broker, but does not offset any counterparty risk. An offer, once accepted, is binding on both parties subject to credit limits not being breached. The risks to lending via limit and market orders are asymmetric. A bank can post an offer to lend funds (i.e. a limit order to lend funds), but there is little control over the counterparty that accepts that transaction. A bank may place a limit order to lend if it cannot immediately place a market order to lend, due to a lack of outstanding limit orders to borrow. Banks set counterparty credit limits, which can rule out or limit transactions with a set of participants. However, it is not possible to offer to lend to good quality banks at one rate and to poor quality banks at a higher rate. The fraction of lending in euros conducted by market order rather than by limit order is almost unchanged from the period before August 2007 to the period since, suggesting that perhaps only the worst banks lend via limit order.

MTS Government Bond Data

European government bond market transactions are conducted over the counter, similar to the U.S. Treasury market. The MTS bond trading platform was first introduced by the Italian government to promote secondary market trading in Italian government securities. In 1997, MTS was privatized, and has since expanded its range of assets to include all euro-area governments plus some quasi- and non-government issues. MTS trading occurs from 8:00 a.m.

until 5:30 p.m. CET. Minimum trade sizes are €2.5 million for automatic matching, though smaller odd lots are accepted at the dealer's discretion. The MTS platform differentiates between dealers and primary dealers in the system. The former can only hit bids or offers, while the latter are required to make a minimum number of two-way quotes in order to maintain their primary dealer status in the system. See Cheung, De Jong and Rindi (2005) for more detail on the MTS platform.

I first construct daily data for the sovereign bond market, by taking the average of MTS bid and ask quotes for each bond on each day. Daily averages instead of end-of-day prices are taken to reduce the effect of end-of-day price volatility. I calculate the yield to maturity for each bond. Bond prices are "clean" and exclude accrued interest, but I take accrued interest into account when computing the yield to maturity. On each day, I then sort the bonds into buckets by time to maturity and country, and compute the average yield for each country-maturity pair. The time-to-maturity buckets are 1.5 to 2.5 years, 4.5 to 5.5 years and 9.5 to 10.5 years, which I refer to as two-, five-, and ten-year yields, respectively. The euro-area government yield curves are sufficiently flat that yield differences among different bonds within each maturity bin are very small for each country. The mean ranges for all bond yields in the two-, five-, and ten-year bins (averaging across all countries and days) are 2.3, 1.4, and 0.9 basis points, respectively.

Sovereign CDS Data

CDS spreads are treated as a measure of the credit default component of government bond yields and are used to explain the effect of sovereign credit on intra-euro-area government bond yields. While there is typically little movement in these spreads, the CDS spread of non-German countries over Germany widened out by as much as 55 basis points over this sample period. Variation in default risk premia for even a very small likelihood of a credit event may be quite large over a period when overall risk aversion is variable and heightened.

Sovereign CDS (credit default swap) spreads are available at two-, five- and ten-year maturities, at a daily frequency, from Lehman Live for Belgium, France, Germany, Greece, Italy, Portugal, and Spain. A CDS is a contract where the buyer of credit protection makes periodic fixed payments as a percent of the notional value of the reference obligation to the seller of protection, in principle to insure the value of a long position in the underlying security. In exchange, if there is a credit event, such as government default, the seller of protection is

obligated to purchase the government bonds from the buyer at face value. Change in the currency of the debt (presumably departure from the euro area is more likely than explicit default) is treated as a credit event. The premium is paid either until the maturity of the contract, or until the credit event occurs, whichever is sooner. As such, a CDS contract is a bet on the creditworthiness of the issuer of the underlying security.

Theoretically, buying (for instance) an Italian bond, a long Italian CDS position, and a short German CDS position should be equivalent to buying the German bond (Duffie, 1999), meaning that the CDS are redundant securities and mechanically reflect *all* the determinants of bond yields, not just the credit risk. However, there are several factors that complicate the theoretical arbitrage relationship between bonds and CDS spreads. As argued by Longstaff, Pan, Pedersen and Singleton (2007) or Longstaff, Mithal and Neis (2005), the theoretical relationship could fail to hold because of transactions costs, tax effects, counterparty credit risk, or the specific bonds that could be delivered in fulfillment of the CDS contract in the event of default. The greater liquidity of the CDS market may make this a more natural means of betting on default.

Traditional Measures of Market Liquidity

For comparison with the existing literature, I compute more traditional measures of market liquidity in the sovereign bond market as controls. MTS bond data show the best three bid and ask quotes and associated volumes that are posted for each security. Let bid_1 , bid_2 , and bid_3 denote the best three bids. Similar notation is used for the asks and the associated quote volumes. The first three measures of market liquidity use the best bid and ask quotes (the most competitive prices posted to buy or sell) and the market depth (the total quantity available for purchase or sale) at the most competitive prices. I construct two additional liquidity measures that reflect the entire spectrum of quotes. The five liquidity measures are as follows: (a) percentage bid-ask spread (in price terms), (b) average quoted depth, (c) the Bollen Whaley (1998) liquidity index, (d) cumulative limit order depth, and (e) a cumulative liquidity index.

These measures are defined as:

Percentage Bid-Ask Spread:
$$\left[\frac{ask_1 - bid_1}{(ask_1 + bid_1)/2} \right] \times 100$$

Average quoted depth:
$$\frac{(bid_1 - vol + ask_1 - vol)}{2}$$

Liquidity index:
$$\frac{(bid_1 - vol + ask_1 - vol)}{20} \div \left[\frac{ask_1 - bid_1}{(ask_1 + bid_1)/2} \right]^{29}$$

Cumulative quoted depth:
$$\frac{(\sum_{i=1}^3 bid_i - vol + \sum_{i=1}^3 ask_i - vol)}{2}$$

Cumulative liquidity index:
$$\sum_{i=1}^3 \left\{ \frac{(bid_i - vol + ask_i - vol)}{20} \times \frac{ask_i - bid_i}{(ask_i + bid_i)/2} \right\} \times \frac{1}{3}$$

For the first measure, a higher percentage bid-ask spread means poorer liquidity, whereas in measures (b) through (e), a higher value means improved liquidity. The bid-ask spread only takes account of the cost of transacting immediately in an arbitrarily small size; the other measures all have the advantage of taking some account of the quantity that can be transacted at that price and/or the other prices available for larger trade sizes.³⁰ Since the liquidity index incorporates both market depth and the bid-ask spread, it can be thought of as a composite measure of immediate market liquidity.

Table A-1 shows summary sample statistics for sovereign liquidity and credit measures and yields by country and maturity. The country-specific measures are all quoted as spreads over Germany, since German assets are widely perceived as benchmark euro-area assets with the best quality of liquidity and credit. The table shows that German bonds have the lowest yield levels and CDS spreads across maturities. For example, German bond yields are on average 7 to 25 basis points below their Italian counterparts, depending on maturity. German bonds also

²⁹ The liquidity index and the cumulative liquidity index measures are scaled down, as shown, for readability in results.

³⁰ Another alternative liquidity measure not considered here is the price impact of order flow (see, for example, Brandt and Kavajecz (2004)). One difficulty with this is in disentangling whether it measures liquidity or private information.

show the narrowest bid-ask spreads of any country in the sample (3, 4, and 6 basis points in the two-, five-, and ten-year maturities, respectively), although there is a higher level of market depth for some other countries, notably in the 2-year maturity category. Some researchers have used market depth scaled by the bid-ask spread as a measure of market liquidity to describe both of these effects, but even this measure will not capture liquidity risk, which is reflected in the liquidity beta.

[Table A-1]

Liquidity, as measured by any of the liquidity variables, is generally best for the shorter maturity bonds. This seems reasonable, since short duration bonds have lower volatility than long duration bonds. Any adverse-selection component of the bid-ask spread reflecting private information about the state of the economy would be smaller for short duration bonds in models such as that of Glosten and Milgrom (1985). This pattern of smaller spreads for short duration bonds was also found by Fleming (1997) in U.S. GovPX data. Market depth measures are likely most affected by the amount of debt outstanding at a given maturity. Governments tend to issue most heavily in relatively short maturity securities, thus providing the largest pool of liquidity at short maturities, which could ostensibly improve any of the liquidity variables shown.

There are large changes in intra-euro-area sovereign yield spreads and credit and liquidity variables over the sample period. Yield spreads of bonds issued by countries with the weakest fiscal positions (Belgium, Italy, Greece and Portugal) rose the most over this period; there is substantial variation across countries in terms of credit ratings from AAA (Germany, Spain, and France) down to A in Greece, as rated by S&P. The sovereign ratings for countries in this study did not change during the sample period, but the perceived risk of default or withdrawal from the euro area at some point over the life of a long-term bond may have increased for some countries over this period (credit ratings are typically lagging indicators). Indeed in 2009 and 2010, S&P downgraded its sovereign ratings for Greece, Portugal, Spain, Italy, and Ireland. A qualifying criterion for entry into the European Monetary Union is that a candidate member has a debt-to-GDP ratio that does not exceed 60 percent. At the end of 2007, Italy, Greece, and Belgium significantly exceeded this threshold at 104 percent, 95 percent, and 85 percent, respectively, compared to Germany at 65 percent and Spain at 36 percent, according to Eurostat. Such statistics had been widely circulated in the markets, fueling the idea that existing euro-area memberships could potentially be reevaluated.

At the time, it may have seemed unreasonable to believe that the probability of a credit event by a euro-area government was substantial. However, CDS prices and bond yields reflect the risk-neutral probabilities of default assigned by risk-averse investors. These could be significantly larger than the physical probability of a credit event, especially during a time of extreme risk aversion such as the credit crisis. Moreover, few people thought the probability of a credit event by Fannie Mae or Freddie Mac was substantial until nearly the time at which it happened.

Appendix 2: Robustness Checks

Credit Measure Checks

Overnight credit as a proxy for short-term credit risk

Since the vast majority of e-MID transactions are overnight, credit tiering in the overnight funding market is much more precisely measured. Using overnight rates to form my credit measure assumes that credit dispersion across banks at one- and three-month borrowing horizons is monotonic in the overnight credit dispersion; when overnight credit tiering is unusually high, it is also high at longer maturities. The partitioning of banks into those that are good versus bad credit risks should be very similar across different horizons of borrowing; a bank that is considered a relatively poor credit risk in the overnight market would surely be considered a relatively poor credit risk for a term loan as well.

To check my assumption that term transactions exhibit a similar pattern of credit tiering to overnight transactions, I compute a measure of credit tiering for one-month maturity transactions. My data for maturities beyond overnight are relatively sparse, but they are sufficient to split one-month transactions into two bins for each day (rather than ten as is done with overnight transactions): one bin for the transactions of better credit banks and one for worse credit banks. First, I apply the bank coefficient estimates from equation (1) (formed with overnight transactions) to one-month transactions. Then, I compute average rates for each bin on each day, and I subtract the rate of the worse credit half from the rate of the better credit half. *Figure A- 1* shows that a measure of credit tiering at the one-month maturity exhibits a very similar pattern to credit tiering of overnight transactions, supporting the argument that credit tiering in term rates is monotonic to that of overnight rates. The number of one-month transactions on each day is very low, but *Figure A- 1* also shows that both the top half and bottom half banks continue to transact throughout the sample period.

Table A- II shows a breakdown of the total volume and number of transactions for each credit quality/maturity pair. Bins one through five are ranked from best to worst credit. The data show that the best credit institutions tend to transact in larger sizes at the overnight horizon. Also, the data indicate that the best credit institutions tend to fund themselves at shorter horizons, perhaps indicating that the availability of term funding is scarce and commands a large premium.

Only those institutions that are worried about the ability to roll over short-term positions are willing to pay this large premium.

[Table A- II]

Sample Selection in Limit Orders to Borrow

In considering only limit orders to borrow, the very worst banks may indeed not be represented in the sample. A good credit bank has an incentive to reveal its identity and borrow via a limit order, whereas a less good credit bank may want to confound its identity by borrowing via market order. It is possible that the credit tiering measure effectively captures the spread between say the 1st and the 8th decile of credit quality rather than the 1st and the 10th decile. So, the measure relies on the assumption that the spread between various deciles is proportional. *Table A- III* shows the correlations of spreads between the average daily rate paid across various credit deciles. The high correlations, ranging from 0.92 to 0.95 indicate that it is reasonable to assume proportionality among credit tiering measures formed from different deciles.

[Table A- III]

Time-of-day Effect

The inclusion of a time-of-day control in equation (1), constructed as a dummy for each hour of the trading day, is included as a robustness check, but does not materially change the coefficient estimates. Time of day is itself a function of credit risk; less creditworthy banks tend to transact earlier in the day since they are closer to funding constraints to start, and thus wish to ensure their funding requirements are satisfied.³¹ The correlation between the credit tiering measure and the intradaily standard deviation of rates is quite high at 0.89, and the difference between these measures should reflect the relatively greater precision of the credit tiering measure. The credit tiering measure should not be contaminated by intraday rate volatility for banks of a given credit quality. The credit tiering measure increases only when good and bad credit banks are borrowing at more widely disparate rates at the same time.

³¹ As an aside, my measure of credit tiering is high on ECB reserve maintenance period end dates. As in the U.S., the last day of a maintenance period can have high volatility. For instance, on March 13, 2007, rates started the day at 3.52 and bottomed at 2.50 between 3:00 and 5:00 p.m., before finishing the session at 3 percent. Poor credit banks may be relatively small; they may wish to meet their reserve obligations early and may thus over borrow. In the afternoon of the final day of the maintenance period, only the best credit banks will be borrowing and they will be doing so at low interest rates because the demand for funds is low. Accordingly, the measure of credit tiering is elevated on these days.

Stability in Cross-Sectional Ranking of Bank Quality

To check whether the estimated credit quality of banks is stable, I re-estimate equation (1) in two separate sub-samples: before and after August 1, 2007. Then, I assign each bank to a bin for each sub-sample. The correlation between the bin rankings of the banks in the two groups is 0.78, indicating a high degree of stability in my measure of banks' relative creditworthiness. *Figure 4* shows the number of daily transactions for the best credit bin and for the worst credit bin. The proportion of transactions by the best versus the worst banks does not vary substantially over time, and neither type of bank drops out of the distribution altogether. In fact, the number of transactions in the worst decile increases in periods of high credit tiering, arguing against a sample selection scenario in which the worst credit banks are unable to obtain any funding and thus drop out of the sample.

Trade Size and Volume

The e-MID interbank dataset includes trade sizes and volumes, but I do not use them either as a measure of liquidity or of credit, since they incorporate both liquidity and credit effects and are therefore not a pure measure of either variable. The best credit banks tend to transact in larger sizes, but less frequently, while the worst credit banks tend to transact in smaller sizes, but more often. It follows that the very worst credit banks likely transact in the very smallest sizes. A credit tiering measure formed by weighted-average rates would lead to an understatement of the degree of credit tiering by putting more weight on better credit banks.

Liquidity Measure Checks

Investor Base Bias

The similarity in the investor base for KfW agency issues relative to German federal government issues makes it very unlikely that the identified liquidity premium in fact represents a type of home bias or segmented investor base, or even a difference in balance-sheet driven demand. The KfW agency maintains a regular cycle of "benchmark" maturity debt auctions, similar to the German government but smaller in size. The agency actively markets its bond issues as "government substitutes," and shows a broad international investor base. As an example, only 10 percent of a €5 billion ten-year benchmark bond, issued in 2008, was placed in Germany. In fact, KfW maintains the fourth highest volume of debt issuance in the euro area (after Germany, France, and Italy). Distribution by investor type for the ten-year benchmark

issue was also varied, being comprised of: banks (39%), funds (33%), central banks (19%), and insurance companies (9%). Nevertheless, there was a large difference in total issuance scheduled for 2008—€70 billion for KfW versus €13 billion for the German federal government. Furthermore, neither KfW nor German federal bonds require an institution to hold any reserves to compensate for a risk of capital loss under Basel II.

German Asset Liquidity as a Broader Liquidity Measure

To check the assumption that the KfW measure of liquidity is not simply a premium for more liquid German government bonds but is rather a broad measure of market liquidity, I compute the correlation between the KfW average yield spread and the ten-year on-the-run U.S. Treasury premium. This measure of U.S. Treasury market liquidity is the spread between the ten-year on-the-run yield and the synthetic yield on the security implied from a smoothed yield curve fitted to off-the-run securities (computed by the Federal Reserve System). This is a fairly strong test, as these spreads refer to different markets and are denominated in different currencies, and it is reasonable to believe that the measure denominated in the same currency as the spread will perform best, all else being equal. Nonetheless, the correlation between these two liquidity spreads is 0.90, providing evidence for the commonality of liquidity across markets and supporting the interpretation of the KfW spread as a comprehensive measure of market liquidity.

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Table I

Determinants of Term Euro LIBOR-OIS Spreads

Maturity	<i>Levels</i>					<i>Changes</i>					
		Constant	Credit	KfW	YE	R ²		Constant	Credit	KfW	R ²
<i>1-Month</i>	(1)	0.12 (0.03)	1.10 (0.25)			0.22	(1)	0.01 (0.03)	0.28 (0.29)		0.02
	(2)	-0.02 (0.03)		1.07 (0.21)		0.31	(2)	0.02 (0.03)		0.59 (0.32)	0.03
	(3)	-0.06 (0.02)	0.95 (0.19)	0.99 (0.16)		0.47	(3)	0.02 (0.03)	0.29 (0.28)	0.65 (0.30)	0.05
	(4)	-0.04 (0.02)	0.55 (0.22)	0.88 (0.10)	0.50 (0.08)	0.80	(4)	0.02 (0.02)	0.35 (0.25)	0.52 (0.26)	0.06
<i>3-Month</i>	(1)	0.25 (0.05)	1.63 (0.29)			0.21	(1)	0.02 (0.02)	0.33 (0.15)		0.07
	(2)	-0.05 (0.06)		2.14 (0.31)		0.55	(2)	0.03 (0.02)		0.71 (0.26)	0.09
	(3)	-0.11 (0.05)	1.32 (0.19)	2.03 (0.26)		0.69	(3)	0.03 (0.02)	0.35 (0.12)	0.78 (0.27)	0.17
	(4)	-0.14 (0.03)	1.01 (0.17)	1.97 (0.19)	0.29 (0.04)	0.84	(4)	0.03 (0.02)	0.38 (0.11)	0.73 (0.27)	0.18

Notes: This Table shows the results from regressions of one- and three-month LIBOR-OIS spreads onto the measure of credit tiering (from e-MID), the KfW spread, and a year-end dummy for the sample period from January 2007 through April 2008. A separate regression is run for the one-month and the three-month maturities. Bolded coefficients are significant at the 5 percent level. Newey West standard errors with lag length 10 are used. Standard errors are in brackets beneath estimates. The LHS reports results in levels. The RHS reports the results in changes.

Table II

e-MID minus LIBOR rates before and after August 1, 2007

	<i>Pre</i>			<i>Post</i>		
	O/N	1M	3M	O/N	1M	3M
Mean	0.00	0.01	0.01	0.02	0.07	0.05
Std Dev	0.02	0.02	0.01	0.06	0.06	0.06
n	148	126	82	191	135	121

Notes: Mean spread in percentage points of e-MID overnight, one-month, and three-month over comparable maturity LIBOR overnight, one-month, and three-month rates. Left side shows sample mean and standard deviation from January 1, 2007 through July 31, 2007. Right side shows sample mean and standard deviation from August 1, 2007 through April 29, 2008.

Table III

Correlation Matrix of Liquidity and Credit Variables in the Interbank Market

<i>Classification:</i>	New Credit	New Liq	Credit	Credit	Credit	Credit	Credit	Credit	Liq	Liq	Liq	Liq
	Interbank Credit	Ave KfW Spread	3M Libor-Repo Spd	5Y Panel Bank CDS	5Y Citi CDS	5Y BoA CDS	3M Libor-Tibor	3M DPCP-ABCP	Interbank bid-ask	Interbank trade no.	Interbank volume	Interbank order flow
Interbank Credit	1	0.07	0.48	0.09	0.06	0.07	0.51	-0.27	0.90	-0.33	0.21	0.61
Ave KfW Spread	0.07	1	0.72	0.95	0.93	0.93	0.47	0.40	0.14	0.11	0.69	0.27
3M Libor-Repo	0.48	0.72	1	0.63	0.61	0.63	0.79	0.12	0.50	-0.02	0.66	0.44
5Y Bank CDS	0.09	0.95	0.63	1	0.99	0.98	0.41	0.52	0.11	0.22	0.64	0.17
5Y Citi CDS	0.06	0.93	0.61	0.99	1	0.98	0.38	0.53	0.07	0.24	0.63	0.16
5Y BoA CDS	0.07	0.93	0.63	0.98	0.98	1	0.39	0.53	0.09	0.22	0.65	0.16
3M Libor-Tibor	0.51	0.47	0.79	0.41	0.38	0.39	1	-0.06	0.49	-0.14	0.47	0.57
3M DPCP-ABCP	-0.27	0.40	0.12	0.52	0.53	0.53	-0.06	1	-0.33	0.29	0.31	-0.18
Interbank bid-ask	0.90	0.14	0.50	0.11	0.07	0.09	0.49	-0.33	1	-0.28	0.23	0.53
Interbank trades	-0.33	0.11	-0.02	0.22	0.24	0.22	-0.14	0.29	-0.28	1	0.36	-0.12
Interbank volume	0.21	0.69	0.66	0.64	0.63	0.65	0.47	0.31	0.23	0.36	1	0.36
Interbank order flw	0.61	0.27	0.44	0.17	0.16	0.16	0.57	-0.18	0.53	-0.12	0.36	1

Notes: This Table reports correlation coefficient estimates for the new private credit tiering measure and the new KfW liquidity measure, as well as several measures of interbank credit and liquidity used by other researchers: (1) the spread of three-month euro LIBOR over three-month GC repo, (2) a simple average of 5-year euro-denominated CDS spreads from 15 of the euro LIBOR panel banks, (3) 5-year euro-denominated Citibank CDS spreads, (4) 5-year euro-denominated Bank of America CDS spreads, (5) three-month LIBOR over three-month TIBOR (Tokyo interbank offer rate) yen borrowing rates, (6) three-month dollar-denominated dealer-placed commercial paper over three-month asset-backed commercial paper rates, (7) bid-ask spreads computed from euro overnight interbank borrowing rates, (8) the frequency of overnight interbank transactions, (9) euro overnight interbank transaction volume, and (10) the price impact of net orders to borrow in the euro overnight interbank market. Taylor and Williams (2008) use dollar-denominated measures, but the euro-denominated versions are used for the correlation matrix, where they are available. A higher value for each variable indicates “deteriorating” liquidity or credit. “Classification” indicates whether the variable proxies for credit or liquidity

Table IV

Panel A

Univariate Time Series Regressions of Sovereign Bond Yield Spread onto KfW Spread, CDS Spread, and Private Credit

	Country	KfW Only			CDS Only		
		Intercept	KfW Sprd	R ²	Intercept	Sov Credit	R ²
2-Year	Belgium	-0.03 (0.00)	0.39 (0.02)	0.71	0.02 (0.01)	0.70 (0.09)	0.57
	Spain	-0.01 (0.01)	0.24 (0.05)	0.31	0.00 (0.01)	0.41 (0.06)	0.54
	France	0.00 (0.00)	0.21 (0.02)	0.55	0.03 (0.01)	0.84 (0.21)	0.19
	Greece	0.02 (0.01)	0.79 (0.05)	0.84	0.11 (0.01)	0.45 (0.07)	0.68
	Italy	-0.06 (0.01)	0.75 (0.04)	0.83	0.00 (0.01)	0.92 (0.11)	0.71
	Portugal	-0.01 (0.01)	0.61 (0.07)	0.70	0.04 (0.01)	0.84 (0.10)	0.78
5-Year	Belgium	-0.03 (0.01)	0.71 (0.05)	0.85	0.05 (0.01)	1.08 (0.16)	0.76
	Spain	-0.02 (0.01)	0.54 0.04	0.82	0.03 (0.00)	0.54 0.04	0.82
	France	-0.03 (0.00)	0.44 (0.03)	0.85	0.04 (0.01)	2.02 (0.43)	0.60
	Greece	-0.04 (0.02)	1.39 (0.14)	0.85	0.10 (0.01)	0.84 (0.12)	0.84
	Italy	-0.07 (0.01)	1.08 (0.10)	0.86	0.04 (0.02)	0.86 (0.15)	0.72
	Portugal	-0.02 (0.01)	0.73 (0.10)	0.74	0.04 (0.01)	0.67 (0.13)	0.70
10-Year	Belgium	-0.05 (0.01)	0.91 (0.04)	0.86	0.09 (0.01)	1.02 (0.16)	0.73
	Spain	-0.07 (0.01)	0.93 (0.06)	0.85	0.04 (0.01)	0.77 (0.06)	0.88
	France	-0.01 (0.01)	0.45 (0.04)	0.69	0.07 (0.01)	1.68 (0.37)	0.51
	Greece	0.09 (0.02)	1.06 (0.10)	0.85	0.22 (0.02)	0.53 (0.11)	0.69
	Italy	0.02 (0.02)	1.04 (0.08)	0.83	0.12 (0.02)	0.69 (0.14)	0.67
	Portugal	0.04 (0.02)	0.91 (0.08)	0.82	0.14 (0.02)	0.69 (0.13)	0.68

Panel B

Multivariate Time Series Regressions of Sovereign Bond Yield Spread onto KfW Spread and CDS Spread

Country	Intercept	KfW Sprd	Sov Credit	R ²
Belgium	-0.02 (0.00)	0.29 (0.04)	0.29 (0.08)	0.75
Spain	0.00 (0.01)	-0.01 (0.07)	0.42 (0.08)	0.55
France	0.00 (0.00)	0.21 (0.04)	-0.05 (0.27)	0.55
Greece	0.04 (0.01)	0.58 (0.05)	0.18 (0.04)	0.89
Italy	-0.05 (0.00)	0.52 (0.04)	0.40 (0.06)	0.89
Portugal	0.02 0.01	0.24 (0.08)	0.58 (0.10)	0.81
Belgium	-0.02 (0.00)	0.51 (0.04)	0.38 (0.11)	0.88
Spain	0.00 (0.01)	0.29 (0.06)	0.28 (0.06)	0.87
France	-0.02 (0.00)	0.36 (0.03)	0.57 (0.24)	0.88
Greece	0.01 (0.01)	0.81 (0.10)	0.43 (0.08)	0.92
Italy	-0.05 (0.01)	0.82 (0.09)	0.29 (0.08)	0.89
Portugal	0.00 (0.01)	0.49 (0.10)	0.27 (0.15)	0.77
Belgium	-0.02 (0.01)	0.70 (0.06)	0.30 (0.11)	0.88
Spain	-0.02 (0.01)	0.43 (0.07)	0.46 (0.06)	0.92
France	0.00 (0.01)	0.40 (0.05)	0.24 (0.27)	0.69
Greece	0.10 (0.02)	0.90 (0.11)	0.11 (0.08)	0.86
Italy	0.03 (0.01)	0.87 (0.08)	0.15 (0.10)	0.84
Portugal	0.05 (0.01)	0.80 (0.10)	0.12 (0.12)	0.83

Notes: Panel A of this Table reports coefficient estimates for two sets of univariate time series regressions of country yield spreads over Germany onto: (1) the KfW liquidity measure, and (2) country CDS spreads over German CDS spreads. Panel B of this Table reports coefficient estimates of the time series regressions of country yield spreads onto the KfW liquidity measure and country CDS spreads jointly. Separate regressions are run for each country-maturity pair. Bolded coefficients are significant at the 5 percent level. Newey West standard errors are used with lag length 10. Standard errors are in brackets beneath estimates.

Table V

**Pooled Regressions of Sovereign Bond Yield Spreads
on Liquidity Beta, Liquidity Index, and CDS Spread**

Maturity		Intercept	Liquidity Beta	Liquidity Index	Sovereign Credit	R ²
2-Year	(1)	0.05 (0.003)	-0.60 (0.034)			0.22
	(2)	0.10 (0.005)	-0.51 (0.025)	-0.04 (0.003)		0.34
	(3)	0.03 (0.002)	-0.31 (0.019)	-0.02 (0.001)	0.53 (0.02)	0.63
5-Year	(1)	0.11 (0.004)	-0.24 (0.031)			0.12
	(2)	0.20 (0.008)	-0.21 (0.022)	-0.12 (0.010)		0.34
	(3)	0.05 (0.003)	-0.02 (0.012)	-0.02 (0.004)	0.77 (0.03)	0.70
10-Year	(1)	0.24 (0.031)	0.04 (0.004)			0.16
	(2)	0.30 (0.012)	0.04 (0.006)	-0.13 (0.022)		0.28
	(3)	0.13 (0.005)	0.01 (0.005)	0.06 (0.017)	0.80 (0.03)	0.73

Notes:

This Table reports the results of a pooled regression (over countries and time) of sovereign yield spreads onto the rolling estimate of the liquidity beta (from equation (5)), the liquidity index, and the CDS spread. Since the liquidity beta is a rolling estimate, the sample period used in this regression is shorter than the full sample period used in Table V. A separate regression is run for the two-, five-, and ten-year maturities. Bolded coefficients are significant at the 5 percent level. Time-clustered standard errors are used. Standard errors are in brackets beneath estimates.

Table VI

Correlation Matrix of Liquidity and Credit Variables in the Government Bond Market

<i>Classification:</i>	Credit	Liquidity	Liquidity	Liquidity	Liquidity	Liquidity	Liquidity	Liquidity	Credit	
	New Private Credit	New Liquidity	New Liquidity Factor	Liquidity Index	Average Depth	Cum. Depth	Percent Bid-Ask Spread	Cum. Liquidity Index	Sovereign CDS Spread	
				<i>2-Year</i>						
Private Credit	1	0.07	-0.10	0.06	0.00	-0.09	-0.03	-0.05	-0.03	
KfW Spread	0.07	1	0.39	0.30	0.15	-0.01	0.46	0.10	0.68	
Liquidity Beta	-0.10	0.39	1	0.10	-0.03	-0.09	0.17	0.06	0.32	
Liquidity Index	0.06	0.30	0.10	1	0.87	0.69	0.22	0.85	0.14	
Ave. Depth	0.00	0.15	-0.03	0.87	1	0.78	0.16	0.75	0.03	
Cum. Depth	-0.09	-0.01	-0.09	0.69	0.78	1	0.18	0.88	-0.11	
Bid-ask Spread	-0.03	0.46	0.17	0.22	0.16	0.18	1	0.21	0.37	
Cum. Liq. Index	-0.05	0.10	0.06	0.85	0.75	0.88	0.21	1	-0.01	
Sovereign CDS	-0.03	0.68	0.32	0.14	0.03	-0.11	0.37	-0.01	1	
				<i>5-Year</i>						
Private Credit	1	0.07	-0.17	-0.10	-0.15	-0.12	-0.01	-0.08	-0.04	
KfW Spread	0.07	1	0.17	0.11	-0.06	0.07	0.24	-0.02	0.70	
Liquidity Beta	-0.17	0.17	1	0.03	0.02	0.07	0.10	0.03	0.38	
Liquidity Index	-0.10	0.11	0.03	1	0.82	0.50	0.09	0.06	0.04	
Ave. Depth	-0.15	-0.06	0.02	0.82	1	0.56	0.02	0.04	-0.13	
Cum. Depth	-0.12	0.07	0.07	0.50	0.56	1	0.12	0.04	-0.14	
Bid-ask Spread	-0.01	0.24	0.10	0.09	0.02	0.12	1	0.01	0.21	
Cum. Liq. Index	-0.08	-0.02	0.03	0.06	0.04	0.04	0.01	1	-0.04	
Sovereign CDS	-0.04	0.70	0.38	0.04	-0.13	-0.14	0.21	-0.04	1	
				<i>10-Year</i>						
Private Credit	1	0.07	0.17	0.09	0.20	0.17	-0.15	0.18	-0.08	
KfW Spread	0.07	1	-0.38	0.08	-0.06	-0.23	0.21	0.01	0.67	
Liquidity Beta	0.17	-0.38	1	-0.05	0.46	0.61	0.02	0.24	-0.42	
Liquidity Index	0.09	0.08	-0.05	1	0.72	0.52	0.22	0.67	0.17	
Ave. Depth	0.20	-0.06	0.46	0.72	1	0.84	0.09	0.60	-0.17	
Cum. Depth	0.17	-0.23	0.61	0.52	0.84	1	0.05	0.71	-0.28	
Bid-ask Spread	-0.15	0.21	0.02	0.22	0.09	0.05	1	0.15	0.26	
Cum. Liq. Index	0.18	0.01	0.24	0.67	0.60	0.71	0.15	1	0.00	
Sovereign CDS	-0.08	0.67	-0.42	0.17	-0.17	-0.28	0.26	0.00	1	

Notes: For two-, five-, and ten-year maturities, this Table reports the correlation (across countries and time periods) among the new private credit tiering measure, the new KfW liquidity measure, and the new liquidity beta (from equation (5)), as well as several measures of euro-area sovereign bond market credit and liquidity used in previous research, defined in Appendix 1. A higher value for each variable indicates a “deterioration” in liquidity or credit. “Classification” indicates whether the variable proxies for credit or liquidity.

Table VII**Pooled Regressions of Sovereign Yield Spread
onto Liquidity Index and CDS Spread**

Maturity	Liquidity		CDS	R ²
	Intercept	Index	Spread	
<i>2-Year</i>	0.04 (0.001)	-0.02 (0.001)	0.60 (0.02)	0.60
<i>5-Year</i>	0.04 (0.002)	-0.02 (0.003)	0.81 (0.03)	0.72
<i>10-Year</i>	0.11 (0.003)	0.06 (0.007)	0.82 (0.03)	0.72

Notes:

This Table reports the coefficient estimates of pooled regressions (across countries and time) of sovereign yields relative to Germany onto the liquidity index relative to Germany and CDS spreads relative to Germany. Separate regressions are run for the two-year, five-year, and ten-year maturities. Bolded coefficients are significant at the 5 percent level. Time-clustered standard errors are used. Standard errors are in brackets beneath estimates.

Table VIII**VAR Estimates in Liquidity and Credit**

	intercept	credit _{t-1}	liq _{t-1}	R ²
liq _t	0.01 (0.00)	-0.04 (0.03)	0.98 (0.03)	0.96
credit _t	0.01 (0.01)	0.69 (0.13)	0.06 (0.03)	0.50

Notes:

This Table shows VAR estimates for two-day averages of the new measures of private credit and German bond market liquidity. Bolded estimates are significant at the five percent level, and standard errors are shown in brackets beneath the coefficient estimates. White standard errors are used.

Table A- I

Sample Statistics of Country Liquidity and Credit Measures Relative to Germany

<i>Panel A: Means</i>									
	Country	Yield Spread	CDS Spread	Liquidity Index Spread	Bid-ask Spread	Depth Spread	Cum. Depth Spread	Cum. Liquidity Index Spread	Liquidity Beta
		(bps)	(bps)		(bps)	(€ mln)	(€ mln)		
2-Year	Belgium	4	3	-0.07	1	2	4	-0.04	-0.02
	Spain	3	8	0.37	1	7	9	0.33	-0.05
	France	3	1	-0.07	1	4	0	-0.21	-0.03
	Greece	16	11	-0.25	2	-1	5	-0.05	-0.05
	Italy	7	10	1.19	0	21	21	0.62	-0.09
	Portugal	10	7	0.84	2	22	16	0.35	-0.01
	KfW	16	na	-0.54	7	0	-6	-0.65	na
5-Year	Belgium	10	5	-0.34	2	-6	2	-0.24	-0.12
	Spain	8	10	-0.36	2	-10	1	-0.11	-0.19
	France	6	1	-0.40	2	-11	-7	-0.34	-0.09
	Greece	22	14	-0.41	8	-7	9	-0.15	-0.12
	Italy	14	12	0.05	1	-1	10	0.08	-0.21
	Portugal	12	11	0.09	2	6	8	-0.01	-0.08
	KfW	18	na	-0.83	9	-17	-12	-0.71	na
10-Year	Belgium	15	6	-0.31	2	-8	-7	-0.20	-0.83
	Spain	14	13	-0.44	4	-13	-17	-0.33	-0.71
	France	9	2	0.00	1	2	3	0.02	-0.69
	Greece	33	20	-0.31	16	-7	-4	-0.19	-0.79
	Italy	25	19	-0.17	1	-5	-1	-0.06	-0.85
	Portugal	24	15	-0.11	3	1	0	-0.07	-0.82
	KfW	22	na	-0.62	11	-14	-14	-0.53	na
<i>Panel B: Standard Deviations</i>									
	Country	Yield Spread	CDS Spread	Liquidity Index Spread	Bid-ask Spread	Depth Spread	Cum. Depth Spread	Cum. Liquidity Index Spread	Liquidity Beta
		(bps)	(bps)		(bps)	(€ mln)	(€ mln)		
2-Year	Belgium	5	5	0.25	3	6	10	0.36	0.03
	Spain	5	8	0.33	4	7	8	0.26	0.05
	France	3	2	0.18	3	5	4	0.18	0.06
	Greece	9	17	0.17	6	5	7	0.16	0.03
	Italy	9	10	1.06	2	11	7	0.41	0.09
	Portugal	8	8	0.58	8	10	7	0.25	0.05
	KfW	11	na	0.29	6	10	10	0.23	na
5-Year	Belgium	7	6	0.18	13	6	5	2.05	0.13
	Spain	6	10	0.19	15	7	5	2.04	0.14
	France	5	2	0.21	13	7	4	2.05	0.15
	Greece	15	16	0.21	37	8	6	2.06	0.21
	Italy	11	11	0.42	13	7	6	2.03	0.23
	Portugal	8	10	0.28	14	9	6	2.04	0.16
	KfW	11	na	0.24	17	7	7	2.31	na
10-Year	Belgium	8	7	0.18	18	7	6	0.18	0.55
	Spain	9	11	0.21	18	7	8	0.21	0.32
	France	5	2	0.23	17	9	9	0.23	0.53
	Greece	10	16	0.23	69	7	8	0.19	0.35
	Italy	10	12	0.20	16	6	7	0.20	0.29
	Portugal	9	11	0.21	18	8	9	0.20	0.41
	KfW	10	na	0.22	15	7	8	0.26	na

Notes: The top panel reports the mean difference in the MTS data for each of these series and their German counterparts at the two-, five- and ten-year maturities. The bottom panel plots the variance in the spread relative to Germany. $x_{sprd_i} = x_i - x_{DE}$, where x is the liquidity or credit variable.

Table A- II**Percentage Share of Total Volume and Transactions by Maturity/Credit Bin in Interbank Market**

		<i>Percent of Total Transactions</i>					
		O/N	1W	1M	3M	6M	1Y
Best	1	18	12	8	9	11	18
	2	17	10	7	10	9	3
	3	19	14	8	16	27	10
	4	19	23	32	27	16	13
Worst	5	27	41	45	38	11	58

		<i>Percent of Total Volume</i>					
		O/N	1W	1M	3M	6M	1Y
Best	1	31	22	24	8	10	26
	2	24	28	9	11	6	1
	3	26	15	14	23	34	7
	4	8	11	22	24	12	23
Worst	5	11	23	30	33	37	44

Total Sample Volume (€mln):	6,337,593	114,788	42,383	25,661	4,079	684
Total Sample Transactions:	129,576	2,567	1,411	938	126	40

Notes: For each maturity, this Table reports the percentage of total volume and number of transactions in the e-MID data sample (January 1, 2007 – April 31, 2008) by banks that are in each of the five credit bins, sorted by the coefficient estimates from equation (1). The bins are shown as quintiles rather than deciles for readability. Since the bins are equally weighted by number of limit order borrowing transactions, the number of total transactions in each bin does not necessarily equal 1/5 of the total.

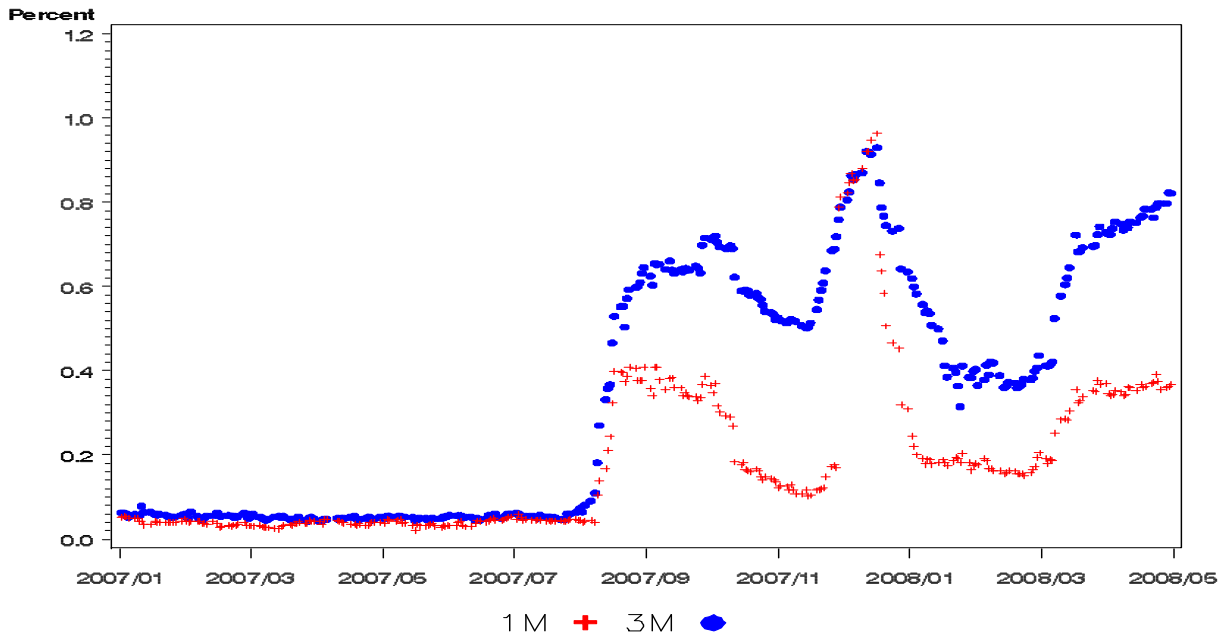
Table A- III**Cross Correlation of Tiers**

<i>Decile Tiering</i>	10th - 1st	9th - 1st	8th - 1st	7th - 1st
10th - 1st	1	0.93	0.95	0.92
9th - 1st	0.93	1	0.94	0.94
8th - 1st	0.95	0.94	1	0.95
7th - 1st	0.92	0.94	0.95	1

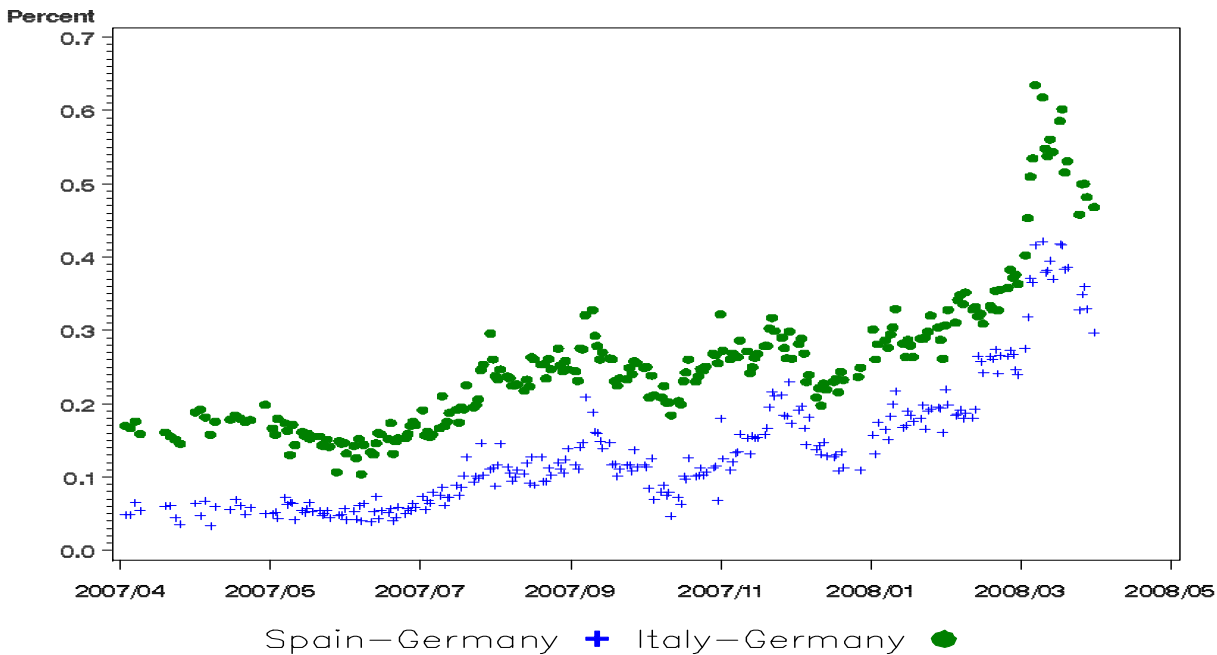
Notes: This Table shows the correlation of spreads between rates paid by good and bad credit risk banks using the indicated deciles of the banks to measure credit quality. The 1st decile represents banks with the best credit quality. The 10th minus the 1st decile spread is the credit tiering measure used in this paper.

Figure 1: Interest Rate Spreads

Euro Libor—OIS Spreads



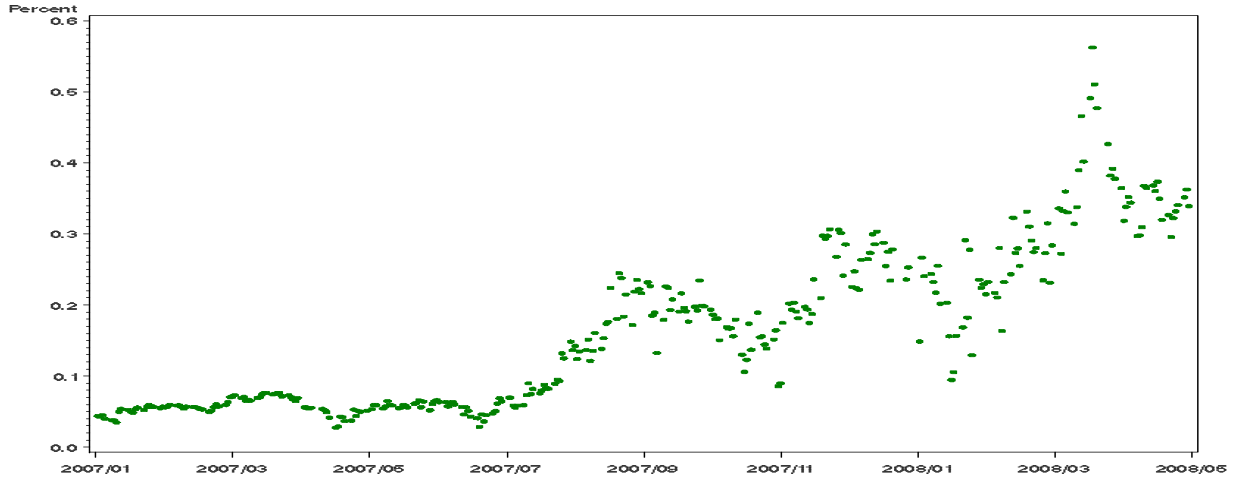
10—Year Sovereign Spanish and Italian Yield Spreads over German



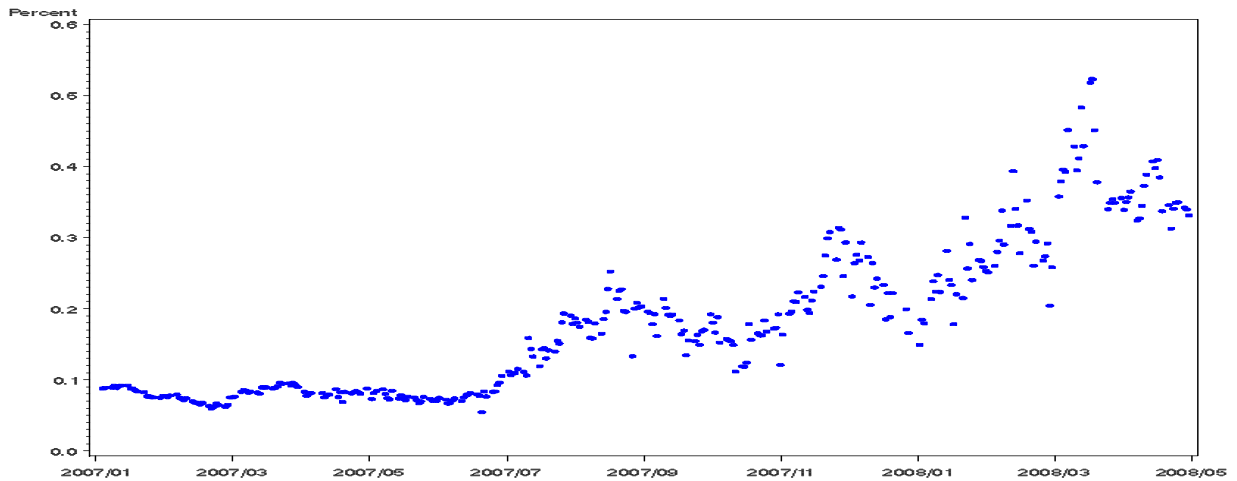
Notes: The top Figure shows one- and three-month euro LIBOR-OIS spreads. The bottom Figure shows the 10-year yield spread of Italian and Spanish government bonds relative to their German counterparts.

Figure 2

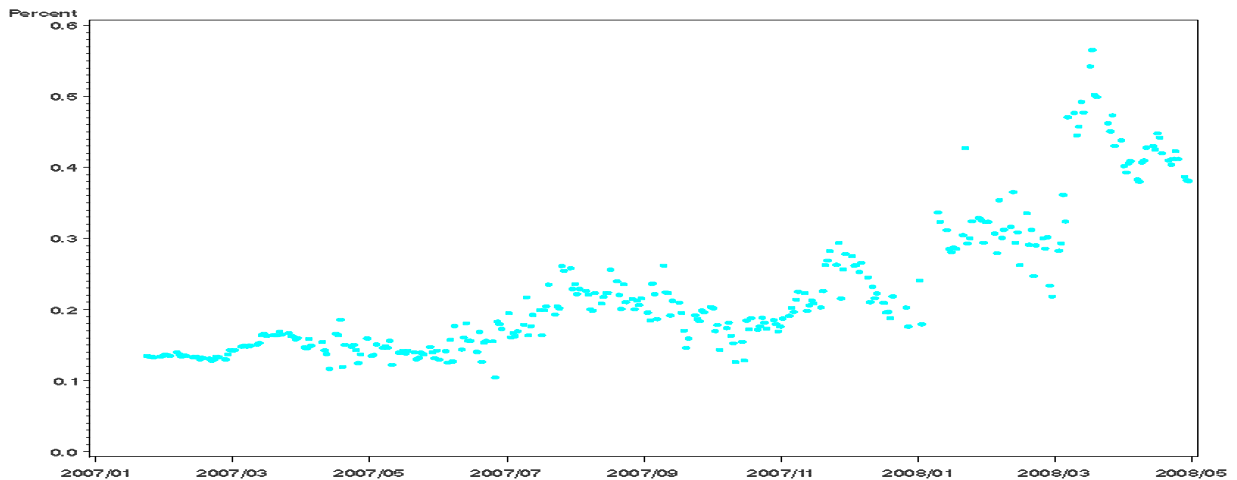
Two—Year KfW over German Federal Bond Yield Spread



Five—Year KfW over German Federal Bond Yield Spread



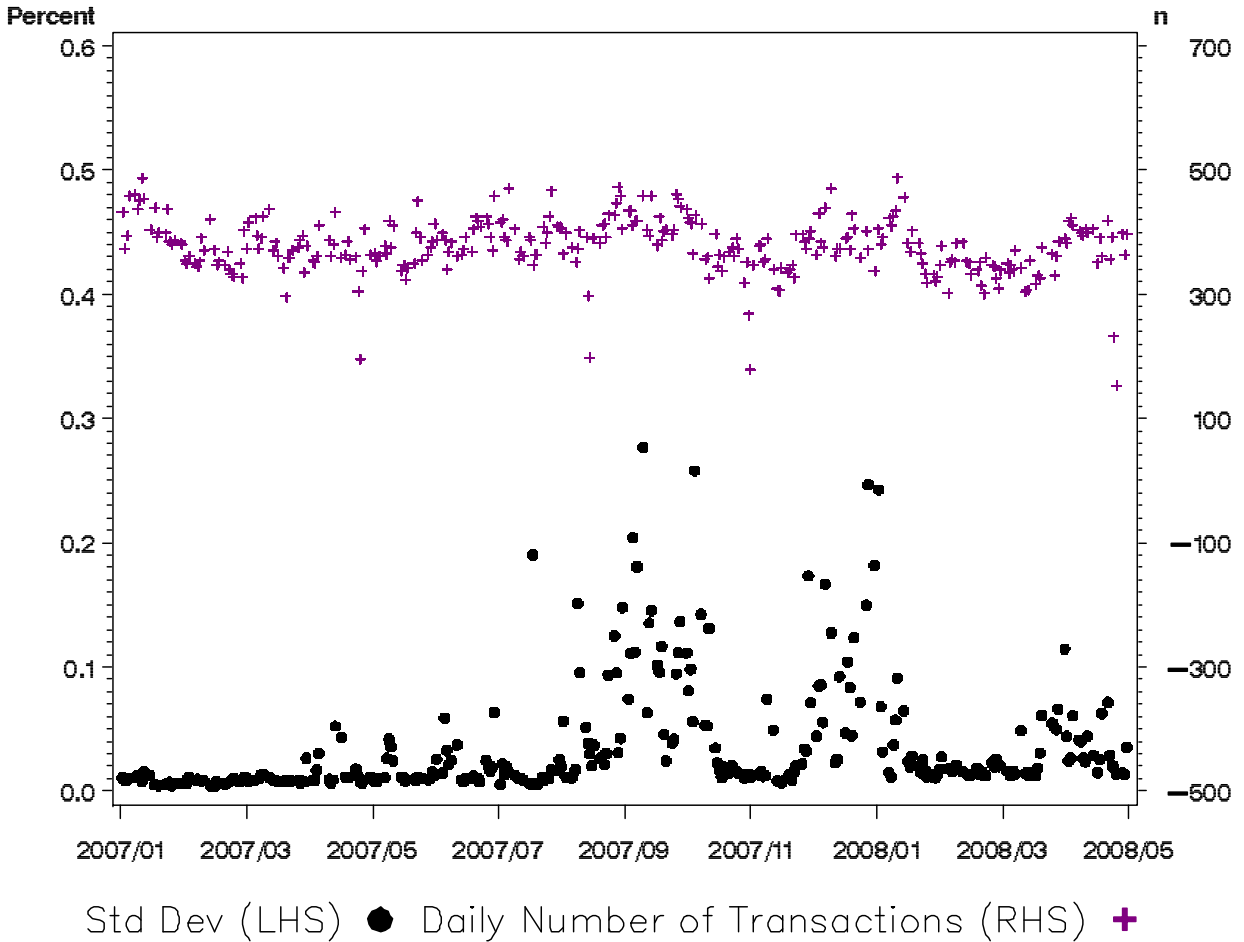
Ten—Year KfW over German Federal Bond Yield Spread



Notes: These Figures show the two-, five-, and ten-year German KfW minus federal government bond yield spread, in the top, middle, and bottom panels, respectively.

Figure 3

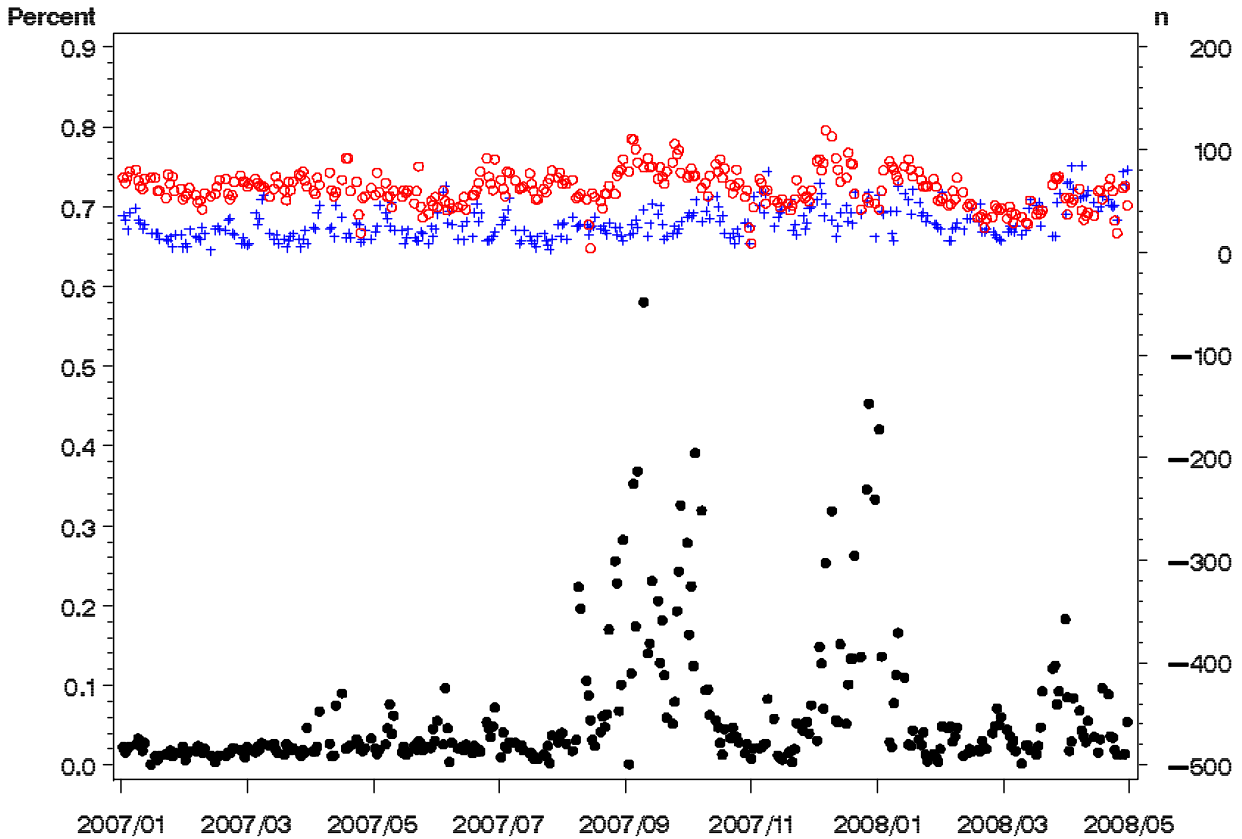
Intraday Std Dev of Overnight Interbank Rates versus Transactions



Notes: This Figure shows the daily number of euro interbank deposit transactions on the e-MID platform (right axis), and the intraday standard deviation of overnight euro deposit transactions on the e-MID platform (left axis).

Figure 4

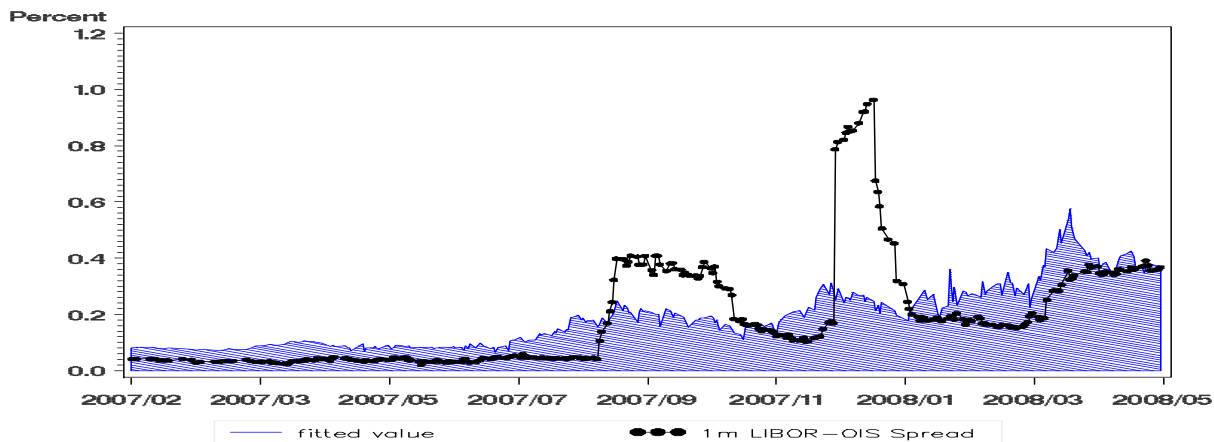
Credit Tiering of Overnight Interbank Borrowing Rates



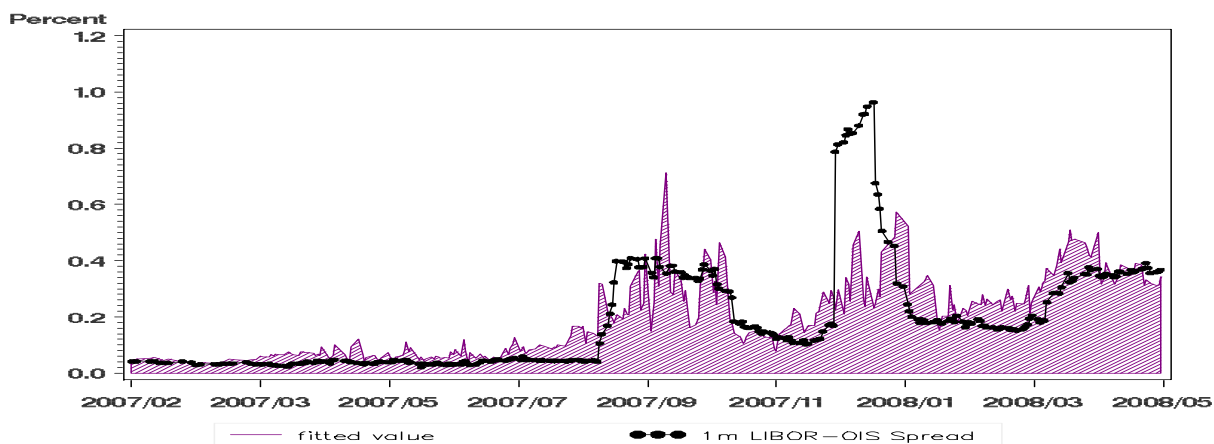
Credit Tiering (LHS) ● Best Credit Transactions (RHS) + Worst Credit Transactions (RHS) ●

Notes: This Figure shows the daily private credit tiering measure computed from overnight euro deposit transactions on the e-MID platform (left axis). This Figure also shows the daily number of euro interbank deposit transactions on the e-MID platform for the decile of banks with the lowest credit premium estimates and the decile of banks with the highest credit premium estimates (right axis).

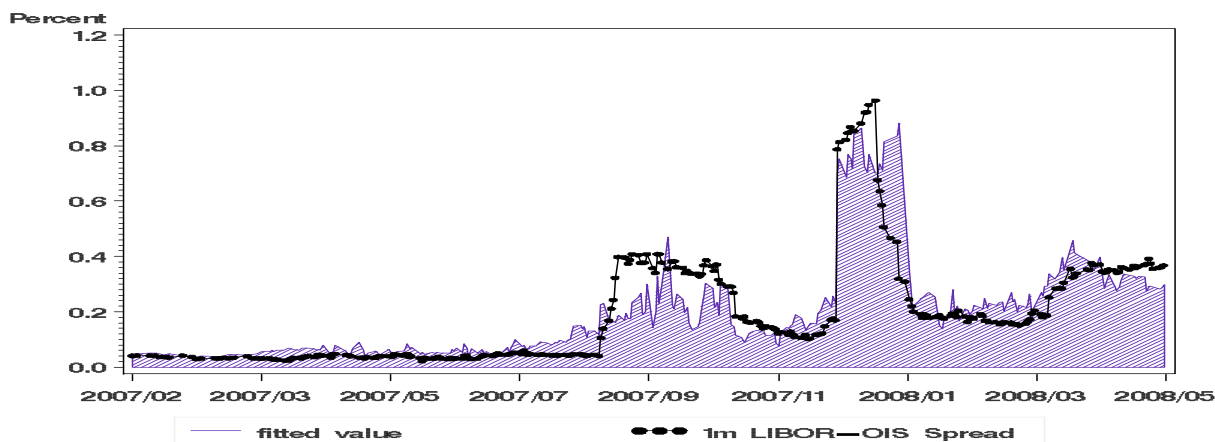
Figure 5
LIBOR—OIS Spread Explained by Liquidity



LIBOR—OIS Spread Explained by Liquidity and Credit



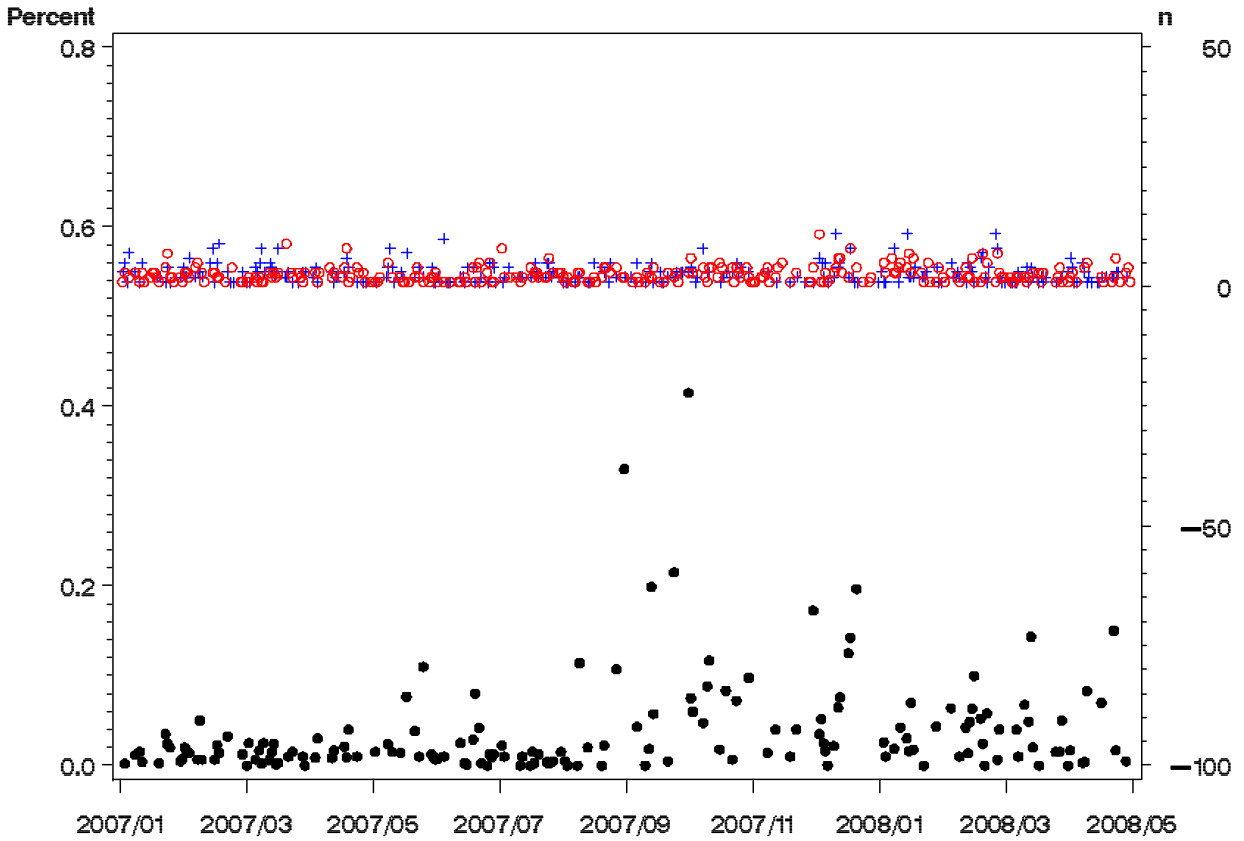
LIBOR—OIS Spread Explained by Liquidity, Credit, and Year—End



Notes: The top panel of this Figure shows the one-month euro LIBOR-OIS spread and the fitted spread from a regression on the KfW liquidity measure alone. The middle panel shows the same spread along with the fitted value using both the KfW liquidity measure and the new credit measure as explanatory variables, and the bottom panel shows this spread along with the fitted value using liquidity, credit, and a year-end dummy as explanatory variables.

Figure A- 1

Credit Tiering of 1—Month Interbank Borrowing Rates



Credit Tiering (LHS) ● Best Credit Transactions (RHS) + Worst Credit Transactions (RHS) ●

Notes: This Figure shows the daily private credit tiering measure computed from one-month euro deposit transactions on the e-MID platform (left axis). This measure is computed by subtracting the average rate paid by banks with the top half of credit premium estimates minus the banks with the bottom half of credit premium estimates. The banks are classified as “top half” or “bottom half” based on the coefficient estimates from equation (1) with overnight transactions. This Figure also shows the daily number of one-month euro interbank deposit transactions on the e-MID platform for the top and bottom halves of banks (right axis).