

Mind the Gap: Disentangling Credit and Liquidity in Risk Spreads

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October 27, 2017

Abstract

Wide and volatile interest rate spreads in the 2007-2009 financial crisis could represent concerns over asset liquidity or issuer solvency. To precisely identify the contribution of these two effects on interest rates, I propose a model-free measure of market liquidity, and use it to decompose euro-area sovereign bond and interbank spreads. Relating the measure to rates across countries reveals that German bonds benefit disproportionately from deteriorating liquidity. Additionally, cross-country bond return variation gives evidence of large and significant liquidity risk premia, the possibility that liquidity could be negatively correlated with marginal utility, something not captured by instantaneous liquidity measures.

JEL Classification: E44, G01, G12, G15

Keywords: market liquidity, interbank credit, liquidity risk, money markets, interest rates, financial crisis.

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Wide and volatile interest rate spreads in the 2007-2009 financial crisis could represent concerns over asset liquidity or issuer solvency. To precisely identify the contribution of these two effects on interest rates, I propose a model-free measure of market liquidity, and use it to decompose euro-area sovereign bond and interbank spreads. Relating the measure to rates across countries reveals that German bonds benefit disproportionately from deteriorating liquidity. Additionally, cross-country bond return variation gives evidence of large and significant liquidity risk premia, the possibility that liquidity could be negatively correlated with marginal utility, something not captured by instantaneous liquidity measures.

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The 2007-2009 financial crisis was marked by extraordinary interest rate spread widening and heightened volatility in asset prices. One example is the increase in euro-area government bond yields, which spiked to levels not seen since the introduction of the common currency in 1999. In the money market, spreads between unsecured interbank borrowing rates (EURIBOR) and overnight-indexed swap (OIS) rates of comparable maturities reached their widest levels since the inception of the OIS market, dramatically tightening financial conditions. Despite the magnitude of these unusual interest rate movements, there has been a lack of consensus on the dominant driver. One hurdle to identification is the difficulty in precisely capturing the risk components in prices. This paper proposes a model-free measure of market liquidity formed directly from asset prices, and uses it to parse these historic movements in interest rate spreads, identifying a large role for liquidity.

Beyond the expected path of future short-horizon interest rates, it is difficult to empirically determine what drives sovereign bond yields or interbank rates, especially at times of market stress. Two possible influences that are explored in this paper are credit, reflecting compensation for heightened default risk (Afonso, Kovner and Schoar (2011), Filipović and Trolle (2013), Taylor and Williams (2009), Beber, Brandt and Kavajecz (2009), and McAndrews, Sarkar and Wang (2008)), and market liquidity, reflecting trading conditions in asset markets (Michaud and Upper (2008), Acharya and Skeie (2011)). The models of Heider and Hoerova (2009) and Heider, Hoerova and Holthausen (2015) also discuss the role of these two risk components in interest rates.

Identifying the default and liquidity components in interest rates is important for portfolio allocation and policy decisions. Investors with the longest investment horizons should prefer to hold higher yielding assets if the elevated yields represent compensation for deteriorating market conditions, but not necessarily if they represent a greater risk of loss due to default. From the

perspective of policymakers, efforts to improve market functioning could help to dampen the effects of poor asset market liquidity on yields. For example, an exchange of more-liquid for less-liquid bonds (such as in the Federal Reserve's securities lending facility) could reduce liquidity premia. On the other hand, if higher yields are attributable to a credit shock, then this argues for addressing solvency.

This paper makes three contributions in the decomposition of interest rates into liquidity and credit components. The first is a new market liquidity measure that captures liquidity broadly by recovering all of the information embedded in yields that is not related to default risk. A growing literature argues that model-driven liquidity indicators (e.g. bid-ask spreads) and liquidity characteristics of assets (e.g. trading volume) do not capture all liquidity channels. For instance, a bond could have low transactions costs and/or high volume today, but still have high liquidity *risk*. Jankowitsch, Mösenbacher and Pichler (2006) find that conventional liquidity measures do not adequately capture liquidity risk in the euro-area sovereign bond market. See also Friewald, Jankowitsch and Subrahmanyam (2012) and Dick-Nielsen, Feldhütter and Lando (2012) in the corporate bond market.

The proposed liquidity measure is model-free – it does not rely on single interpretation of liquidity frictions. The measure is constructed directly from asset prices, and is defined as the difference in yields between two duration-matched bonds that share an identical credit guarantee from the German federal government, but differ in market liquidity. Specifically, the measure compares the German federal government bond yield to that of its less-liquid agency counterpart, KfW (Kreditanstalt für Wiederaufbau). This liquidity yield differential is referred to as the K-spread. The K-spread therefore identifies any deviation in an asset's price from its hold-to-maturity value, fully capturing liquidity and liquidity risk effects impounded in prices. It is also tradable in

that an investor can form a portfolio comprised of a long KfW bond position and a corresponding short German federal bond position. This position earns the “liquidity spread” and hedges against credit fluctuations.

The second contribution is to use the K-spread as a common liquidity factor to parse the components of rates for the euro-area sovereign bond and interbank markets. Researchers have proposed theoretical models in which liquidity can have an important effect on bond yields, especially during a crisis; Acharya and Skeie (2011), Favero, Pagano and von Thadden (2010) and Manganelli and Wolswijk (2009). In the decomposition of sovereign bond yields, the K-spread is used to identify liquidity effects in the cross section of euro-area countries, and so identification relies on commonality in market liquidity. Chordia, Sarkar and Subrahmanyam (2005) and Brunnermeier and Pedersen (2009) show that common factors drive liquidity premia across various markets. Indeed, the K-spread explains more variation across different euro-area country yields than several country-specific liquidity measures capture jointly. I find there is large variation in the relative role of credit and liquidity by country, and that the liquidity effect varies in sign. In particular, German bonds benefit disproportionately from a negative shock to euro-area liquidity.

I use the K-spread to decompose euro-area unsecured interbank rates in order to assess a possible link between aggregate bond liquidity and money markets.¹ Brunnermeier and Pedersen (2009) and Bolton, Santos and Scheinkman (2011), model the relationship between aggregate market liquidity and idiosyncratic funding liquidity to explain market features seen in the early stages of the 2007-2009 financial crisis. To estimate this liquidity channel, I first obtain a novel dataset of interbank transactions, with which I form a new bank-tiering credit measure and several microstructure liquidity measures. The K-spread’s large role in interbank rates after controlling

¹ Unsecured interbank rates, considered in this paper, are a close substitute to secured interbank rates (repo funding), which are directly affected by the liquidity premia of assets used as collateral.

for all interbank credit and liquidity measures gives strong empirical evidence for the general equilibrium relationship between bond and funding markets.

The final contribution of this paper is to explicitly test the pricing of liquidity *risk*, in order to better understand the nature of the large role for liquidity identified in interest rates over the crisis. Liquidity risk is a forward-looking component of market liquidity that is not captured by traditional measures. The concept of liquidity risk is proposed in the theoretical models of Acharya and Pedersen (2005), Pastor and Stambaugh (2003) and Vayanos (2004), representing the possibility that liquidity will dry up in the future at exactly the time when investors' marginal utility is at its highest. However, empirically, there are differing views on the importance of this liquidity risk relative to the level of liquidity *per se*. In corporate bond markets, Lin, Wang and Wu (2011) find that liquidity risk premia can help to explain corporate bond returns, whereas Bongaerts, de Jong, and Driessen (2013) find that liquidity risk is priced in equity markets but not in corporate bond markets.

Empirically, liquidity risk is defined as the covariance of government bond returns with changes in market liquidity. The rich cross section and time series of euro-area sovereign bond data makes it ideally suited to this estimation. Applying a two-step Fama MacBeth procedure, I find a systematic relationship between liquidity factor sensitivity in bonds and their expected returns across countries and maturities. Large and significant euro-area liquidity risk premia help to explain the sizeable overall liquidity effect in interest rates in the 2007-2009 financial crisis.

The plan for the remainder of this paper is as follows. Section 1 introduces the framework that underlies the empirical analysis. Section 2 introduces the data. Section 3 constructs the K-spread liquidity measure and parses the relative euro-area sovereign bond yields into liquidity and credit components. Section 4 identifies liquidity and credit effects in interbank interest rates.

Section 5 tests the pricing of liquidity risk premia in the euro-area sovereign bond market. Section 6 concludes with the paper's contributions and implications.

1. A Simple Framework

This section introduces the particular euro-area interest rates considered, and describes a simple structural model that isolates the risk component in these rates.

1.1 The Common Component in Euro-Area Interest Rates

Upon the introduction of the single euro currency in 1999, the European Central Bank (ECB) became independently responsible for managing the common path of short-term interest rates that are now shared by all euro-area member countries. The expected future path of euro-area monetary policy anchors the hypothetical riskfree term structure of euro-denominated rates, in the absence of liquidity effects, but this hypothetical yield curve is not directly observable. The focus of this paper is to explain the variation in rates that is unrelated to the riskfree term structure. During normal times, limited variation in the risk components of rates can make identification challenging. However, substantial crisis-driven movement in market liquidity (the ease with which a security is traded) and credit (the possibility that a financial instrument pays off below its face value) presents a unique opportunity to cleanly identify their separate effects in interest rates.

There are two classes of interest rates that I aim to parse: (1) euro-area sovereign bond yields, and (2) euro interbank borrowing rates (EURIBOR). Both classes of rates share a common euro-area term structure. EURIBOR is the reference rate for large euro-area banks borrowing some notional amount of euro currency from one another, uncollateralized, for a specified term.² Euro-

² EURIBOR is a survey rate of unsecured interbank euro borrowing rates compiled by the European Money Markets Institution (formerly the European Banking Federation) for eight maturities, from overnight- to one-year. LIBOR, also

area sovereign debt has a well-defined cross section of individual country bond yields, without a single reference rate.

1.2 *Isolating the Risk Component in Sovereign Bond Yields*

First, to isolate the risk component in the sovereign bond market, consider a model in which sovereign yields are expressed as a function of three components: the riskfree rate, expected default and market liquidity.³ Specific measures of liquidity and credit will be proposed in Sections 2 and 3. The model relates individual country yields at each maturity to credit and liquidity as:

$$y_{cmt} = r_{mt} + \beta_{1cm}\kappa_{mt} + \beta_{2m}d_{cmt} + \varepsilon_{cmt} \quad (1)$$

where y_{cmt} is the sovereign bond yield for country c at maturity point m and time t , r_{mt} is the riskfree rate at maturity m , κ_{mt} represents a single market liquidity factor and d_{cmt} is the sovereign default risk premium for country c . There is a single market liquidity factor and a common riskfree rate across countries, and so these variables vary over time and by maturity but not by country, reflected in the absence of a c subscript. The model's representation is consistent with the euro-area's framework as a single currency union with an institutionally integrated secondary market. Monetary union has prompted much market harmonization, such as the concentration of euro-denominated sovereign debt transactions on a few dedicated platforms. Allowing the bonds of different countries to load on a common liquidity factor leaves scope for divergent responses to an aggregate liquidity shock. For instance, a flight-to-liquidity may support sovereign bonds that already enjoy a relatively high level of liquidity as market participants concurrently shun less-

a survey of interbank borrowing, has been widely cited as manipulated to some degree by the contributing banks. To the extent that manipulation may have occurred in the EURIBOR survey, it is unlikely that the effect would be systematically related to the measures used in this paper, none of which settle to EURIBOR. If there were a systematic relationship, it is not clear in which direction this might shift the relative breakdown of liquidity versus credit.

³ Market liquidity is broadly defined as any influence on asset prices outside of credit.

liquid markets, thus increasing the liquidity discount in the less-liquid bond yields. In contrast, default risk is idiosyncratic according to each country's fiscal position, distinctly increasing for a country as its federal budget deteriorates. For robustness, the decomposition in Section 3 also includes an augmented model that allows for country-specific liquidity.

To measure each country's relative sovereign yield premium within the model, without taking a stance on the level of the unobserved riskfree rate, we can consider a yield *spread* for each country-maturity pair. The yield spread is the difference between each country's sovereign yield

and the euro-area weighted average yield.⁴ The weights are defined as $w_{cm} = \frac{Q_{cm}}{\sum_{c'=1}^{11} Q_{c'm}}$, where Q_{cm} is

the quantity of debt outstanding for each country c , at each maturity point m and c' is a counter variable indexing each of the countries for the purpose of computing the euro-area weighted average.⁵ From Equation (1) we can deduce that:

$$y_{cmt} - \sum_{c'=1}^{11} w_{c'm} y_{c'mt} = (\beta_{1cm} - \sum_{c'=1}^{11} w_{c'm} \beta_{1c'm}) \kappa_{mt} + \beta_{2m} (d_{cmt} - \sum_{c'=1}^{11} w_{c'm} d_{c'mt}) + \varepsilon_{cmt} - \sum_{c'=1}^{11} w_{c'm} \varepsilon_{c'mt}, \quad (2)$$

which can be written more concisely as:

$$\tilde{y}_{cmt} = \tilde{\beta}_{1cm} \kappa_{mt} + \beta_{2m} \tilde{d}_{cmt} + \tilde{\varepsilon}_{cmt} \quad (3)$$

where \tilde{y}_{cmt} is the sovereign yield spread for country c , at the m -year maturity point, on day t .⁶

⁴ Correlations of euro-area bond yield *levels* rose around the time of monetary union and were high from then until the European debt crisis -- see Ehrmann, Fratzscher, Gürkaynak and Swanson (2011) -- largely reflecting the common component influenced by the state of euro-area monetary policy.

⁵ The maturity buckets comprise the total amount of debt outstanding for securities in the following duration ranges: 1-year bucket = 0.5 to 1.5, 2-year bucket = 1.5 to 2.5, 3-year = 2.5 to 3.5, 4-year bucket = 3.5 to 4.5, 5-year bucket = 4.5 to 6.5, 7-year bucket = 6.5 to 8.5, and 10-year bucket = 8.5 to 10.5. The quantities are averaged over all days in the sample period. The seven maturities are chosen in order to match the particular maturities of the credit default swaps introduced later in this section. The weights do not vary over the sample, because there is little change in relative debt quantities outstanding during this short period.

⁶ The pattern in sovereign yield spread widening, shown in Figure 1 Panel B, suggests that the weights provide a reasonable anchor to the spreads; the spreads of small countries would likely be the widest if the weights of large countries had a disproportionate influence on the spreads. For instance, the yield spreads of Finland and Austria are very close to the 11-country average over the sample, even though these countries jointly have a weight of less than 5 percent at any maturity point.

1.3 Isolating the Risk Component in Interbank Interest Rates

The interbank counterpart to Equation (1) describes EURIBOR as a function of the riskfree rate, expected default and market liquidity, without the country subscript c , which gives:

$$y_{mt} = r_{mt} + \beta_{1m}\kappa_{mt} + \beta_{2m}d_{mt} + \varepsilon_{mt} \quad (4)$$

where y_{mt} is the unsecured interbank rate at maturity point m and time t , r_{mt} is the riskfree rate, and κ_{mt} and d_{mt} denote liquidity and credit factors, respectively. The credit factor, d_{mt} , represents the aggregate likelihood of repayment by euro-area banks borrowing from one another. The liquidity factor, κ_{mt} , represents the effect of aggregate sovereign bond market liquidity in interbank rates. One possible transmission channel is through the use of sovereign bonds as collateral in funding markets, such as in the ECB's massive repo operations with banks.⁷

Since there is no distinct cross section of interbank rates by country, the unobservable riskfree interest rate cannot be eliminated by subtracting the euro-area average rate, as in the sovereign bond market in Equation (2). So, the riskfree rate in the interbank market is proxied by the euro overnight-index swap (OIS) rate. An OIS is a money market instrument with a payoff determined by the future path of overnight interest rates plus a pure term premium.⁸ The difference in the EURIBOR rate and the same-maturity OIS rate at a given point in time, $y_{mt} - r_{mt}$, gives the risk component in interbank rates, represented as \tilde{y}_{mt} in the model:

⁷ Haircuts on ECB collateral differ by credit category and maturity of a security.

⁸ Default and liquidity premia in OIS rates are negligible (Brunnermeier (2009) and Packer and Baba (2009)), minimizing a possible risk premium effect. The default premia are negligible because the OIS rate reflects a sequence of refreshed overnight bank credits, no matter how long the term of the swap. The liquidity component of OIS rates 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, because unsecured funding is a close substitute for repo funding. Meanwhile, OIS is not a proxy for repo funding. Also, an OIS is a derivative in zero net supply. As such, it is unclear whether a liquidity premium would be demanded by 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.

$$\tilde{y}_{mt} = \beta_{1m}\kappa_{mt} + \beta_{2m}d_{mt} + \varepsilon_{mt} \quad (5)$$

Section 4 shows an augmented specification that includes interbank market liquidity.

2. Data

The sample period for this paper is January 1, 2007 through September 30, 2009, which captures the nascent financial crisis in the summer of 2007, the height of asset price volatility following Lehman Brothers' bankruptcy, and the broad reversal in asset prices in the spring and summer of 2009. This section describes the construction of the EURIBOR-OIS and euro-area sovereign debt spreads, and discusses the data used to construct the risk measures.

2.1 *Sovereign Bond Yield Spreads*

Starting with the sovereign bond market, the data sample includes 77 country-maturity pairs: the government debt securities for 11 euro-area member countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain) at seven specific sovereign bond maturity points (1, 2, 3, 4, 5, 7, and 10 years). To precisely compare these yields, I estimate a smoothed zero-coupon sovereign yield curve, for each maturity m , each country c , and each day t , by applying the six-parameter model of Svensson (1994) to the prices of all euro-denominated nominal coupon sovereign debt securities, using bond prices from Bloomberg.⁹

Figure 1 compares the movements in sovereign bond yields (Equation (1), Panel A) and yield spreads (Equation (3), Panel B), respectively, for each of the countries in the sample. The yields mostly decline over the sample, but the yield *spreads* widen dramatically for several countries. Figure 1 shows that the five-year spread ranges from -23 to 55 basis points. Other

⁹ See Gürkaynak, Sack, and Wright (2006) for a discussion of the methodology: <http://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html>.

horizons show similar widening, as reported in the sovereign bond summary statistics in Table 1.

2.2 *Interbank Interest Rate Spreads*

In the money market, I consider the 1-, 3-, 6-, and 12-month-maturity EURIBOR-OIS interest rate spreads. These are EURIBOR maturities commonly referenced in financial contracts. Panel A of Figure 2 illustrates an even steeper decline in EURIBOR levels than those of sovereign bonds over the same period (Figure 1, Panel A). The roughly 450 basis point drop in short-term rates over the sample is largely driven by the ECB's crisis-driven monetary policy easing in 2008 and 2009, and thus a lower riskfree rate. On the other hand, Panel B shows that the *spread* between EURIBOR and OIS rates spikes higher, first in August 2007, and then most dramatically following Lehman's Brothers' bankruptcy in the fall of 2008. The 1-month EURIBOR-OIS spread (which is always positive) has a standard deviation of 30 basis points, the same as its sample average level, as shown in Panel A of Table 2. The rise in short-term spreads in 2007 and 2008 received considerable attention in the press and from policymakers. Widening spreads mean less accommodative financial conditions *ceteris paribus*, since many private lending rates are tied to term interbank rates.¹⁰ EURIBOR and OIS rates are obtained from Bloomberg.

2.3 *Market Microstructure Liquidity Measures*

In order to compare the proposed K-spread liquidity measure with traditional euro-area sovereign bond liquidity measures, and to allow for country-specific liquidity effects, I obtain transaction data from MTS, a large electronic European bond trading platform, aggregated to a

¹⁰ Swap rates, forward rate agreements, interest rate futures contracts, and many mortgage rates in the euro area reference EURIBOR.

daily frequency.¹¹ With these data, I construct five microstructure liquidity measures for each of the 77 country-maturity pairs: average trade size, total trading volume, the average bid-ask spread, order flow, and the bid-ask spread scaled by trading volume (Bollen and Whaley (1998) liquidity index), each aggregated to the daily frequency. Let X_{cmt} be a vector of the five microstructure liquidity measures for country, c , at maturity m , on day t , and let $\sum_{c'=1}^{11} w_{c'm} X_{c'mt}$ be the sovereign debt-weighted euro-area average of these liquidity measures at maturity m , where w is the set of weights used in Equation (2), and c' is a counter variable indexing each of the countries. The microstructure liquidity measure for each country-maturity pair is defined as:

$$\tilde{X}_{cmt} = X_{cmt} - \sum_{c'=1}^{11} w_{c'm} X_{c'mt} \quad (6)$$

Table 1 reports the country-level summary statistics for the microstructure liquidity measures, defined as deviations from the weighted average as in Equation (6), showing that each measure gives a different perspective on liquidity. For instance, the German sample average bid-ask spread is 7.9 basis points below the euro-area average, at the 10-year maturity, the largest of all of the country deviations from average. Meanwhile, Italian bonds are traded far more frequently than those of the other euro-area countries. This suggests that German and Italian bonds enjoy relatively high liquidity. However, trade sizes are smallest for Italian bonds at each maturity point.

The interbank market uses a parallel set of the five microstructure liquidity measures, formed directly from unsecured overnight interbank borrowing transactions, data that are notoriously opaque and difficult to obtain. The measures are denoted X_{mt} , as they are euro-area aggregates. The transaction data are sourced from e-MID, a large electronic euro-area interbank

¹¹ MTS is an acronym for Mercato dei Titoli di Stato (Market for Sovereign Bonds). MTS is the largest inter-dealer European sovereign bond market platform, comprising an estimated 80 percent of electronic inter-dealer transactions (Euroweek special report, May 2007).

trading platform.¹² Euro interbank transactions are concentrated at the very shortest maturities; more than 90 percent of unsecured interbank borrowing is for a horizon of less than one month.¹³ Because of sparse observations at other horizons, the microstructure measures are formed with overnight transactions. Table 2 summarizes statistics and correlations among the interbank microstructure liquidity measures. In Panel B, the average level of the interbank bid-ask spread is only a few basis points, 4.5. Sample average daily transaction volume captured by the e-MID platform is €11 billion, and the average trade size is €33 million

2.4 Credit Risk Measures

To identify the credit factor in sovereign bond yields, I collect the sovereign credit default swap (CDS) premium separately for the 77 country-maturity pairs considered. I treat the CDS spread as a directly observable credit measure, denoted, d_{cmt} , in Equation (1). I then subtract the sovereign debt-weighted euro-area average CDS premium from each sovereign CDS premium, notated as $d_{cmt} - \sum_{c'=1}^{11} w_{c'm} d_{c'mt}$ in Equation (2), giving \tilde{d}_{cmt} in Equation (3).

Measuring interbank credit risk with bank CDS premia faces the challenge that EURIBOR-OIS spreads reflect short-horizon risk, while CDS issuance is concentrated at the 5-year maturity. Very short- (or long-) maturity CDS contracts are less likely to be precise measures of default risk due to possible liquidity premia, as per Pan and Singleton (2008). Motivated by the default-horizon mismatch of CDS, I propose a new short-horizon measure of interbank credit risk. The measure is the dispersion of rates paid by different borrowers in the overnight interbank market, and it is

¹² e-MID is an acronym for Elettronica Mercato Interbancario dei Depositi (Electronic Interbank Deposit Market). Transactions on this platform comprise roughly 20 percent of all unsecured euro-denominated interbank transactions over the sample period. 98 percent of the unsecured interbank e-MID sample is comprised of overnight transactions.

¹³ The ECB's annual euro money market reports give detailed statistics on borrowing and lending each year. The maturity distribution has consistently shown that the largest share of transactions occurs at the overnight maturity.

formed directly from transactions executed on the e-MID trading platform (described earlier in this section). The use of this credit-tiering indicator is motivated by an assumption that the dispersion and level of credit risk are proportional. This idea has been used by several researchers to explain events in the financial crisis. For example, Heider, Hoerova, and Holthausen (2015) model this relationship specifically in interbank markets. Gorton and Ordoñez (2014) use variation in the cross section of stock returns as a proxy for the level of perceived collateral value. The proposed bank-tiering measure is the baseline credit factor representation, d_{mt} in Equation (5). Appendix I describes the bank-tiering measure and its construction in detail.

For comparison with the bank-tiering measure, I also consider bank CDS premia. In order to precisely capture the credit risk that is impounded in EURIBOR, I obtain the 1-year CDS premia for each EURIBOR participant bank.¹⁴ Then, I use the simple average of these banks' CDS premia on each day. All CDS data are obtained from Markit. Figure 4 illustrates a large spike in both measures of bank credit over the sample. However the bank-tiering measure reaches its highest level in the fall of 2008 (Panel A), whereas the bank CDS premium peaks in early 2009 (Panel B).

3. Credit versus Liquidity in Euro-Area Sovereign Bond Spreads

This section describes the proposed liquidity measure, and then uses it to empirically determine whether – and to what extent – credit and liquidity potentially drive the unprecedented cross-sectional variation in euro-area sovereign yield spreads during the sample period.

¹⁴ EURIBOR is a trimmed arithmetic average of interbank survey rates collected from a particular set of banks. The 22 EURIBOR survey banks are: Banco Bilbao Vizcaya Argentaria (BBVA), Banco Santander SA, Barclays, Bank of Tokyo Mitsubishi, BNP Paribas, Caiza General de Depositos, Citibank, Credit Agricole, Credit Suisse First Boston (CSFB), Danske Bank, Deutsche Bank, DZ Bank, HSBC, ING, Intesa San Paolo, JP Morgan Chase, Mizuho, Monte dei Paschi di Siena, Lloyds, National Bank of Greece, Natixis, Nordea, Pohjola, Rabobank, Royal Bank of Scotland, Societe Generale, and Unicredit. I do not trim the bank CDS premia before averaging them, because it is not clear that the same banks would be trimmed from the EURIBOR survey as those trimmed according to the distribution of bank CDS premia.

3.1 *The K-spread Measure of Market Liquidity*

Market liquidity is the premium demanded for buying or selling a large quantity of an asset, such as a sovereign bond, with immediacy.¹⁵ Measuring this empirically is challenging. To identify the liquidity component of euro-area interest rate spreads, I form a new measure of market liquidity that is constructed entirely from observed bond prices. Identification is not limited to any single model of liquidity frictions (e.g. asymmetric information). The measure reflects all information impounded in bond yields, including forward-looking information about future liquidity conditions, which is a potentially large dimension of liquidity not captured by market microstructure or transaction-based liquidity measures. Credit and asset characteristics are entirely controlled for by the nature of the measure's construction, as described below.

The new measure compares the yields of German government bonds with German agency bonds, at specific maturities. German government bonds are highly liquid euro-area securities, backed by the full faith and credit of the German federal government. Their less-liquid counterparts are bonds issued by the German federal government-owned development bank, KfW, which was founded in 1948 to facilitate post-war reconstruction. A key feature of the KfW agency bonds, which safeguards the new liquidity measure against any credit effects, is that the German federal government has an *explicit* iron-clad guarantee – written into the German constitution – for all of KfW's current and future obligations, equally and without any difference in priority relative to the federal government bond issues. Since default risk is identical for the two categories of bonds, market liquidity is the only substantive difference reflected in their yield spread. KfW and federal

¹⁵ An important but conceptually distinct type of liquidity is *funding* liquidity, an institution's precautionary demand for term funding so as to have liquid assets on its balance sheet. In the interbank market, precautionary demand for funding is closely tied to market participant's creditworthiness. Credit and *funding* liquidity are thus particularly hard to disentangle and I do not attempt to do so; in this paper, credit incorporates both default risk and associated funding liquidity.

government bonds also have identical tax treatment (Germany does not have a class of tax-exempt bonds as in the U.S.), and both classes of bonds have an identical zero risk weight for determining Basel II capital ratios.

To precisely compare the two classes of German yields, I first estimate a smoothed zero-coupon yield curve for the KfW bonds, on each day, using the same methodology as described for the sovereign yield curves in subsection 2.1. I then take the zero-coupon yield spread between the KfW bond and the corresponding German federal government bond at each of the seven maturity points considered. The m -year K-spread is defined as:

$$\kappa_{mt} = KfW_{mt} - Y_{Germany,mt} \quad (7)$$

where KfW_{mt} and $Y_{Germany,mt}$ denote the m -year zero-coupon yields for the KfW agency and German government bonds, respectively. The K-spread, denoted κ_{mt} in Equations (1) through (5), is treated as a directly observable liquidity measure. Its identifying assumption is that German sovereign and KfW yields have identical credit but that they load differently on the common liquidity factor. Time series variation in interest rates that comes from market liquidity will load on the K-spread, but variation due to default will not. Hence, the spread between KfW and German sovereign yields allows for recovery of that liquidity factor.

Panel A of Figure 3 plots the K-spread for the 1- and 5-year maturities over the sample. The spread is always positive, reflecting the relative ease with which the federal government debt is traded as compared to the agency debt. The measure rises most substantially in the second half of the sample, reaching a local peak of 47 basis points around the collapse of Bear Stearns in March 2008, at the 5-year maturity, and a global peak of 90 basis points following Lehman Brothers' bankruptcy in the fall of 2008.

There are some institutional differences between KfW and German federal government

bonds that could contribute to their liquidity differential. Although they share the same creditworthiness, the KfW and German federal government bonds are not fungible, even in the absence of any difference in characteristics. For instance, there is an active futures market for German 2-, 5- and 10-year federal government bonds, but the comparable-maturity KfW securities cannot be delivered into these futures contracts.¹⁶ Federal government bond issuance is also larger and trading volume is higher than for KfW securities.¹⁷ Moreover, euro repo funding rates are consistently slightly higher for KfW collateral than for German federal government collateral, reflecting the relative attractiveness of the federal government securities as collateral in funding markets.¹⁸ The financing rate differential could be both a cause and a consequence of their greater liquidity (Brunnermeier and Pedersen (2009) and Gorton and Metrick (2012)). The K-spread is similar in spirit to the measure proposed by Longstaff (2004), who uses the yield spread between Refcorp (Resolution Funding Corporation) and U.S. Treasury bonds to proxy liquidity premia in U.S. Treasury markets. But, the K-spread is constructed in the euro-area market, and I directly apply it to quantify the aggregate bond market liquidity effects in different euro-area country bond yields and interbank rates.

3.2 *The Independent Component of Credit versus Liquidity in Yield Spreads*

To investigate the drivers of sovereign yield spreads, I match each of the seven sovereign

¹⁶ The existence of futures markets enhances the liquidity of Treasury securities in the U.S. (Fleming (1997), allowing an investor to hedge a position in the underlying security.

¹⁷ In 2008, gross annual issuance was €216 billion in federal government debt versus €74 billion for KfW, and the size of government debt was about 8 times that of KfW agency debt. Issue sizes outstanding at the time were around €20 billion for benchmark federal debt issues versus €5 billion for benchmark KfW issues. Nonetheless, KfW is the 4th largest euro-area debt issuer by volume, after the sovereigns of Germany, France and Italy. Trading volume for the federal government debt is roughly 10 times higher than that of the agency market (a daily average of €443 million versus €42 million, respectively), on the MTS platform, over the sample period.

¹⁸ KfW bonds may not be used as collateral in federal government repo agreements and vice versa. However, both securities are actively used for funding purposes; they each have centrally cleared general collateral repo markets, and the settlement convention is the same: three days following trade execution (t+3).

maturities with the corresponding-maturity K-spread; the 2-year Italian yield spread is decomposed with the 2-year K-spread, and so on. Similarly, I match the sovereign CDS spread maturities, and since the CDS are also country-specific, I additionally match these for each country in the sample. At each maturity point, Equation (3) is then fit as a separate seemingly unrelated regression (SUR). This allows for the restriction that β_{2m} is the same across countries, and accounts for contemporaneous cross-equation error correlation. The coefficient $\tilde{\beta}_{1cm}$ represents the intertemporal sensitivity of sovereign yield spreads to a common euro-area liquidity factor, directly measured by the K-spread, for each of the 77 country-maturity pairs. The coefficient β_{2m} measures the common loading across different country default premia, measured by country CDS spreads, at each of the seven maturities. An increase in the K-spread or the sovereign CDS spread means a deterioration in liquidity and credit, respectively.

Table 3 reports the sovereign bond spread estimation at the 2-, 5-, and 10-year maturities in Panels A, B and C, respectively, with the univariate results in the first four columns of each panel.¹⁹ Market liquidity and credit are independently significantly related to sovereign yield spreads at each maturity. The estimates for the regressions onto the K-spread alone are highly significant for 31 out of 33 country-maturity pairs, and a test of the hypothesis that $\tilde{\beta}_{1cm} = 0$ for all countries jointly is strongly rejected, supporting the idea that the measure identifies commonality in liquidity.

In a joint regression of sovereign yield spreads onto credit and liquidity together, both variables remain highly significant (Column 5), giving additional evidence that these two variables are independently important. Further, an average of the adjusted R-squared values by maturity in

¹⁹ Results across the other eight maturities are similar, and detailed in a web appendix (<http://finance.wharton.upenn.edu/~kschwarz/Mind%20the%20Gap%20Web%20Appendix.pdf>).

Column 6, shows that credit and liquidity together explain 80 to 85 percent of the variation in sovereign bond yield spreads. This is substantially more than is explained by either variable alone. For liquidity, the average univariate R-squared values range from 61 to 68 percent, depending on the maturity, and for credit, the univariate R-squared values range from 21 to 40 percent.

3.3 *The Relative Role of the K-spread versus Sovereign CDS Spreads*

To assess each country's relative sensitivity to liquidity versus credit, I consider the change in the sovereign bond yield spread associated with a one standard deviation shock to liquidity and a comparable shock to credit, using the coefficients estimated jointly in Column 5 of Table 3. The bond summary statistics in Table 1 are used for calibration; a one standard deviation deterioration in market liquidity corresponds to an 18 to 25 basis point increase in the K-spread (Panel C), depending on the maturity, and a comparable credit shock corresponds to a 5 to 66 basis point increase in the CDS spread (Panel A), depending on the country-maturity combination. Figure 5 summarizes these responses, comparing each country's yield spread sensitivity in basis points, averaged over maturities, to a one standard deviation credit (x axis) versus liquidity (y axis) worsening.

For countries in the upper right quadrant of Figure 5, such as Greece and Ireland, a negative shock to either credit or liquidity is associated with a higher spread. For those in the lower right quadrant, a negative liquidity shock has a spread-narrowing effect. German sovereign spreads show the greatest benefit from worsening liquidity, narrowing by 13 basis points, on average. In comparison, a one standard deviation deterioration in credit widens average German spreads by only 5 basis points. So, a concurrent and comparable deterioration in credit and liquidity would leave German sovereign spreads narrower on net, by 8 basis points. This dynamic is suggestive of a liquidity feedback effect in the euro-area sovereign debt market, whereby the most liquid

securities become more liquid and conversely for the least liquid securities (Amihud and Mendelson (1986), Dow (2004), Musto, Nini, and Schwarz (2017)). It is also consistent with Germany's anecdotal reputation as a euro-area liquidity haven, similar to the documented liquidity concentration in on-the-run U.S. Treasury securities (Krishnamurthy, 2002).

The two countries furthest from the origin in Figure 5 are clearly Greece and Ireland, showing the largest absolute sensitivity to both types of shocks. Irish bond sensitivity tilts toward credit, which may not be surprising since the Irish government explicitly raised its default risk by guaranteeing the debt of its private banks in 2008 to prevent their collapse. A country close to the default boundary would naturally be sensitive to further credit shocks. Greek bonds, on the other hand, are more than twice as sensitive to liquidity as compared to credit, on average. The Greek debt crisis had not yet taken hold during the sample period, though Greece's fiscal position was already the weakest in the euro area.

3.4 *Controlling for Country-Specific Liquidity*

To compare the K-spread with traditional liquidity measures, and to address the potential concern that a measure with German origins may not fully capture other countries' liquidity effects, Equation (3) is now expanded to contain the five country-specific market microstructure liquidity measures \tilde{X}_{cmt} , as defined in Section 2:

$$\tilde{y}_{cmt} = \tilde{\beta}_{1cm} \kappa_{mt} + \beta_{2m} \tilde{d}_{cmt} + \beta'_{3m} \tilde{X}_{cmt} + \tilde{\varepsilon}_{cmt} \quad (9)$$

The coefficient β_{3m} measures yield spread sensitivity to the additional liquidity measures at each maturity point. For two of the microstructure measures, the bid-ask spread and the Bollen-Whaley index, a higher value indicates deteriorating liquidity. For the remaining three measures (volume, trade size and order flow), a higher value denotes improving liquidity.

The two right-most columns of Table 3 show the expanded SUR results. A joint hypothesis test of the null that $\beta_{3m} = 0$, for all five market microstructure liquidity measures, is strongly rejected. However, no single microstructure measure is significant at all maturities, and the estimates are unstable in sign, except for trade size. The country CDS and the K-spread estimates remain highly significant and remarkably close to their values in the bivariate case. A comparison of the R-squared values for the different specifications shows little incremental benefit to adding the microstructure measures; averaged across countries and maturities, the adjusted R-squared is 83 percent with only sovereign CDS and the K-spread as explanatory variables, compared to 85 percent with the full specification.

The relatively small role for microstructure measures of liquidity is consistent with Beber, Brandt and Kavajecz (2009), who found that credit (measured with sovereign CDS spreads) was far more important than microstructure liquidity variables for euro-area sovereign yields over 2003 and 2004. In a calibration of the estimates from Equation (9) with the summary statistics in Table 1, a one standard deviation shock to the microstructure liquidity measures is associated with an average of less than 1 basis point change in sovereign yield spreads. Despite the empirical advantage of the microstructure measures in relating distinctly to each country's sovereign bond yield spreads, the K-spread and CDS remain paramount in explaining sovereign spreads. Section 5 sheds light on the nature of the liquidity effect – does it represent the manifestation of poor liquidity or the risk of worsening liquidity?

4. The Role of Aggregate Bond Market Liquidity in Euro-Area Interbank Spreads

The models of Brunnermeier and Pedersen (2009) and Bolton, Santos and Scheinkman (2011) describe a close relationship between bond and funding markets. This section empirically

assesses the effect of aggregate bond liquidity in the funding market by using the K-spread to parse interbank rates.

4.1 *Aggregate Bond Market Liquidity and Bank-Tiering Credit in Interbank Interest Rates*

To estimate risk effects in euro-area interbank rates, I conduct a time-series regression corresponding to the framework set out in Equation (5). The specification is:

$$\tilde{y}_{mt} = \beta_{1m}\kappa_t + \beta_{2m}d_t + \beta_{3m}d_t^{cds} + \beta'_{4m}X_t + \varepsilon_{mt} \quad (10)$$

where \tilde{y}_{mt} denotes the EURIBOR minus OIS spread at maturity m on day t , κ_t is the K-Spread measure of euro-area sovereign bond market liquidity²⁰, d_t is the bank-tiering measure of credit risk, d_t^{cds} is the average EURIBOR bank CDS premium and X_t is a vector containing the interbank market microstructure liquidity measures. Separate regressions are run for the 1-, 3-, 6- and 12-month EURIBOR-OIS maturities.

Table 4 shows the estimation results for Equation (10) in Panels A through D, at each of the four maturity points. Univariate regression estimates, reported in the first three columns of each panel, show that the K-spread, the bank-tiering credit measure, and the bank CDS premia, are each independently significant at the 1 percent level. The estimates are all positive, consistent with the intuition that a deterioration in either credit or aggregate market liquidity conditions would lead banks to charge one another a higher borrowing premium.

The fourth column of each panel in Table 4 shows the joint effect of credit and liquidity, estimated with a regression of EURIBOR-OIS spreads onto both the K-spread and the bank-tiering credit measure. In comparison to the univariate case, the K-spread coefficient estimates are nearly

²⁰ Results are reported when using the one-year maturity K-spread measure for the analysis of interbank spreads, but the estimation is not sensitive to the choice of maturity.

unchanged in size, but the bank-tiering credit estimates fall to less than one quarter of their size in univariate regressions. With these bivariate estimates and the summary statistics in Panel B of Table 2, I assess the EURIBOR-OIS spread sensitivity to a one standard deviation shock in credit and liquidity. A 9 basis point increase in bank tiering implies a 2 to 4 basis point EURIBOR-OIS spread increase, depending on the maturity. A comparable shock to the K-spread is associated with a 22 basis point increase in the 1-month EURIBOR-OIS spread, and a 49 basis point increase in the 12-month spread. For comparison, a typical ECB policy tightening is a 25 basis point increase in the policy rate. Considering that trillions of euros worth of contracts are linked to prevailing EURIBOR, worsening bond liquidity implies substantially tighter financial conditions.

4.2 Controlling for Bank CDS and Interbank Market Liquidity Effects

To address the possibility that bank CDS capture additional default risk in EURIBOR-OIS spreads, or that idiosyncratic interbank liquidity plays a role, I now estimate Equation (10) with these additional variables as controls. The fifth column of Table 4 reveals that the bank CDS estimates are unstable in sign and insignificant at 6- and 12-month maturities. Bank CDS premia explain little in interbank spreads beyond what is already captured by the K-spread and bank-tiering measures. The sixth column of Table 4 gives estimates with the full set of controls, now adding the five interbank microstructure liquidity measures (bid-ask, volume, bid-ask/volume, order flow and trade size). The interbank liquidity measures seem to contain little information, if any, beyond the liquidity effect from the K-spread. The adjusted R-squared values, when including the full set of controls, range from 86 to 92 percent (column 6), which is little changed from the range of 86 to 89 percent (column 5) without the five interbank liquidity measures. The final column of Table 4 shows the result from the expanded specification, including all variables except the K-spread. Without controlling for the K-spread measure of aggregate liquidity, the adjusted R-

Squared value falls by more than one-quarter (column 7).

The estimation results in Table 4 suggest that steps to improve market liquidity could narrow interbank spreads substantially, independent of any credit effect. In the fall of 2008, EURIBOR-OIS spreads rose from less than 10 basis points to 150 and 240 basis points at the 1- and 12-month maturities, respectively. Now, consider an extreme hypothetical counterfactual scenario in which all assets are made equally liquid. The K-spread would then be zero (below even the small positive spread prior to the crisis). Judging from the bivariate regression results in the fourth column of Table 4, this would narrow the sample average EURIBOR-OIS spread to 6 basis points at the 1-month maturity and 20 basis points at the 12-month maturity, closely approximating the narrowness of pre-crisis interbank spreads (illustrated in Figure 2, Panel B).²¹ The other regression specifications give similar implications.

The relatively small role for credit risk in the euro-area interbank market may seem surprising at first, but it could partly stem from a belief that government intervention would prevent near-term bank defaults, especially for the large banks that comprise the EURIBOR survey. Beginning in August 2007, U.S. and European central banks took many operational measures to target general funding pressures.²² Though such measures may mitigate default risk in the short run, they could exacerbate risk in the long run if the extraordinary measures taken are not sustainable. The importance of liquidity in interbank spreads is broadly consistent with the results

²¹ The sample average EURIBOR-OIS spread is 30.4 and 75.1 basis points at the 1- and 12-month maturities, respectively (Table 2, Panel A), and the K-spread is 26.4 basis points on average over the sample (Table 2, Panel B). At the 1-month maturity, the K-spread equal to 0 implies a decline in the 1-month EURIBOR-OIS spread to $0.94 \times 26.4 = 24.8$ basis points, and $2.08 \times 26.4 = 54.9$ basis points at the 12-month maturity. Subtracting these from the sample-average OIS spreads gives 1- and 12-month EURIBOR-OIS spreads of $30.4 - 24.8 = 6$ and $75.1 - 54.9 = 20$ basis points, respectively.

²² 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 (2009) for a detailed account of liquidity and credit events over this period.

of Gefang, Koop and Potter (2011) who find that a liquidity factor helps explain much of the variation in a panel dataset of LIBOR-OIS spreads. The large role for the K-spread suggests that it may capture a channel that is missed by the other liquidity measures considered. The pricing of liquidity risk will be directly tested for in the next section.

5. Pricing Liquidity Risk

Liquidity risk, defined as the covariance of sovereign bond returns with changes in market liquidity, is a forward-looking manifestation of market liquidity. Liquidity characteristics, such as trading volume, or model-based measures, such as the bid-ask spread, gauge prevailing market conditions. To the extent that the liquidity risk dimension matters, the effect of liquidity captured by instantaneous measures alone will be underestimated. The liquidity risk channel could help to explain the relatively small role for the traditional microstructure liquidity measures in euro-area interest rate spreads, as compared to the proposed K-spread liquidity measure that contains the risk information embedded in bond yields (Sections 3 and 4).

5.2 Estimating Each Country's Bond Return Sensitivity to Liquidity

The rich cross section of bond returns across countries and maturities in the euro-area is an ideal setting in which to directly test the pricing of liquidity risk.²³ I employ a two-step Fama MacBeth procedure to estimate liquidity risk premia. In the first step of the estimation, I assess the factor sensitivity of each country's sovereign bonds to changes in the K-spread by running a separate time series regression for each country-maturity combination, as follows:²⁴

$$\tilde{y}_{cmt} - \tilde{y}_{cmt-1} = \alpha_{cm} + \beta_{cm}^{Liq} (\kappa_{mt} - \kappa_{mt-1}) + \varepsilon_{cmt} \quad (11)$$

²³ The EURIBOR-OIS spread does not have the same cross-country variation needed for liquidity risk identification.

²⁴ The excess return is approximately the negative change in yield, multiplied by the duration.

where $\tilde{y}_{cmt} - \tilde{y}_{cmt-1}$ denotes the change in the country-maturity yield spread, relative to the corresponding 11-country average, from day $t-1$ to day t , and $\kappa_{mt} - \kappa_{mt-1}$ denotes the corresponding change in the K-spread. I estimate β_{cm}^{Liq} for each of the 77 country-maturity pairs, which identifies each country-maturity pair's sensitivity in sovereign bond returns to changes in aggregate market liquidity. An asset with a negative β_{cm}^{Liq} is a good hedge because it has high returns (narrowing yield spreads) when liquidity worsens, whereas an asset with a very positive β_{cm}^{Liq} has relatively low returns when aggregate liquidity deteriorates. The β_{cm}^{Liq} estimates range from -0.31 for Germany to 0.38 for Greece, both at the 5-year maturity, and the standard deviation of β_{cm}^{Liq} is 0.17. Variation in β_{cm}^{Liq} helps to precisely identify the price of liquidity risk in the next stage.

5.1 *A Systematic Relationship Between Country Sensitivity to Liquidity and Yield Spreads*

In the second stage of the Fama MacBeth procedure, I relate the cross-sectional variation in β_{cm}^{Liq} to the cross section of average yield spreads. In this step, to control for effects that are separate from liquidity risk, I include the sovereign CDS spreads and microstructure liquidity measures as considered in the sovereign decomposition in Section 3. The second stage cross-sectional regression is:

$$\tilde{y}_{cm} = \gamma_0 + \gamma_1 \hat{\beta}_{cm}^{Liq} + \gamma_2' X_{cm} + \varepsilon_{cm} \quad (12)$$

where \tilde{y}_{cm} is the sample average sovereign yield spread (relative to the euro-area average) for country c , at maturity m , $\hat{\beta}_{cm}^{Liq}$ is the coefficient estimate on the K-spread in the time series regression from Equation (11), and X_{cm} represents the CDS and microstructure liquidity

controls.²⁵ In this regression, γ_1 gives the market pricing of liquidity risk and γ_2 gives the direct effects of CDS spreads and liquidity characteristics on yield spreads. In the context of the liquidity controls, the coefficients γ_1 and γ_2 can be thought of as a liquidity factor and a liquidity characteristic, respectively, in the terminology of Daniel and Titman (1997).

The results in Table 5 show that liquidity risk is priced in sovereign bond markets, with or without including the control variables. The coefficient estimate, γ_1 , is highly significant and positive, in all specifications, reflecting the premium demanded by investors for the *risk* that bonds will become less liquid in the future. An investor demands a higher yield on bonds that are risky in the sense of offering lower returns when aggregate liquidity is poor. The coefficient estimate on sovereign CDS spreads, γ_2 , shown in the second and third columns of Table 5, is also highly significant and positive, consistent with the important role shown for credit in the sovereign yield spread estimation in Section 3. However, the incremental role of liquidity characteristics, as represented by the microstructure liquidity variables, is small once controlling for liquidity betas. The adjusted R-squared value from a regression onto $\hat{\beta}_{cm}^{Liq}$ and CDS alone is 87 percent, and this increases to 89 percent when including all of the liquidity characteristics.

Using the second stage regression estimates that include all controls (column 3 of Table 5), Figure 7 plots the average basis point effect of liquidity risk priced into country sovereign bond yield spreads, by maturity. Perhaps unsurprisingly, liquidity risk tends to play the smallest role in short-maturity bonds. German bonds benefit more from their potential to hedge worsening liquidity than any of the other euro-area country bonds. Because of this, German yields are 12 basis points lower on average over the sample. Italian and Greek sovereign bonds, on the other

²⁵ The strategy is similar in spirit to Calomiris, Love, and Peria (2012), who consider a cross-sectional regression of firms' average stock returns onto their time series betas with respect to crisis shocks.

hand, show sample average yields that are 13 and 14 basis points higher, respectively, due to liquidity risk premia. These bonds suffer most from the perceived risk of low returns in times of poor liquidity.

The results in this section evidence the large role of liquidity risk premia in euro-area yields over the crisis period, a channel of market liquidity that is not captured by traditional measures.

6. Conclusion

Beginning in August 2007, interest rate spreads across markets widened dramatically, threatening the stability of the financial system and the broader economy. There are two primary factors behind these movements: (1) a higher likelihood of default, and (2) market liquidity effects, separate from default risk. Policy prescriptions for addressing risk conditions differ, depending on the primary driver of interest rate spread widening. If the chief component is default, then only actions to improve the solvency of the issuer are likely to be successful. On the other hand, if the main driver is market liquidity, then measures to improve market functioning are the most appropriate. From a practitioner standpoint, a disruption to market liquidity may represent an attractive opportunity for a long-horizon investor to exploit, whereas deteriorating credit risk would not.

The first contribution of this paper is to construct a new measure of market liquidity from asset prices that does not rely on any single model of market liquidity. The measure is the difference in yields between two bonds that have identical credit risk but differing market liquidity: German KfW-agency bonds and their federal government counterparts. This spread, the K-spread liquidity measure, recovers all information in bond yields that is not related to default risk.

Second, the K-spread liquidity measure is used to estimate the precise contribution of credit and market liquidity risks, independent from one another, in explaining euro-area sovereign

bond and EURIBOR-OIS spreads during the 2007-2009 financial crisis. The K-spread shows a substantially larger role for market liquidity than traditional microstructure measures. Additionally, relating the K-spread measure to interbank rates gives empirical evidence of the large and significant influence of aggregate bond market liquidity on interbank rates, supporting the idea of a general equilibrium relationship between asset markets and funding markets.

Finally, through dispersion in return sensitivities over time, countries and maturities, I find large and highly significant liquidity factor risk premia in bonds over the crisis sample period. These risk premia represent compensation demanded by investors for the possibility that liquidity will worsen in the future at precisely the time when they most want to transact. The K-spread liquidity measure includes this liquidity risk channel because of its construction from forward-looking bond yields. In contrast, transaction-based measures of instantaneous liquidity will tend to understate the contribution of liquidity to interest rates by missing liquidity risk premia. This underestimation is most critical in times of market stress when risk premia play an important role.

The results in this paper have implications for policymakers and for the portfolio choices of investors. For practitioners, a long/short position mimicking the K-spread can hedge against credit fluctuations. The measure itself can gauge real-time pricing of market liquidity risk, helping to inform investment decisions. For policymakers, the results imply that measures to improve market functioning, or even an action that addresses risk perceptions alone, could be effective in bringing down risk spreads. Importantly, such measures 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.

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Appendix I

Bank Credit Tiering Measure Estimation

Default risk premia in unsecured interbank interest rates are unobservable, But, the *difference* in interbank borrowing rates at the same point in time controls for the common component and isolates the difference in risk premia between these borrowers.²⁶ The new bank-tiering credit measure takes the difference between two contemporaneous unsecured borrowing rates: the daily-average rate paid by banks in the highest quintile of credit and the daily-average rate paid by banks in the lowest quintile of credit. Considering only the spread between the two rates removes the common risks and market conditions that are faced by all market participants on the e-MID platform. The bank-tiering credit measure, d_t , driven by the *relative* credit premia of the two bank types, is defined as follows:

$$d_t = \bar{r}_{t,High} - \bar{r}_{t,Low} \quad (13)$$

where $\bar{r}_{t,High}$ and $\bar{r}_{t,Low}$ denote the average unsecured interbank borrowing rates paid by the banks in the highest and lowest risk quintiles, respectively, on day t .

To motivate this approach, 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 multiplicative of the form $b_j r_t$ where 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 of b_j be θ . Then the average credit premium on any day is r_t and the dispersion across banks on any day is θr_t . The average credit premium on day t is thus

²⁶ In the unsecured interbank market, the lender is fully exposed to the credit risk of the borrower, and this is the only credit risk that the lender faces. The interbank rate thus prices the likelihood of repayment by the borrower.

proportional to the dispersion in rates.²⁷ In this model, as the default risk of low credit institutions worsens, that of high credit institutions worsens proportionately more, and so an increase in the average rate difference between these two tiers of borrowers reflects an increase in the overall level of credit. The intuition is consistent with that of structural credit models. For instance, Merton’s 1974 model predicts that the credit premium is approximately proportional to rate volatility. It is also consistent with the idea that credit is largely driven by a systemic factor (Longstaff, Pan, Pedersen and Singleton (2011)).

To operationalize this bank-tiering measure, I use the unique database of signed interbank transactions from e-MID, an electronic interbank trading platform. These data show the negotiated rate and bank identities of the borrower and lender for each individual trade that takes place over the sample, plus the time stamp, maturity, volume, and the initiating side of each trade.²⁸ There are two key features of the e-MID platform that are important to the interpretation of the transaction rates. First, the lender in a trade is fully exposed to the default risk of a borrower in these trades that are facilitated but not backed by e-MID. This contrasts with trades in centrally cleared markets, such as futures, where the clearinghouse effectively becomes the counterparty to each trade. Second, e-MID transactions are identity-transparent; a participant can view all limit orders posted by platform participants, alongside of their respective bank identities, and can choose to take the other side of any order that is posted.²⁹ A bank will initiate a market order to lend only if the posted

²⁷ A simple example illustrates the model’s multiplicative assumption. Suppose $r_l = 1$ on a day with low credit and $r_h = 5$ on a day with high credit, 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 $r_{high} b_{worst} - r_{high} b_{best} = 5$.

²⁸ One distinct advantage of the new credit measure is that it is constructed from rates on actual unsecured interbank transactions and thus reflects true borrowing costs, whereas survey-derived rates such as LIBOR may be affected by manipulation. A comparison of LIBOR and other measures of bank borrowing costs is reported in Kuo, Skeie and Vickery (2012).

²⁹ In contrast, the MTS bond trading platform follows conventional price-time priority; trades are matched automatically based on the most attractive quote submitted, with priority given to the earliest submission. The

borrowing rate sufficiently compensates the lender for the risk of the trade. It follows that the credit-relevant information on e-MID comes from the rates on limit orders to borrow (or equivalently market orders to lend), where trades are agreed to with the foreknowledge of the borrower's identity.³⁰

I use the rate and borrower identity information in e-MID limit order data to form a bank-tiering measure of credit, in the following 3 steps.

1. First, to estimate banks' credit quality, I run the following pooled regression:³¹

$$r_{h,i,j,t} = \alpha + \sum_{h=1}^{m-1} \beta_{1,h} T_h + \sum_{j=1}^{n-1} \beta_{2,j} B_j + \sum_{t=1}^{T-1} \beta_{3,t} D_t + \varepsilon_{i,h,j,t} \quad (14)$$

where $r_{h,i,j,t}$ denotes the unsecured interbank rate paid by borrower j in its i^{th} transaction on day t in hour h . T_h denotes the time-of-day indicator variable for each hour, h , B_j denotes the indicator variable for bank borrower j , and D_t denotes the indicator variable for day t . The day and time indicators control for effects common to all rates, including interbank market-wide liquidity shocks.³² The bank dummy coefficient, $\beta_{2,j}$, estimates the average credit quality of each bank.³³ Considering only the borrowing side of the quote avoids any contribution of noise

counterparty's identity is revealed only after the trade is agreed to, which eliminates counterparty risk effects from bond trades on the MTS platform.

³⁰ The intuition behind an identity-transparent platform for interbank markets is that the interbank loan is effectively the equivalent to the traded asset in an asset market. Just as a bond market participant would find it difficult to price a bond without knowing the identity of the bond issuer, an interbank market participant would be reluctant to lend unsecured funds to a mystery borrower. The relationship between counterparty default risk and the credit of an interbank trade is precisely what drives the transparent information structure of the e-MID platform. The importance of the borrower's identity is evident; 81 percent of interbank lending volume in the sample is via market order. Following the crisis, e-MID introduced a parallel platform where identities were not revealed, but there was very little market interest to transact "confidentially."

³¹ Estimation is necessary because each bank in the sample has a unique but generic identifier that does not reveal the bank's actual identity. *A priori*, I cannot tell which banks are good/bad credits from their e-MID identifiers alone.

³² Controlling for the day effect in Equation (14) is important as the overall level of rates changed over the sample. The ECB raised its policy rate by 25 basis points on March 14, 2007 and again on June 13, 2007. Another way to isolate the credit component of interbank rates is to subtract the daily GC repo rate from the left-hand side of Equation (14). However, this approach confounds the credit component with repo market seasonality.

³³ 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

to the measure from the bid-ask bounce. I re-estimate the banks' creditworthiness each day, using the past 30 days of transactions, updating each banks' relative ranking based on its most recent borrowing rates.

2. Next, I sort borrowers into credit quintiles according to their $\beta_{2,j}$ credit coefficient estimates; the top quintile represents banks that paid the highest average rates, and are thus perceived as the worst credits.³⁴ Each quintile contains the same number of banks. For an apples-to-apples comparison, I use only maturity-matched trades.³⁵ To mitigate any survivorship bias, I only use rates of banks transacting in both the first and last quarters of the sample, reducing the bank sample to 135.

In the third and final step, I define the bank-tiering credit measure. Let $\bar{r}_{t,High}$ and $\bar{r}_{t,Low}$ denote the average rates paid by the banks in the highest and lowest risk quintiles, respectively, on day t (averaged across all hours on each day). The bank-tiering credit measure is then simply $\bar{r}_{t,High} - \bar{r}_{t,Low}$ as in equation (13).

Figure 4, Panel A plots the new bank-tiering credit measure, showing that it peaks at 63 basis points in October 2008. This compares a less-than 5 basis point difference in average rates paid by the best- versus worst-credit banks in normal times.

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.

³⁴ To check whether I have captured the difference between rates paid by high credit and low credit institutions, I consider the propensity to borrow via limit order versus market order for different credit quintiles. Low credit banks should prefer to borrow via limit order so that their identity is factored into the counterparty's lending rate; the lending bank will know that the borrower is low risk and will thus agree to a relatively low rate. It turns out that borrowing via market order as a fraction of total borrowing is 92 percent in the best credit quintile, compared to 57 percent in the lowest credit quintile. In fact, the propensity to borrow via limit order is monotonically increasing in credit quintile, supporting the idea that the grouping of banks by quintile has indeed separated the good credit banks from the bad credit banks.

³⁵ In the sample, 91 percent of transaction volume is agreed to for maturity on the following business day. This is comparable to the interbank market as a whole, in which the vast majority of transactions are overnight, to help banks meet day-to-day fluctuations in their funding needs.

Table 1. Sovereign Bond Market

Panel A: Sovereign Yield Spreads, Sovereign CDS Spreads, and Microstructure Liquidity Measures (Deviations from 11-Country € Average)

	Sovereign Yield Spread _c		Sovereign CDS _c		Bid-Ask _c		Volume _c		Trade Size _c		Order Flow _c		BW Index _c	
	(bps)		(bps)		(bps)		(€bn)		(€mn)		(€bn)		(ratio)	
	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
2-Year Maturity														
Austria	1.83	7.09	10.63	23.19	0.29	0.91	-0.11	0.09	1.39	1.91	-0.01	0.26	0.05	0.21
Belgium	4.49	5.26	-2.33	4.95	0.75	0.75	-0.09	0.09	1.02	2.13	-0.08	0.39	0.01	0.30
Germany	-14.97	16.52	-12.85	15.34	-0.19	0.36	-0.07	0.08	-0.01	1.88	0.02	0.18	0.08	0.26
Spain	5.07	6.76	5.96	6.69	0.62	0.64	-0.10	0.08	1.07	2.52	0.00	0.26	0.05	0.22
Finland	-7.42	7.62	-11.98	14.37	-0.28	1.02	-0.12	0.09	-0.60	2.76	0.00	0.21	0.18	0.31
France	-7.50	9.34	-11.63	13.60	0.39	0.52	-0.08	0.08	0.62	2.13	-0.04	0.21	0.03	0.21
Greece	42.60	47.52	32.90	40.47	0.29	0.93	-0.11	0.08	-0.69	2.37	0.02	0.22	0.11	0.28
Ireland	17.14	33.27	44.74	65.60	-0.75	1.09	-0.12	0.09	1.40	2.06	0.14	0.20	-0.09	0.21
Italy	14.54	16.37	15.35	18.15	-0.55	0.37	0.26	0.20	-2.02	1.30	0.02	0.24	-0.13	0.15
Netherlands	-9.75	10.48	-4.77	4.63	0.01	0.62	-0.09	0.14	2.39	4.74	0.03	0.63	-0.03	0.20
Portugal	14.00	13.73	4.39	5.57	-0.34	1.21	-0.07	0.09	1.24	1.81	0.02	0.44	-0.11	0.21
5-Year Maturity														
Austria	1.25	7.48	10.00	26.10	0.47	2.20	-0.05	0.07	0.90	2.33	-0.03	0.25	0.09	0.74
Belgium	7.33	7.99	-2.31	4.86	1.38	1.38	-0.01	0.08	0.55	1.96	-0.05	0.28	0.05	0.72
Germany	-23.37	22.26	-17.68	17.07	-2.18	1.70	-0.04	0.06	-0.55	1.81	0.00	0.17	0.07	0.64
Spain	4.33	7.16	10.17	8.26	1.26	2.40	-0.03	0.07	1.16	2.44	0.02	0.24	0.09	0.96
Finland	-3.34	4.24	-16.35	15.65	-0.15	2.08	-0.03	0.07	1.65	1.80	-0.12	0.36	-0.12	0.56
France	-8.52	9.74	-14.88	14.77	1.26	1.20	-0.04	0.06	-0.20	1.90	-0.01	0.16	0.15	0.60
Greece	54.94	59.45	41.69	43.41	0.41	1.84	-0.04	0.06	-0.42	2.01	0.00	0.16	0.20	0.68
Ireland	35.76	54.79	44.41	63.10	-0.44	1.78	-0.05	0.06	0.73	2.47	-0.01	0.27	-0.24	0.56
Italy	15.66	13.41	21.09	18.96	-0.74	1.25	0.16	0.19	-1.60	1.14	0.03	0.31	-0.27	0.46
Netherlands	-4.29	3.76	-9.20	6.46	-0.64	1.97	-0.03	0.12	2.35	2.64	0.04	0.51	-0.17	0.52
Portugal	16.09	15.69	7.32	6.73	0.52	2.14	-0.01	0.09	1.12	2.03	0.01	0.36	-0.14	0.47
10-Year Maturity														
Austria	-2.36	6.47	5.55	23.04	-0.16	3.79	-0.03	0.06	1.18	2.35	-0.02	0.22	-0.38	1.46
Belgium	-0.29	4.48	-5.13	6.45	1.30	3.97	-0.03	0.06	2.15	2.13	0.04	0.23	-0.27	1.37
Germany	-26.76	22.33	-21.73	19.15	-7.93	4.72	-0.02	0.06	1.21	2.15	-0.06	0.25	-0.99	1.34
Spain	1.44	6.56	9.07	7.79	0.79	4.50	-0.03	0.06	2.26	2.18	-0.03	0.20	-0.16	1.70
Finland	-13.19	7.27	-19.40	16.57	-2.89	4.91	-0.01	0.08	2.74	1.68	-0.19	0.47	-0.89	1.30
France	-13.43	12.75	-18.29	16.30	2.70	3.18	-0.03	0.06	-0.59	1.68	0.02	0.14	0.59	1.46
Greece	50.20	46.18	40.85	37.37	2.61	4.67	-0.02	0.06	-0.06	2.58	0.02	0.17	0.42	1.52
Ireland	34.64	55.50	39.14	56.05	-0.19	3.03	-0.03	0.06	0.97	2.68	-0.01	0.18	-0.08	1.57
Italy	20.93	13.44	21.37	15.44	-0.28	3.00	0.08	0.15	-1.96	1.04	0.02	0.19	0.02	1.40
Netherlands	-11.74	8.91	-12.79	8.06	3.40	6.50	-0.02	0.15	0.91	2.80	0.06	0.72	0.38	2.15
Portugal	11.27	10.14	6.13	8.95	-0.27	5.24	0.01	0.09	0.23	2.08	-0.04	0.44	-0.30	1.77

Panel B: Credit and Liquidity Correlation, by Maturity							
	K-Spread (bps)	Sovereign CDS (bps)	Bid-Ask (bps)	Volume (€bn)	Trade Size (€mn)	Order Flow (€bn)	BW Index (ratio)
2-Year Maturity							
K-Spread	1.00						
Sovereign CDS	0.19	1.00					
Bid-Ask	-0.12	-0.12	1.00				
Volume	0.17	0.07	-0.17	1.00			
Trade Size	0.00	-0.05	0.02	-0.08	1.00		
Order Flow	0.04	0.06	-0.11	0.14	0.13	1.00	
BW Index	-0.12	-0.19	0.30	-0.24	-0.30	-0.01	1.00
5-Year Maturity							
K-Spread	1.00						
Sovereign CDS	0.21	1.00					
Bid-Ask	0.03	-0.07	1.00				
Volume	0.04	0.04	-0.10	1.00			
Trade Size	-0.05	-0.22	0.03	0.02	1.00		
Order Flow	0.03	0.03	0.00	0.16	0.09	1.00	
BW Index	-0.03	-0.07	0.26	-0.21	-0.37	-0.01	1.00
10-Year Maturity							
K-Spread	1.00						
Sovereign CDS	0.15	1.00					
Bid-Ask	0.11	0.20	1.00				
Volume	0.05	0.02	-0.12	1.00			
Trade Size	-0.07	-0.21	-0.20	0.07	1.00		
Order Flow	0.05	0.02	0.12	0.21	0.00	1.00	
BW Index	-0.05	0.09	0.41	-0.14	-0.37	0.08	1.00

Panel C: K-Spread Statistics and Correlation with Euro-Area Average Microstructure Measures							
	K-Spread (bps)		Bid-Ask _€ (bps)	Volume _€ (€bn)	Trade Size _€ (€mn)	Order Flow _€ (€bn)	BW Index _€ (ratio)
	Mean	St Dev	Correlation with K-Spread				
2-Year Maturity	30.70	25.23	0.70	-0.55	0.01	0.01	0.49
5-Year Maturity	35.72	24.87	0.83	-0.36	-0.17	0.03	0.60
10-Year Maturity	27.60	18.30	0.82	-0.33	-0.52	0.03	0.58

Table 1. This table reports summary statistics for euro-area sovereign bonds, at the 2-, 5-, and 10-year maturities. Panel A reports the mean and standard deviation for sovereign zero-coupon yield spreads, CDS spreads and microstructure liquidity measures for each of the 11 countries separately. Each of the measures is expressed as the country indicator's deviation from the sovereign debt-weighted euro-area average indicator. Panel B reports correlations among the K-spread liquidity measure and the other sovereign bond market measures that are reported in Panel A. The correlations are run separately for each maturity, using all country data. The CDS spreads and microstructure liquidity measures are de-measured, but the K-spread is not, as it does not vary by country. Panel C reports the K-spread mean and standard deviation, and the K-spread's correlation with the euro-area average of each of the microstructure liquidity indicators. All statistics are formed from data at the daily frequency. The sample period is from January 1, 2007 to September 30, 2009.

Table 2. Interbank Money Market

Panel A: Interest Rates and Spreads by Maturity								
	EURIBOR		OIS		EURIBOR - OIS			
	(pct pts)		(pct pts)		(bps)			
	Mean	St Dev	Mean	St Dev	Mean	St Dev		
1-Month Maturity	3.33	1.47	3.02	1.45	30.41	29.54		
3-Month Maturity	3.63	1.45	3.02	1.48	60.04	42.33		
6-Month Maturity	3.73	1.40	3.04	1.51	69.05	48.19		
12-Month Maturity	3.84	1.37	3.09	1.48	75.06	53.88		

Panel B: Credit and Liquidity Indicators								
	K-Spread	Bank-Tiering	Bank CDS	Bid-Ask	Volume	Trade Size	Order Flow	BW Index
	(bps)	(bps)	(bps)	(bps)	(€bn)	(€mn)	(€bn)	(ratio)
Mean	26.40	8.27	59.26	4.52	11.29	33.35	-7.40	1.01
Std. Dev.	23.57	9.03	56.79	6.28	6.15	14.12	4.66	1.91
Correlation								
K-Spread	1.00							
Bank-Tiering	0.74	1.00						
Bank CDS	0.69	0.59	1.00					
Bid-Ask	0.19	0.39	0.58	1.00				
Volume	-0.56	0.22	-0.69	-0.61	1.00			
Trade Size	-0.52	0.37	0.54	0.51	0.15	1.00		
Order Flow	0.42	-0.48	-0.60	-0.55	-0.58	-0.12	1.00	
BW Index	0.06	-0.44	0.41	0.92	-0.90	-0.51	0.50	1.00

Table 2. This table reports summary statistics for euro-area interbank money markets. Panel A reports the mean and standard deviation of the EURIBOR and OIS rates and spreads at 1-, 3-, 6-, and 12-month maturities. Panel B reports the mean and standard deviation for the one-year maturity K-spread liquidity measure, the overnight bank-tiering credit measure, the overnight interbank market microstructure liquidity measures and the one-year euro-area average bank CDS premia. Correlations among these indicators are also reported. The K-spread is constructed as the one-year KfW yield minus the one-year German federal government yield. The bank-tiering credit measure is formed as the difference in average unsecured interbank borrowing rates paid by the banks in the highest and lowest risk quintiles (estimated in Appendix 1) on each day, using data on overnight interbank borrowing transactions from a large electronic trading platform, e-MID. The market microstructure liquidity measures are also formed with the overnight interbank data. The bank CDS measure is the simple average of the EURIBOR panel banks' one-year CDS premia on each day. The sample period is from January 1, 2007 to September 30, 2009.

Table 3. Credit versus Liquidity in the Bond Market

Dependent Variable: Sovereign Yield Spread_{cm}t

Panel A: 2-Year Maturity

	Country	Est.	Adj. R ²	Est.	Adj. R ²	Est.	Adj. R ²	Est.	Adj. R ²
		(SE)		(SE)		(SE)		(SE)	
K-Spread	Austria	0.00 (0.03)	0.00	-0.10*** (0.01)	0.47	-0.09*** (0.01)	0.59		
	Belgium	0.18*** (0.01)	0.72	0.18*** (0.00)	0.83	0.18*** (0.00)	0.86		
	Finland	-0.26*** (0.01)	0.76	-0.13*** (0.00)	0.89	-0.15*** (0.00)	0.92		
	France	-0.32*** (0.02)	0.73	-0.15*** (0.00)	0.96	-0.17*** (0.00)	0.97		
	Germany	-0.62*** (0.03)	0.90	-0.40*** (0.00)	0.98	-0.42*** (0.00)	0.98		
	Greece	1.60*** (0.13)	0.72	1.12*** (0.01)	0.97	1.16*** (0.01)	0.98		
	Ireland	1.00*** (0.10)	0.58	0.28*** (0.02)	0.75	0.32*** (0.02)	0.80		
	Italy	0.59*** (0.02)	0.83	0.35*** (0.01)	0.95	0.38*** (0.01)	0.96		
	Netherlands	-0.31*** (0.02)	0.57	-0.28*** (0.01)	0.78	-0.28*** (0.01)	0.81		
	Portugal	0.50*** (0.03)	0.86	0.44*** (0.00)	0.94	0.44*** (0.00)	0.94		
Spain	0.23*** (0.02)	0.76	0.15*** (0.00)	0.83	0.15*** (0.00)	0.85			
Sovereign CDS _c	Joint		0.42*** (0.00)	0.30	0.31*** (0.00)	0.27*** (0.00)			
Bid-Ask _c	Joint					-0.21*** (0.05)			
Volume _c	Joint					-3.96*** (0.37)			
Trade Size _c	Joint					-0.02 (0.02)			
Order Flow _c	Joint					0.27** (0.13)			
BW Index _c	Joint					-0.27 (0.17)			

Hypothesis Tests

	F-Statistic	F-Statistic	F-Statistic
H ₀ : $\tilde{\beta}_{1cm} = 0$	9244.36***	2940.57***	5128.03***
H ₀ : $\beta_{2m} = 0$		4962.43***	2299.94***
H ₀ : $\beta_{3m} = 0$			16.71***

Panel B: 5-Year Maturity

	Country	Est.	Adj. R ²	Est.	Adj. R ²	Est.	Adj. R ²	Est.	Adj. R ²
		(SE)		(SE)		(SE)		(SE)	
K-Spread	Austria	0.14*** (0.03)	0.23	-0.06*** (0.00)	0.81	-0.06*** (0.00)	0.82		
	Belgium	0.29*** (0.01)	0.84	0.25*** (0.00)	0.89	0.25*** (0.00)	0.91		
	Finland	-0.08*** (0.01)	0.23	0.06*** (0.00)	0.54	0.07*** (0.00)	0.62		
	France	-0.34*** (0.02)	0.77	-0.13*** (0.00)	0.93	-0.13*** (0.00)	0.94		
	Germany	-0.85*** (0.03)	0.91	-0.55*** (0.00)	0.98	-0.55*** (0.00)	0.99		
	Greece	2.11*** (0.13)	0.78	1.32*** (0.02)	0.94	1.32*** (0.02)	0.95		
	Ireland	1.49*** (0.19)	0.46	0.71*** (0.02)	0.94	0.69*** (0.02)	0.94		
	Italy	0.48*** (0.04)	0.79	0.26*** (0.01)	0.93	0.25*** (0.01)	0.93		
	Netherlands	-0.09*** (0.01)	0.33	-0.04*** (0.00)	0.71	-0.03*** (0.00)	0.74		
	Portugal	0.56*** (0.03)	0.79	0.44*** (0.01)	0.93	0.44*** (0.01)	0.93		
Spain	0.22*** (0.02)	0.56	0.07*** (0.00)	0.63	0.07*** (0.00)	0.64			
Sovereign CDS _c	Joint		0.31*** (0.00)	0.40	0.31*** (0.00)	0.32*** (0.00)			
Bid-Ask _c	Joint					-0.03 (0.02)			
Volume _c	Joint					-3.02*** (0.49)			
Trade Size _c	Joint					-0.07*** (0.02)			
Order Flow _c	Joint					0.04 (0.13)			
BW Index _c	Joint					-0.38*** (0.07)			

Hypothesis Tests

	F-Statistic	F-Statistic	F-Statistic
H ₀ : $\tilde{\beta}_{1cm} = 0$	9244.36***	4969.22***	4550.69***
H ₀ : $\beta_{2m_1} = 0$		4345.31***	4563.43***
H ₀ : $\beta_{3m_1} = 0$			10.89***

Panel C: 10-Year Maturity									
	Country	Est.	Adj. R ²	Est.	Adj. R ²	Est.	Adj. R ²	Est.	Adj. R ²
		(SE)		(SE)		(SE)		(SE)	
K-Spread	Austria	0.15*** (0.04)	0.19			-0.14*** (0.01)	0.64	-0.12*** (0.01)	0.64
	Belgium	0.04 (0.03)	0.02			0.06*** (0.00)	0.37	0.06*** (0.00)	0.43
	Finland	-0.35*** (0.02)	0.76			-0.22*** (0.01)	0.93	-0.21*** (0.01)	0.95
	France	-0.64*** (0.03)	0.85			-0.33*** (0.00)	0.97	-0.34*** (0.01)	0.97
	Germany	-1.16*** (0.04)	0.90			-0.78*** (0.01)	0.98	-0.77*** (0.01)	0.98
	Greece	2.35*** (0.10)	0.87			1.52*** (0.02)	0.94	1.53*** (0.02)	0.95
	Ireland	2.32*** (0.20)	0.59			1.07*** (0.02)	0.94	1.09*** (0.02)	0.94
	Italy	0.67*** (0.04)	0.84			0.51*** (0.01)	0.97	0.51*** (0.01)	0.98
	Netherlands	-0.45*** (0.01)	0.84			-0.31*** (0.00)	0.95	-0.32*** (0.00)	0.96
	Portugal	0.43*** (0.06)	0.59			0.38*** (0.01)	0.82	0.38*** (0.01)	0.83
	Spain	0.23*** (0.04)	0.41			0.03*** (0.01)	0.29	0.05*** (0.01)	0.42
Sovereign CDS _c	Joint			0.39*** (0.00)	0.21	0.29*** (0.00)		0.28*** (0.00)	
Bid-Ask _c	Joint							0.04*** (0.01)	
Volume _c	Joint							0.97* (0.50)	
Trade Size _c	Joint							-0.13*** (0.02)	
Order Flow _c	Joint							-0.19* (0.10)	
BW Index _c	Joint							0.19*** (0.03)	
Hypothesis Tests									
		F-Statistic			F-Statistic			F-Statistic	
H ₀ : $\tilde{\beta}_{1cm} = 0$		9244.36***			3362.65***			1946.88***	
H ₀ : $\beta_{3m} = 0$					1808.37***			2274.84***	
H ₀ : $\beta_{5m} = 0$								39.85***	

Table 3. This table reports the coefficient estimates from the estimation of equation (3) regressions of yield spreads onto the K-spread liquidity measure alone and on the sovereign CDS spreads alone. The fifth and sixth columns report the results of regressions of yield spreads onto the K-spread and sovereign CDS spreads jointly. The final two columns augment these regressions with sovereign bond market microstructure liquidity measures, as in equation (9). All equations are estimated at the daily frequency over the sample period from January 1, 2007 to September 30, 2009 using seemingly unrelated regressions for each maturity point separately. Newey-West standard errors are in parentheses with the Newey (1994) lag length. One, two and three asterisks denote statistical significance at the 10, 5 and 1, percent levels, respectively. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 4. Credit versus Liquidity in the Money Market

Dependent Variable: EURIBOR - OIS Spread_{mt}

Regressions onto K-Spread, Bank Tiering Credit Measure, Bank CDS Premia, and Microstructure Liquidity Measures

	Panel A: 1-Month Maturity						Panel B: 3-Month Maturity							
K-Spread	1.08*** (0.07)		0.94*** (0.07)	1.23*** (0.05)	1.29*** (0.06)		1.67*** (0.07)		1.61*** (0.08)	1.78*** (0.08)	1.76*** (0.09)			
Bank-Tiering		2.32*** (0.20)	0.49** (0.24)	0.74*** (0.11)	0.58*** (0.12)	2.31*** (0.20)		3.30*** (0.31)	0.20 (0.22)	0.34** (0.16)	0.14 (0.16)	2.51*** (0.27)		
Bank CDS			0.21*** (0.04)	-0.21*** (0.02)	-0.25*** (0.03)	-0.01 (0.04)		0.42*** (0.06)		-0.12*** (0.03)	-0.24*** (0.03)	0.09* (0.05)		
Bid-Ask					0.94*** (0.26)	-1.46*** (0.51)					1.39*** (0.35)	-1.88*** (0.69)		
Volume					0.01 (0.33)	-1.93** (0.77)					-1.22** (0.55)	-3.93*** (1.07)		
Trade Size					-0.07 (0.14)	-0.18 (0.22)					-0.14 (0.14)	-0.26 (0.25)		
Order Flow					-0.17 (0.16)	-1.29*** (0.41)					-0.20 (0.40)	-1.83*** (0.67)		
BW Index					-1.93** (0.79)	-1.17 (1.49)					-4.18*** (1.11)	-3.07 (1.98)		
R ² - Adjusted (%)	75.81	50.27	16.08	76.81	85.51	85.87	59.93	86.31	49.53	31.07	86.38	87.76	89.55	66.49
	Panel C: 6-Month Maturity						Panel D: 12-Month Maturity							
K-Spread	1.92*** (0.08)		1.81*** (0.09)	1.84*** (0.10)	1.86*** (0.10)		2.14*** (0.09)		2.08*** (0.11)	2.16*** (0.12)	2.13*** (0.12)			
Bank-Tiering		3.88*** (0.36)	0.41** (0.20)	0.44** (0.20)	0.20 (0.19)	2.69*** (0.30)		4.21*** (0.39)	0.20 (0.26)	0.26 (0.25)	0.06 (0.23)	2.91*** (0.35)		
Bank CDS			0.54*** (0.06)	-0.03 (0.04)	-0.19*** (0.04)	0.15*** (0.05)		0.59*** (0.07)		-0.05 (0.05)	-0.23*** (0.05)	0.17** (0.07)		
Bid-Ask					1.20*** (0.31)	-2.23*** (0.68)					1.20*** (0.45)	-2.74*** (0.86)		
Volume					-2.55*** (0.58)	-5.40*** (1.03)					-3.38*** (0.76)	-6.65*** (1.18)		
Trade Size					0.12 (0.13)	-0.01 (0.22)					0.27 (0.17)	0.12 (0.25)		
Order Flow					-0.66* (0.39)	-2.37*** (0.65)					-1.00** (0.44)	-2.96*** (0.72)		
BW Index					-2.67*** (0.94)	-1.50 (1.81)					-3.31*** (1.23)	-1.97 (2.23)		
R ² - Adjusted (%)	88.39	52.89	40.52	88.64	88.67	91.63	71.92	87.62	49.65	38.03	87.65	87.80	90.49	69.71

Table 4. This table reports the results from regressing the EURIBOR-OIS spread at different maturities onto the one-year K-spread liquidity measure, the proposed overnight bank-tiering credit measure, the one-year bank CDS premia, and overnight interbank market microstructure liquidity measures, as in equation (10). The equation is estimated at the daily frequency, over the sample period from January 1, 2007 to September 30, 2009. Newey-West standard errors are in parentheses with the Newey (1994) lag length. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 5. Liquidity Risk Pricing in the Cross Section of Sovereign Bond Yield Spreads

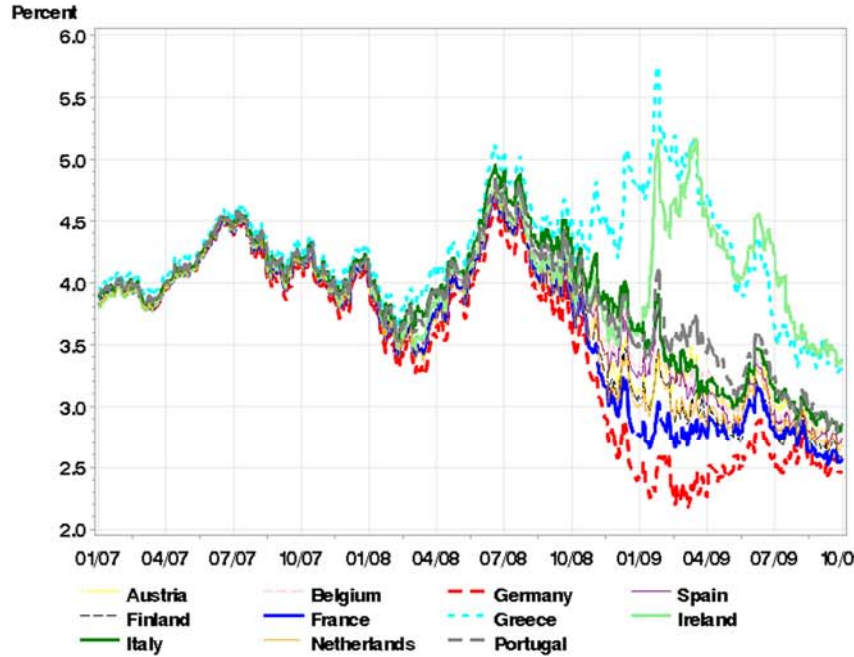
	Dependent Variable: Average Sovereign Yield Spread _{ct}		
	Regression onto Credit and Liquidity Indicators		
$\hat{\beta}_{cm}^{Liq}$	93.77*** (21.55)	34.34** (13.70)	50.09*** (12.95)
Sovereign CDS _{cm}		0.68*** (0.10)	0.62*** (0.05)
Bid-Ask _{cm}			-0.90 (1.48)
Volume _{cm}			-15.87 (12.82)
Trade Size _{cm}			1.13 (1.22)
Order Flow _{cm}			-44.38** (18.66)
BW Index _{cm}			14.85 (10.93)
R ² - Adjusted (%)	64.03	86.62	89.01

Table 5. This table reports the results from a cross-sectional regression as in equation (12) over all country-maturity pairs of average yield spreads onto the liquidity beta estimates (from equation (11)), sovereign CDS spreads, and sovereign market microstructure liquidity measures. Standard errors, clustered by country, are included in parentheses. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Figure 1. Euro-Area Government Bond Market

Panel A: Country Yields

5-Year Maturity



Panel B: Country Yields minus 11-Country Average Yield

5-Year Maturity

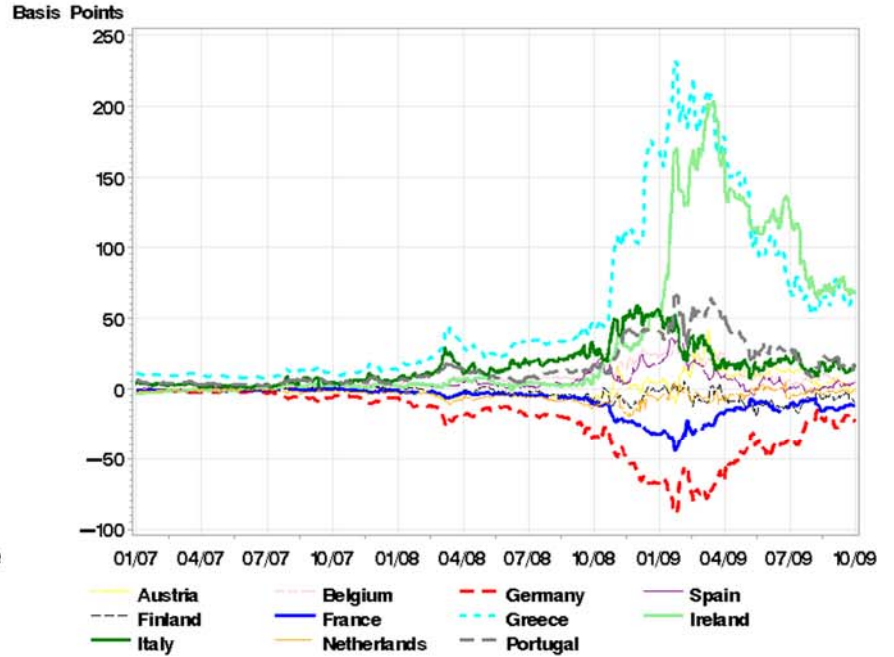


Figure 1. This figure shows government debt yields (Panel A) and spreads (Panel B) for each of the 11 euro-area countries in the sample, at the 5-year maturity, at a daily frequency. The yield spread is defined as $\tilde{y}_{cmt} = y_{cmt} - \sum_{c'=1}^{11} w_{c'm} y_{c'mt}$, where \tilde{y}_{cmt} is the sovereign yield spread for country c , at the m -year maturity point,

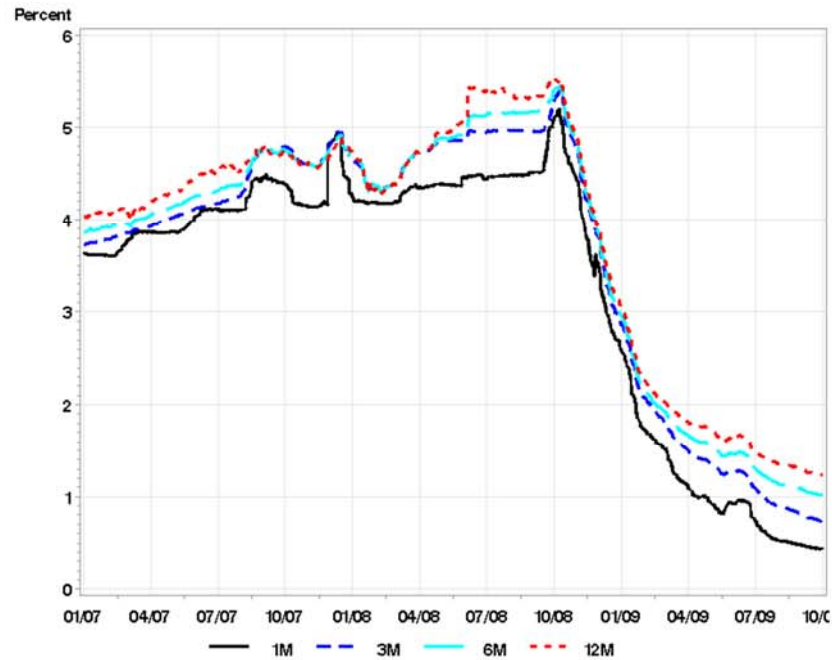
on day t , minus the euro-area weighted-average yield, as in Equations (2) and (3). The weights are defined as $w_{cm} = \frac{Q_{cm}}{\sum_{c'=1}^{11} Q_{c'm}}$, where Q_{cm} is the quantity of debt

outstanding for each country, c , at each maturity point m and c' is a counter variable indexing each of the countries for the purpose of computing the euro-area weighted average. These are based on zero-coupon yields, formed from smoothed curves fitted to all coupon securities, estimated separately for each country and each day.

Figure 2. Euro-Area Money Market

Panel A: EURIBOR Rates

1-, 3-, 6-, 12-Month Maturities



Panel B: EURIBOR minus OIS Interest Rate Spreads

1-, 3-, 6-, 12-Month Maturities

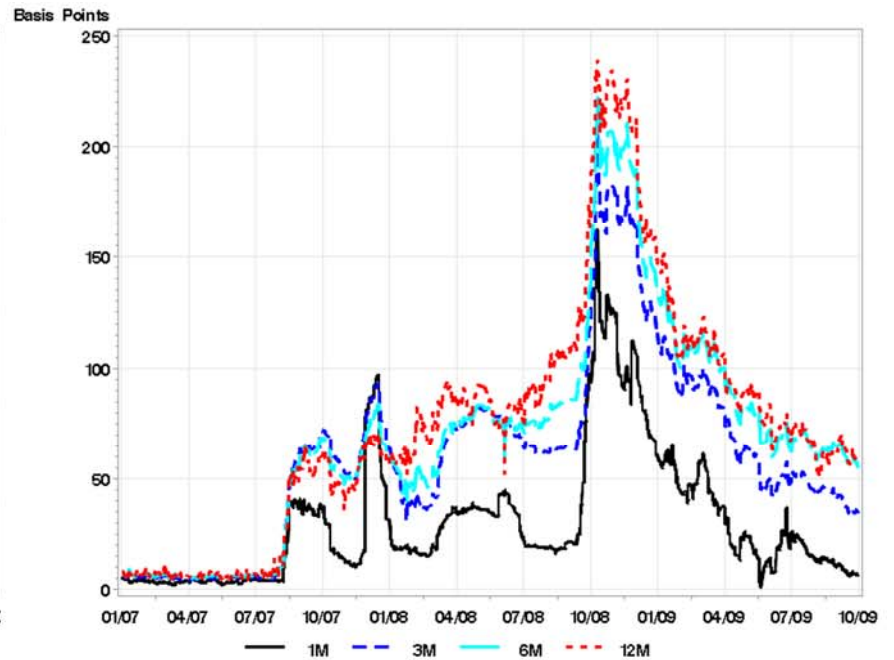


Figure 2. This figure shows interest rate levels (Panel A) and spreads (Panel B) for euro-area interbank money markets for the 1-, 3-, 6- and 12-month maturities, at a daily frequency. Panel A shows the level of EURIBOR rates. Panel B shows the EURIBOR-OIS interest rate spread, defined as the EURIBOR rate minus the comparable-maturity OIS rate.

Figure 3. K-Liquidity Spread and Country CDS Spreads

Panel A: K-Liquidity Spread (KfW Yield minus German Government Yield)

Panel B: Country CDS Spread (Country Premia minus 11-Country Average)

1- and 5-Year Maturities

5-Year Maturity

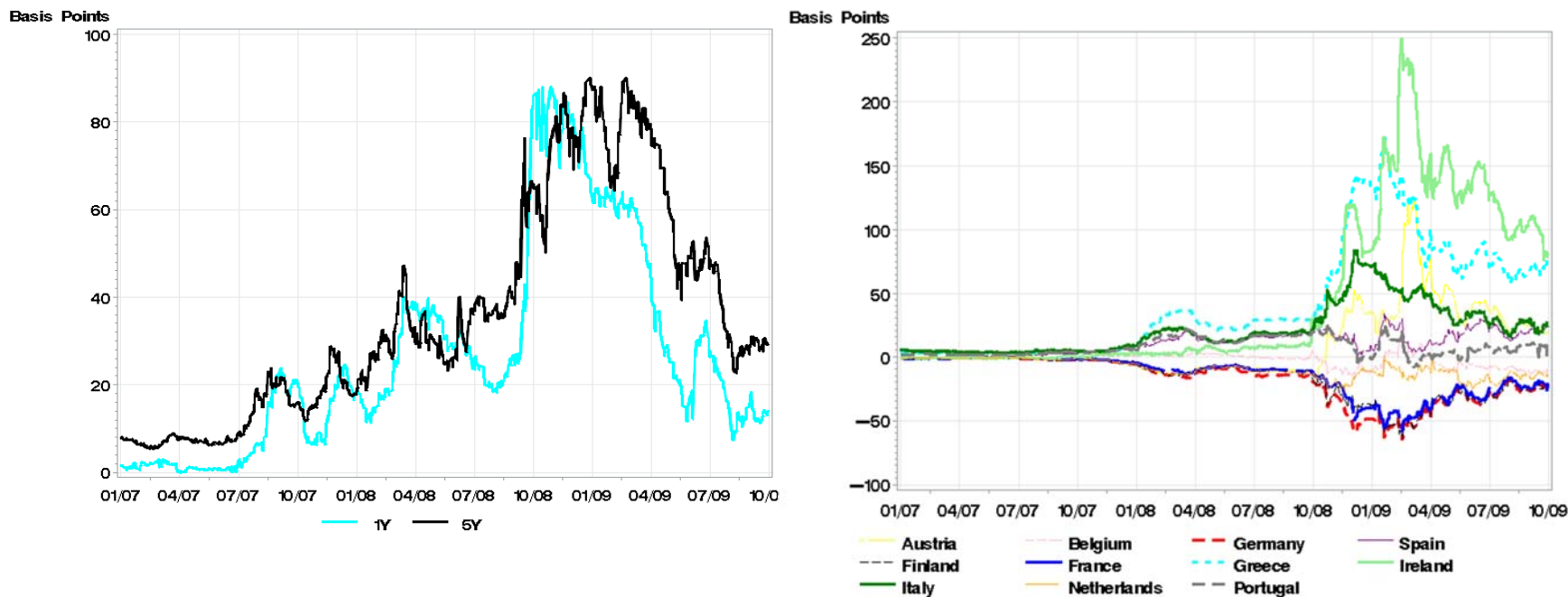


Figure 3. This figure shows a time series of the K-spread liquidity measure and the CDS spread credit measure, at a daily frequency. Panel A shows the K-spread liquidity measure, at the 1- and 5-year maturities. The K-spread is constructed as the KfW yield minus the comparable-maturity German federal government yield (both zero-coupon yields, formed from smoothed curves fitted to all coupon securities, estimated separately for each day). Panel B shows the Credit Default Swap (CDS) spreads for the sovereign debt of each of the 11 euro-area countries in the sample, relative to the 11-country average CDS premium, notated as

$$\tilde{d}_{cmt} = d_{cmt} - \sum_{c'=1}^{11} w_{c'm} d_{c'mt}$$

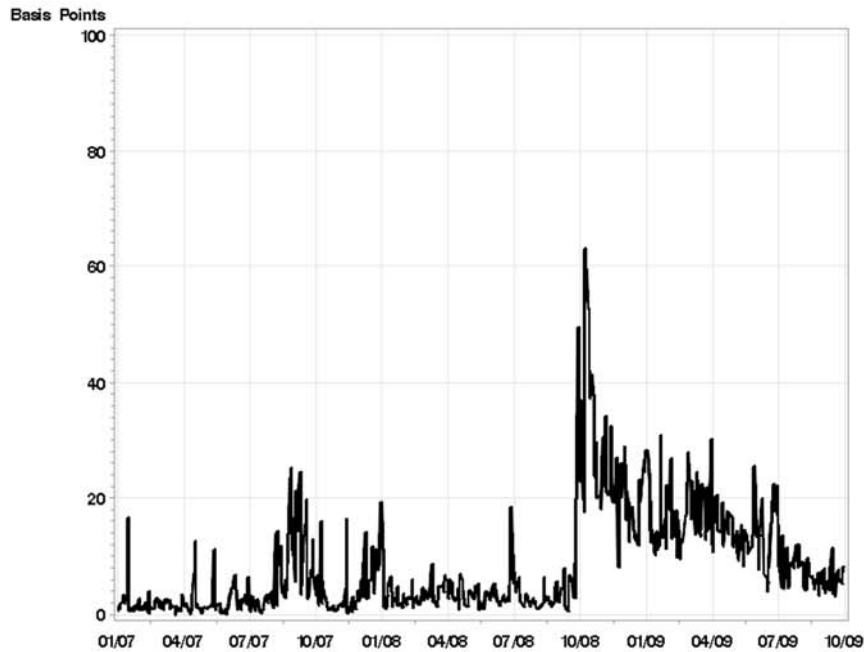
in Equations (2) and (3). The weights are defined as $w_{cm} = \frac{Q_{cm}}{\sum_{c'=1}^{11} Q_{c'm}}$, where Q_{cm} is the quantity of debt outstanding for each country, c ,

at each maturity point m and c' is a counter variable indexing each of the countries for the purpose of computing the euro-area weighted average.

Figure 4. Money Market Credit Measures

Panel A: Bank-Tiering Credit Spread

1-Day Maturity



Panel B: Average EURIBOR-Panel Bank CDS Premia

1-Year Maturity



Figure 4. This figure plots the time series of the two credit measures used to decompose interbank money market spreads at a daily frequency. Panel A shows the overnight bank-tiering credit measure, which is formed as the difference in average unsecured interbank borrowing rates paid by the banks in the highest and lowest risk quintiles (estimated in Appendix 1) on each day. Panel B shows the one-year bank CDS measure, which is the simple average of the EURIBOR panel banks' one-year CDS premia on each day.

Figure 5. Basis Point Change in Sovereign Bond Yield Spreads Explained by One Standard Deviation Shocks to Credit and Liquidity

All Countries (Maturity-Averaged)

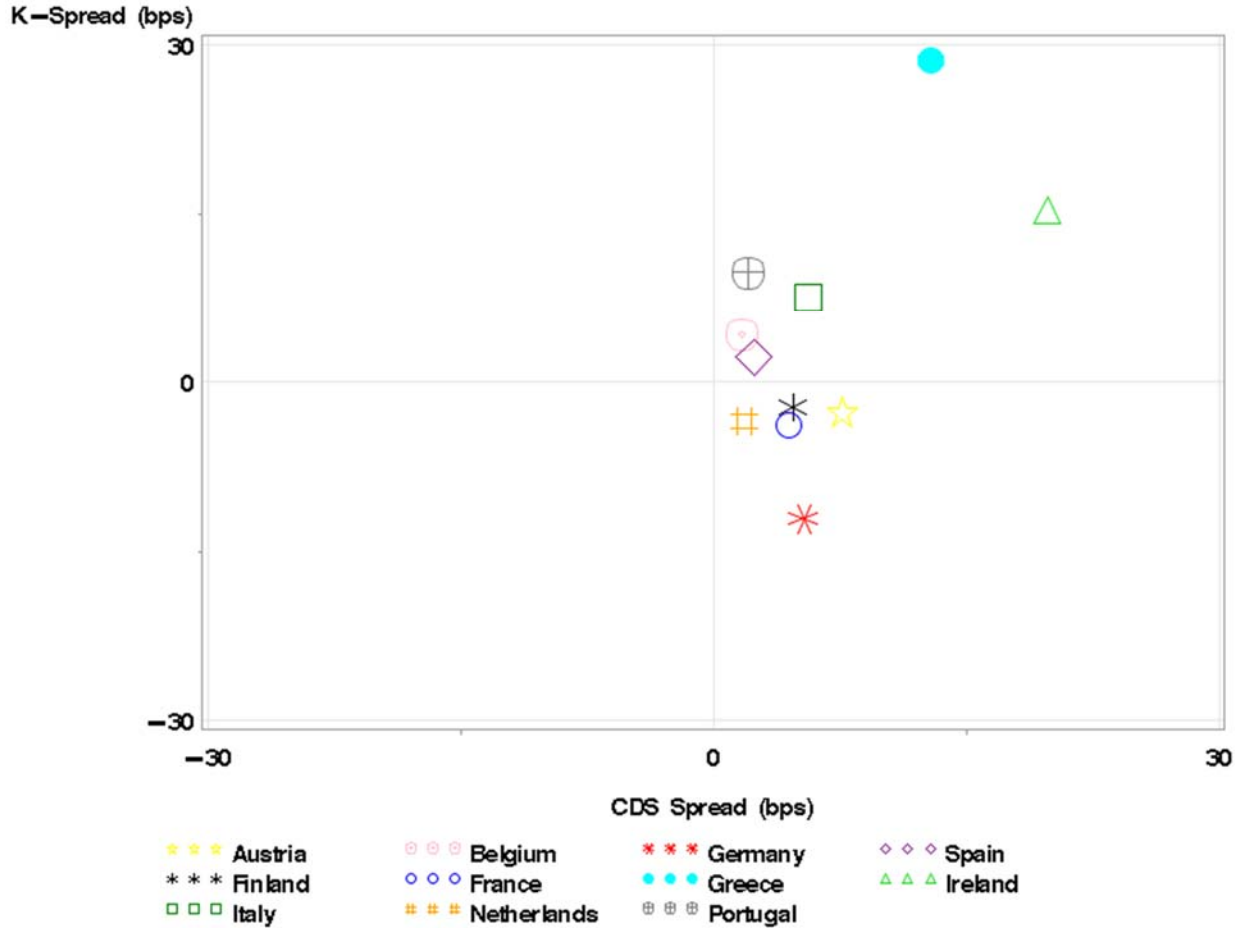


Figure 5. This figure plots the basis point change in country sovereign bond yield spreads (averaged across maturities) associated with a one standard deviation increase in the country CDS spread (x axis) versus a one standard deviation increase in the K-spread (y axis). The plotted values are based on coefficient estimates from a regression of sovereign bond yield spreads onto the K-spread and the country sovereign CDS spreads, shown in column 5 of Table 3. The country sovereign CDS spread and the K-spread standard deviations are shown in Panels A and C of Table 1.

Figure 6. Basis Point Change in EURIBOR-OIS Spreads Explained by One Standard Deviation Shocks to Credit and Liquidity

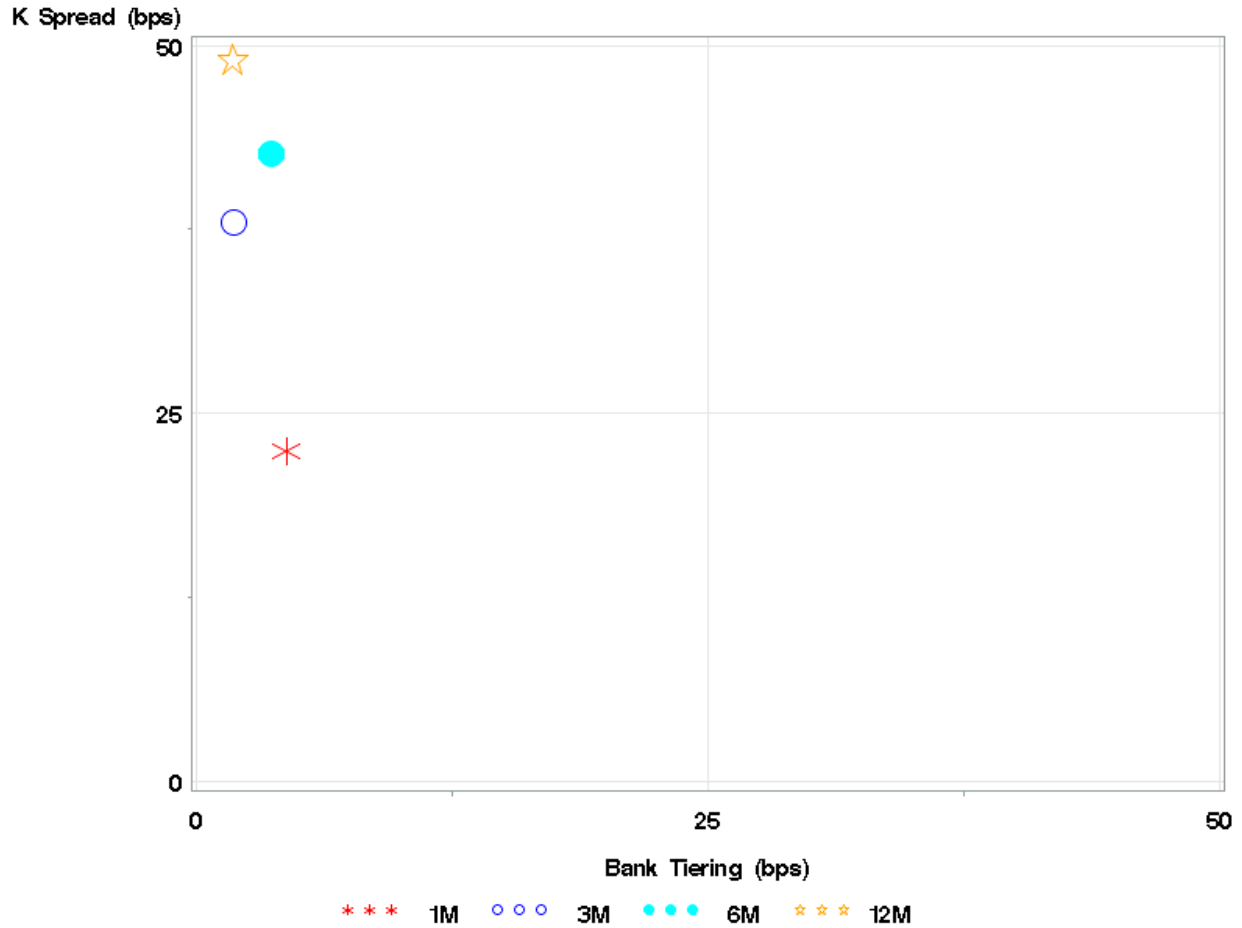


Figure 6. This figure plots the basis point change in EURIBOR-OIS spreads, by maturity, associated with a one standard deviation increase in the country bank-tiering credit measure (x axis) versus a one standard deviation increase in the K-spread (y axis). The plotted values are based on coefficient estimates from a regression of EURIBOR-OIS spreads onto the K-spread and the bank-tiering credit measure jointly, shown in column 4 in Panels A through D of Table 4. The bank-tiering credit measure and the K-spread standard deviation are shown in Panel B of Table 2.

Figure 7. The Sensitivity of Government Bond Yields to Liquidity Risk

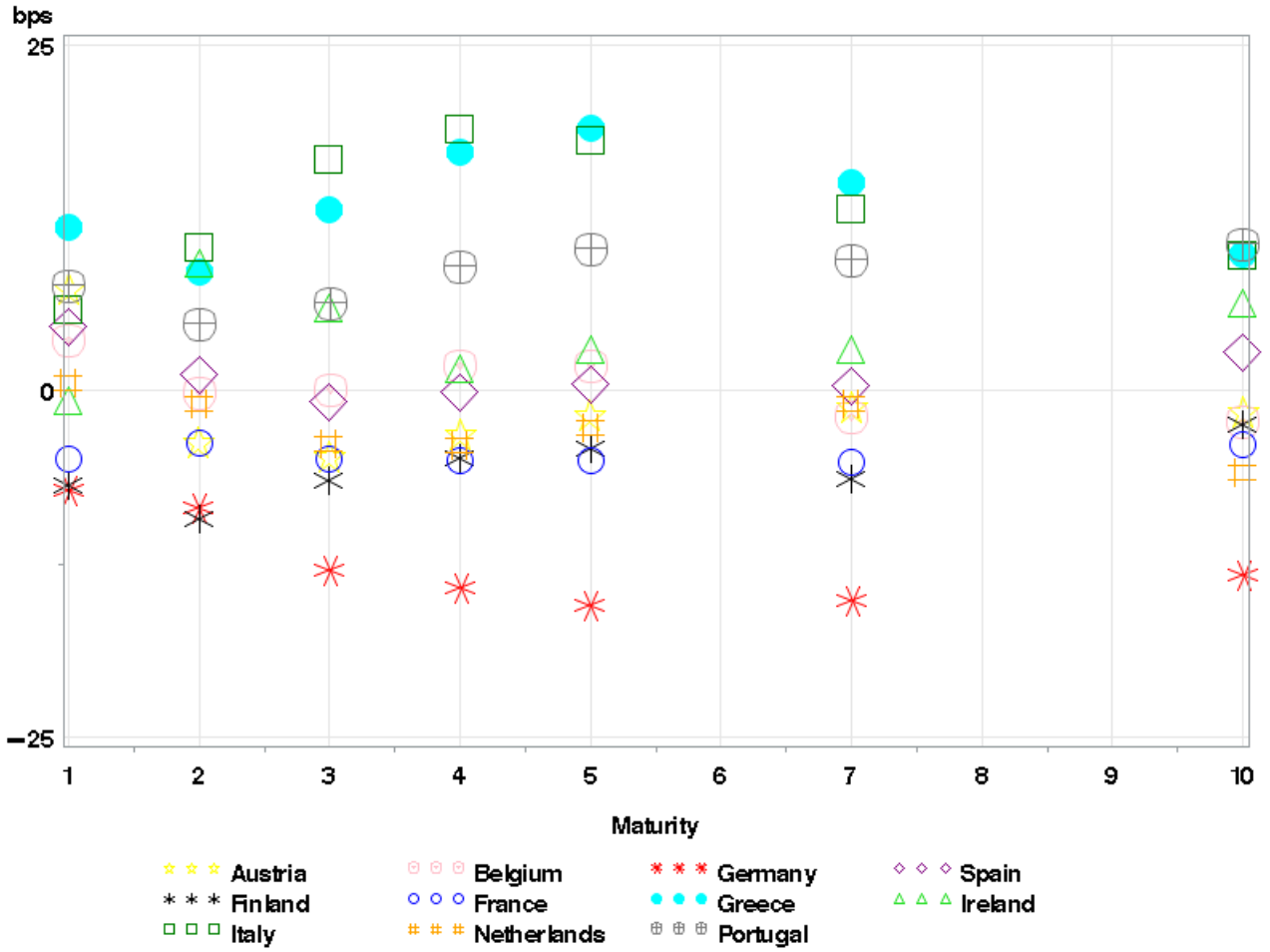


Figure 7. This figure plots the sample-average basis point effect of liquidity risk on sovereign yield spreads, as estimated in Equation (12), including all controls: $\gamma_1 \hat{\beta}_{cm}^{Liq}$. The values are estimated at each maturity point for each country.