Liquidity commonality in the secondary corporate loan market*

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Abstract

This study is the first to identify a parsimonious measure of liquidity and examine liquidity commonality in the U.S. secondary corporate loan market. Using recently available liquidity data from Markit, we demonstrate that among a range of liquidity proxies, the bid-ask spread is the most effective liquidity measure. Liquidity commonality shows an 18-fold increase during the 2007-09 global financial crisis over its pre-crisis level, implying substantial variation in liquidity risk across market states. A greater variation in loan market liquidity commonality relative to the equity market is consistent with the nature of the loan market, a relatively illiquid over-the-counter market characterized by vulnerability to weakness in the banking and shadow-banking sectors. There is some evidence that liquidity commonality in the loan market is influenced by funding liquidity.

Keywords: Liquidity, liquidity commonality, liquidity risk, financial crisis, OTC markets, loan market

JEL codes: C23, G01, G12, G14

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1. Introduction

Policy makers and regulators are concerned that “fragile” market liquidity will lead to more volatile market outcomes, particularly in relatively illiquid markets (IMF, 2015). Recent empirical studies have explored liquidity commonality, a common measure of liquidity risk, across various markets. For example, Karolyi, Lee, and van Dijk (2012) in the equity market, Corò, Dufour, and Varotto (2013) in the corporate credit default swap market, and Marshall, Nguyen, and Visaltanachoti (2013) in commodities markets. Liquidity commonality in the secondary corporate loan market (herein the loan market) has received very little attention despite the economic significance and low liquidity of the loan market.[1] One reason for this gap has been the lack of data in the loan market, as in most over-the-counter (OTC) markets, that can be used to adequately measure liquidity. The recent availability of a new dataset from Markit, which consists of trading liquidity data in the loan market, provides additional means to measure liquidity (see www.markit.com). Trading liquidity data was introduced by Markit in March 2008 in response to demand for additional liquidity information in the midst of the financial crisis. This study applies Markit loan market data to achieve four objectives. First, several proxies for liquidity measuring various facets of liquidity are evaluated in order to identify which measure best captures liquidity in the loan market. Second, we estimate liquidity commonality in the loan market and examine its variation across market states. Finally, both demand-side and supply-side drivers of liquidity commonality are examined.

The market microstructure literature identifies several influences on market liquidity, including asymmetric information between broker-dealers and traders, inventory risk and processing costs for broker-dealers, search costs for traders, and rents to monopolistic broker-dealers.[2] Each market has different characteristics and data availability such that different proxies for liquidity are more appropriate across different markets. In OTC markets such as the loan market, we cannot use many of the standard measures of liquidity used in exchange-traded markets. For example, similar to the corporate bond market, there is

[1] The loan market is sometimes referred to as the leveraged loan market, given the preponderance of low grade leveraged credits.

[2] See Foucault, Pagano, and Roell (2013) for a detailed description of each component of liquidity.

insufficient trading data to compute the effective bid-ask spread, a common measure of liquidity in equity markets.[3] In the bond market, Schestag, Schuster, and Uhrig-Homburg (2016) show that low frequency autocovariance measures that use transaction prices such as Roll (1984) are highly correlated with high frequency intraday measures. They also show that quoted bid-ask spreads are more closely correlated with intraday measures for large institutional trades, and executable quotes have higher correlations than generic quotes. Extant loan market studies typically use the quoted bid-ask spread without examining the efficacy of this measure in the loan market. For example, Wittenberg-Moerman (2008) use quoted bid-ask spreads to investigate information asymmetry in the loan market.[4] Quoted bid-ask spreads are also used to measure liquidity in other OTC markets such as the corporate credit default swap (CDS) market (Bongaerts, De Jong, and Driessen, 2011).[5]

In OTC markets such as the loan market, dealer depth can be limited. In our sample, 42% of loans are quoted by one broker-dealer, and 29% of loans are quoted (on average) by more than two broker-dealers. This suggests that broker-dealers may have monopolistic power in the loan market. In the theoretical model of Duffie, Gârleanu, and Pedersen (2005) bid-ask spreads in OTC markets are increasing in broker-dealer market power and decreasing in the ability of investors to find willing counterparties directly. Unlike information asymmetry models, where sophisticated investors pay higher prices due to their access to insider information, in Duffie et al. (2005) large and sophisticated investors are more likely to pay

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[3] The effective bid-ask spread is the difference between the mid-quote and the executed price that follows the mid-quote. See Foucault et al. (2013) for further details.

[4] The loan market is subject to extensive analysis in the corporate finance and banking literature. For example, Drucker and Puri (2009) investigate differences between loans that are traded in the secondary loan market and untraded loans. They find that traded loans have more restrictive covenant structures and that borrowers accept these structures to gain greater access to credit. Altman, Gande, and Saunders (2010) find that bank loan returns Granger cause bond returns prior to a loan default, implying that bank loans have an information advantage over bonds. Bushman, Smith, and Wittenberg-Moerman (2010) provide evidence that institutional investors exploit information obtained from loan investments for equity trading. Other studies consider the impact of secondary loan markets on relationship banking, balance sheet management and banking sector risk (Parlour & Plantin, 2008).

[5] Quote data is an important source of liquidity information in both the loan market and the CDS market. However, there is more volume information available in the CDS market, for example official books of record and clearing submissions. Detailed information on CDS and loan market data is available at www.markit.com.

lower spreads given greater direct access to willing counterparties. While services such as Markit provide some transparency, there is no record of transaction prices in the loan market, and dealers are likely to benefit from this opaqueness, particularly when their bargaining power is high (Green, Hollifield, & Schürhoff, 2007). Jankowitsch, Nashikkar, and Subrahmanyam (2011) demonstrate theoretically that the dispersion of quotes should be lower in more liquid markets, and argue empirically that price dispersion is superior to quoted bid-ask spreads in the corporate bond market. They show that price dispersion effects are larger than the bid-ask spread, have greater variation across bonds and 49% of transaction prices are outside of the quoted bid-ask spread. Jankowitsch et al. (2011) attribute their findings to lower liquidity in the corporate bond market and the OTC market structure. Similar to the loan market, quotes in the corporate bond market are typically non-binding, may be for small quantities or become stale. Thus we include a measure of price dispersion, the deviation of quotes amongst active broker-dealers, as an additional measure of liquidity.

Empirical evidence suggests that some commonly used measures of liquidity may not capture the ability to trade in size, which we call trading liquidity. The introduction of TRACE transaction data in the corporate bond market led to decreases in price dispersion and transaction costs, however trading activity decreased (Asquith, Covert, & Pathak, 2013; Edwards, Harris, & Piwowar, 2007). Trading liquidity in the loan market increased immediately following the Global Financial Crisis (GFC), however trading liquidity subsequently declined, even though other measures of liquidity continued to improve.[6] Given that liquidity is measured with noise, superior measures of liquidity should load heavily on the dominant principal component of liquidity measures, and alternative facets of liquidity should be evident in other significant principal components. For this reason, we use principal component and canonical correlation analysis to examine time-series movements in loan market liquidity measures. We show a clear distinction between several of the

[6] The decline in trading liquidity in the latter sample period may be due to restrictions on proprietary trading by broker-dealers. However, these longer-term structural trends do not explain various short-term correlations between alternative liquidity measures (refer Section 3). Moreover, different movements in these measures suggest that they have different drivers and therefore address different facets of liquidity.

transaction cost and trading liquidity measures, and find that the bid-ask spread parsimoniously measures liquidity in the loan market.[7]

Having identified an appropriate measure of liquidity, we test for the presence of liquidity commonality in the loan market and investigate whether it differs across market states. Liquidity commonality is one source or "channel" for liquidity risk in the Acharya and Pedersen (2005) liquidity-adjusted CAPM model. Investors prefer assets with low liquidity commonality. These assets are relatively more liquid when the market is illiquid, when liquidity is more valuable. Loans that react strongly to movements in market liquidity or market returns also have higher liquidity risk. Acharya and Pedersen (2005) demonstrate empirically that betas on alternative sources of liquidity risk are closely correlated, perhaps validating the wide spread use of liquidity commonality as a measure of liquidity risk. In Vayanos (2004), investors demand a higher risk premium on illiquid assets when volatility is high. The model predicts "flights to liquidity" wherein fund managers become more concerned about withdrawals when volatility is high, and preference their portfolio toward more liquid assets. Lagos, Rocheteau, and Weill (2011) also predict more volatile outcomes in markets where liquidity frictions are severe, as broker-dealers with market power have limited incentive to accumulate inventories during a crisis, thus limiting liquidity when it is most required. Rösch and Kaserer (2013) and Karolyi et al. (2012) present evidence of increases in liquidity commonality during more volatile periods in equity markets. Relative to the equity market and the bond market, the loan market is illiquid and subject to substantial frictions. We therefore hypothesize that liquidity commonality is time varying in the loan market and related to market conditions. Splitting our sample into sub-sample periods, we find that liquidity commonality increases during the GFC, and the amount of increase in commonality compared to the non-GFC period appears greater than that in equity markets.

Theoretical models posit a link between liquidity commonality and both demand-side and supply-side drivers. On the supply side, Brunnermeier and Pedersen (2009) links

[7] Other measures of liquidity may still be useful to market participants that require liquidity data for mark-to-market pricing or investment decisions. For example, trading liquidity measures may be useful when investors heavily weight their ability to trade with size.

liquidity commonality with variations in funding liquidity, that is, the ability of traders to fund positions in the market. Traders could be intermediaries or fund managers with leveraged positions. Traders avoid taking positions when funding liquidity is tight, leading to a mutually reinforcing process or "liquidity spiral" of funding liquidity, market liquidity and price declines. Increased liquidity commonality during a crisis is evidence of a liquidity spiral, as a crisis will simultaneously affect numerous loans and many intermediaries. In Kyle and Xiong (2001), financial intermediaries are 'convergence traders' that benefit from temporary movements away from fundamental value. In a crisis period, trading losses reduce the ability of market makers to hold inventory, reducing liquidity across markets where they operate. As market makers in the loan market are typically banks, trading losses may be particularly relevant during periods of banking sector weakness.[8] Liquidity commonality may also be driven from the demand-side by investor activity. During volatile periods fund managers are less willing to hold illiquid assets, or may be forced to liquidate when performance declines (Vayanos, 2004). Koch, Ruenzi, and Starks (2010) show that the co-movement of stocks with high mutual fund ownership is twice that of low mutual fund ownership stocks, and turnover is related to both the liquidity position of mutual funds and liquidity commonality. However, Favero, Pagano, and von Thadden (2010) present a model where investors are less concerned about liquidity when market volatility is high because of a decline in alternative investment opportunities. Karolyi et al. (2012) find that correlated trading by institutional investors as well as investor sentiment are able to explain a greater proportion of commonality compared with supply-side drivers in various global equity markets. The empirical evidence presented in this paper indicates that funding liquidity has weak explanatory power over and above market conditions, providing some evidence of a supply-driven liquidity spiral as in Brunnermeier and Pedersen (2009).

The remainder of the paper is structured as follows. In Section 2, we describe the data that is available from Markit. In Section 3, we explore the measurement of liquidity in the loan market. In Sections 4 and 5, we investigate the extent of liquidity commonality and its

[8] As of June 2014, according to Markit, 54 of 63 global loan trading desks were owned by a bank (see www.markit.com for further information). The proportion of non-banks was higher prior to the GFC given the disappearance of several investment banks and the conversion of some investment banks into bank holding companies (Adrian & Shin, 2010).

drivers. In Section 6 we conduct additional robustness testing using alternative measures of liquidity. A brief conclusion follows.

2. Data description and summary

In 1991 just $7 billion of loans were traded in the loan market; however the market grew to $510 billion by 2008.[9] An active secondary loan market significantly reduces funding costs in the primary loan market (Gupta et al., 2008; Kamstra, Roberts, & Shao, 2014). While the loan market is economically significant, it has relatively low liquidity as evidenced by trading costs. Over our sample period, mean proportional bid-ask spreads in the loan market range from 64 to 287 basis points. In contrast effective bid-ask spreads for NYSE listed stocks are typically below 10 basis points, although they rose to almost 30 basis points during 2008 (Chordia, Roll, & Subrahmanyam, 2011). The loan market is therefore an economically significantly and relatively illiquid market.

Markit collects and validates intraday loan pricing data from 40 global loan trading institutions. The Thomson Reuters LPC database used in extant studies of the loan market includes information on bid-ask spreads and the number of quoting broker-dealers (herein *Depth*). From March 2008, Markit began publishing additional information relating to trading liquidity including the number of broker-dealers that move their daily quote (herein *Movers*) and total daily quotes (herein *Quotes Count*). Total daily *Quoted Depth* can be derived from the number of firm quotes and average quote size. Firm quotes are volume specific, intended to be executed and typically represent around 20% of all quotes. Schestag et al. (2016) show that executable bid-ask quotes are more closely related to transaction costs in the corporate bond market. Firm quotes provide increased insight into trading volumes, executed prices and liquidity.

The sample begins on September 28, 2001, the earliest date that Markit makes loan market data available, and ends on October 28, 2013. The dataset includes 25,485,145 daily bid-ask quotes relating to 27,702 loans globally. We focus on U.S. issuers, reducing the

[9] Trading volume data is obtained from the Loan Syndications and Trading Association (LSTA, 2014).

sample by 40.3% to 16,534 loans. Potential errors are screened by eliminating any loans that include a daily pricing movement in excess of 50%, or that trade below 10% or above 150% of par. At least 20 days of data is required for each loan. The screens reduce the sample by 9.6% to 14,952 loans with 12,838,083 quotes. To avoid survivorship bias we include all loans that mature within the sample period. Moreover loans typically have relatively short tenors, and restricting the sample to long-life loans would severely restrict the sample size or require a reduction in the sample period. Markit provides loan characteristics such as age, size, issue date, maturity date and initial spread. Markit also maps Moody's credit rating data to individual loans from January 2007, giving us 3,717 rated loans. Thus for analysis that relies on ratings data we restrict the sample to the period from January 2007 through October 2013. Similarly, where we use trading liquidity data, the sample is restricted to the period from March 2008 through October 2013.

For the purpose of analysis we split the sample into three sub periods. Following Dick-Nielsen, Feldhütter, and Lando (2012) the GFC is defined as the 24-months from July 2007 through June 2009. The 24-month period before and after the GFC is the pre-GFC and post-GFC period respectively. During the GFC monthly average Treasury bond market volatility, measured by MOVE, is more than one standard deviation above the historic mean in 16 of 24 months.[10] Average monthly volatility in the pre-GFC period is more than one standard deviation below the mean in 19 of 24 months. The post GFC period is characterized by more normal levels of volatility; just two months (July and August 2009) are more than one standard deviation above the mean, and average volatility (98.0) is consistent with the historic mean (98.9).

Table 1 presents the time-series average of the cross-sectional sample statistics over the full sample. Bao, Pang and Wang (2011) report that the mean age of corporate bonds in their sample ranges from 2.7 years in 2003 to 7.2 years in 2009. However, the average life of loans in our sample is just 1.5 years. The relatively short life of loans is explained by their callability; loans are opportunistically repaid when better financing opportunities arise or due to merger activity (Standard & Poor's, 2013a). The average initial tenor of loans (5.6 years)

[10] We measure the historical mean of MOVE using the sample period available from Datastream, being April 4, 1988 through March 27, 2015.

also reflects their relatively short-term nature. The average loan size is $392 million; although there is substantial right-tail skew reflecting the presence of several very large loans, such as the $16 billion term loan to the private entity TX Competitive Electric Holdings in April 2011. The mean initial coupon rate is 360 basis points over LIBOR with positive skew. Ratings are tightly clustered at Ba3/B1, reflecting the relatively low credit quality of loans that trade in the secondary loan market, and contrasts with the investment grade heavy corporate bond market.[11] These significant differences in the characteristics of loans compared with corporate bonds warrant an investigation of the most effective measure of liquidity in the loan market.

[Insert Table 1]

Annual cross-sectional summary statistics for our sample of loans are shown in Table 2. There is substantial time-series variation in several measures. Average loan age reaches a high point of 2.5 years at the end of the GFC, and a low point of 1.1 years just prior to the crisis. This reflects refinancing conditions; by the fourth quarter of 2008 there was a 79% reduction in primary market lending compared to the second quarter of 2007 (Ivashina & Scharfstein, 2010). Callability means that loans rarely trade above par. Loans are also quasi floating rate instruments, where the floating portion is typically the London Interbank Offer Rate ("LIBOR"), and are therefore less sensitive to interest rate movements than fixed rate instruments. In more volatile times loans often trade significantly below par.

[Insert Table 2]

3. Liquidity measures

We compare the effectiveness of several proxies for liquidity in the loan market. The bid-ask spread is the most utilized measure of liquidity (Chen et al., 2007) and is found to be the most effective measure of liquidity in certain asset classes such as Treasury Bonds (Fleming, 2003). The theoretical literature shows that bid-ask spreads can capture several

[11] For example, just 11% of corporate bonds analyzed by Chen, Lesmond, and Wei (2007) are below investment grade (that is, rated below Baa3 by Moody's or its equivalent).

facets of liquidity such as inventory costs, information asymmetry and search and bargaining costs (Duffie et al., 2005). Following Chen et al. (2007), we use the proportional quoted bid-ask spread to analyze loan liquidity, that is, the quoted bid-ask spread divided by the quoted mid-price (herein *Bid-Ask*). Roll (1984) shows that transient movements in prices away from fundamental value can reflect liquidity frictions and will manifest as negative autocovariance. A similar measure is applied by Bao, Pan, and Wang (2011) in the corporate bond market. We take the square root of negative autocovariance in price movements (labelled *Gamma*) as an additional measure of liquidity. Similar to Houweling, Mentink, and Vorst (2005) we measure *Dispersion* using the standard deviation of quotes. Appendix A contains a detailed description of Gamma and Dispersion. In Lesmond, Ogden, and Trzcinka (1999), low liquidity assets experience less movement in returns due to lower trading activity. They measure liquidity as the percentage of days in a month with no movement in returns. We calculate *Zero Trading* as the percentage of days in a month that do not include a firm quote, a proxy for trading volumes. For ease of explanation, we label the measures based on Markit data the *trading liquidity* measures, and *Bid-Ask*, *Gamma* and *Dispersion* as the *transaction cost* measures. Other than the Markit trading liquidity variables and *Zero Trading*, all the liquidity measures can be computed for the entire sample period.[12] Daily measures are converted to monthly averages to facilitate comparisons with monthly measures.

Table 3 provides descriptive statistics for the liquidity measures. Panel A shows mean market-weighted liquidity measures. Transaction costs show a pattern of declining liquidity during the crisis and subsequent recovery. Trading liquidity increases in the latter stages of the GFC and continues to increase beyond the GFC, only decreasing in the latter part of the sample. Interestingly, twice annualized *Gamma* (136 basis points), equivalent to Roll's (1984) effective bid-ask measure, closely approximates average *Bid-Ask* over the sample period (129 basis points).[13] Panel B shows significant pair-wise time-series correlations between each measure. Correlation results suggest that each liquidity proxy is either a noisy measure of the same facet of liquidity, or that alternative facets of liquidity are correlated.

[12] To facilitate comparisons with measures that use firm quote data, when comparing alternative measures we restrict our analysis to the period from March 2008.

[13] Roll (1984) used actual transaction prices. γ will estimate Roll (1984) exactly to the extent that mid-quotes reflect actual traded prices.

Other than *Quotes Count* each measure is also positively correlated with volatility. This may reflect the impact of volatility on the funding liquidity of intermediaries as in Brunnermeier and Pedersen (2009), or the impact of volatility on investor activity.

[Insert Table 3]

To understand whether the liquidity measures are driven by one or more common factors, we extract components using principal component analysis (see Table 4). The approach is similar to Dick-Nielsen et al. (2012), who use principal component analysis to identify four key liquidity measures from eight potential measures. We analyze changes in each liquidity measure because each measure is non-stationary at level form. The analysis is restricted to two components as the eigenvalue of the third principal component is less than one. The sign of each correlation coefficient is as expected, with the exception of *Movers*.[14] Thus we exclude *Movers* from our analysis, although we note that results are similar when this measure is included. The first principal component explains 54.4% of variance and loads heavily on several measures, providing evidence that several measures address a similar facet of liquidity. A varimax (orthogonal) rotation produces a component that loads heavily on *Bid-Ask* and *Dispersion*.[15]

The second principal component is also noteworthy as it explains 21.1% of variance. The varimax rotation indicates that the second component primarily represents *Quotes Count* and *Quoted Depth* measures. The difficultly with trading liquidity measures is separating information and liquidity components. For example, traded volume may increase due to information shocks (Darolles, Fol, & Mero, 2015). To further explore the relationship between variables, we conduct a canonical correlation analysis, splitting transaction cost variables from the trading liquidity variables. The analysis indicates that *Bid-Ask* and *Dispersion* explain a substantial portion of the common variance amongst the trading

[14] For example, if there is an increase in the number of broker-dealers that move their quote, the liquidity of a loan should increase. However, an increase in average *Movers* is associated with a decrease in liquidity for all other measures.

[15] The varimax rotation provides uncorrelated principal components that are strongly related to the fewest possible number of liquidity measures.

liquidity variables (loading 0.885 and 0.893 respectively on the first canonical variable).[16] This result complements the principal component analysis results. As *Dispersion* is only computed when at least two quotes exist, its usefulness is limited to situations where there are two or more quotes. We conclude that *Bid-Ask* parsimoniously captures the level of liquidity in the loan market. Further analysis using *Dispersion* as the liquidity measure is provided in Section 6. Additional analysis of the cross sectional characteristics of level of liquidity is contained in Appendix B.

[Insert Table 4]

4. Commonality in liquidity

During the GFC the average spread to maturity over LIBOR in the loan market reached 1699 basis points, compared to 244 points on average during 2006 (Standard & Poor's, 2013b). The increases are larger when viewed in context of very large increases in LIBOR during the GFC, as loans are quoted over LIBOR. An important question is the extent of liquidity risk during periods of high volatility. Several studies beginning with Chordia, Roll, and Subrahmanyam (2000) and later Karolyi et al. (2012) and Rösch and Kaserer (2013), among others, show that liquidity commonality is increasing in volatility. In the bond market Bao et al. (2011) point to an increase in the level of market illiquidity by 12 standard deviations as evidence of commonality during the GFC. To investigate liquidity commonality in the loan market, we follow a similar method to Chordia et al. (2000). We consider changes rather than the level of liquidity, as we are primarily interested in co-movement and liquidity is non-stationary at the level form. Liquidity commonality for each loan is measured using the following time series regression,

$$\Delta Liquidity_{i,t} = \alpha_i + \beta_i \Delta Liquidity_{m,t} + \varepsilon_{it}, \qquad (1)$$

[16] Results are available from the corresponding author on request.

where $\Delta Liquidity_{it}$ is the monthly change in *Bid-Ask* for each loan i in month *t*, $\Delta Liquidity_{mt}$ is the monthly change in sample-wide average *Bid-Ask* weighted by market value, and β_i is the liquidity beta for loan i.

Eq. (1) is estimated separately for pre-GFC, GFC and post-GFC sub-periods. We focus primarily on R^2 as a measure of liquidity commonality. As shown in Table 5, liquidity commonality increases during the GFC. We report both average and median coefficients and *t*-statistics due to some positive skewness in the distribution of these parameters, although the results are similar and the conclusions identical. For the market weighted portfolio, average adjusted R^2 is 0.02 in the 24 months immediately preceding the crisis, increasing to 0.36 during the crisis. Liquidity betas are also telling. Average *t*-statistics on liquidity beta are only significant during the crisis (average p-value less than 0.001). The percentage of loans with significant liquidity betas increases from 18% to 66% in the GFC period, and the percentage with positive liquidity betas increases from 56% to 90%.[17] Significance levels and R^2 remain slightly elevated in the post-GFC period, perhaps due to ongoing high volatility in the initial months of the post-GFC period.

The contrast between crisis and non-crisis periods appears more pronounced in the loan market compared with other markets that have been previously examined. Karolyi et al. (2012) report equity market R^2 in the 20-25% range in normal times, increasing to 25-40% during the GFC.[18] In the German equity market Rösch and Kaserer (2013) find that R^2 increases by 5.4 times during the GFC, compared to 18 times in the loan market, and average equal-weighted liquidity beta increases by 5 times, compared to 9 times in the loan market.

[Insert Table 5]

There are several potential explanations for a relatively large increase in liquidity commonality during the GFC. First, the loan market may be disproportionately affected by a

[17] We use a one-tailed test as, by definition, commonality is a one-way relationship between individual loan liquidity and market liquidity.

[18] R^2 is more volatile during the crisis, including one month above 40% (Karolyi, Lee, & van Dijk, 2012).

banking crisis. Banks, as dominant market maker, indicate their reduced appetite for holding inventory by increasing bid-ask spreads. Banks remain a significant investor class, and distressed banks, to the extent they are diversified, will sell a broad range of assets. Second, Culp (2013) shows that the loan market is heavily reliant on shadow-banking entities, particularly Collateralized Loan Obligation funds (CLOs), and there was a dearth of new money raised by CLOs during the early stages of the GFC. The absence of new money forced primary market underwriters to break ranks with their syndicates and sell loans directly into the secondary loan market (Culp, 2013). Third, relatively large changes in commonality may reflect the structure of the loan market, that is, an OTC market characterized by significant frictions. Various researchers show theoretically and empirically that liquidity risk is increasing in expected illiquidity (for example, see Acharya and Pedersen (2005) and Lin, Wang, and Wu (2011)). It follows that more illiquid markets may display greater variation in liquidity risk. In the theoretical model proposed by Vayanos (2004), fund managers prefer liquid assets when volatility is high. Those fund managers with flexibility to switch asset classes may weight their portfolio away from less liquid markets such as the loan market. Finally, Vayanos and Wang (2012) present a model wherein illiquidity is increasing in information asymmetry. This may be significant in the loan market, given that issuers are typically private companies. For example, investors do not have the benefit of issuer-specific equity information, an important input into structural models of default prediction. However, investors do receive quarterly financial results and covenant compliance certificates (Standard & Poor's, 2013b). We investigate some of these demand and supply drivers of liquidity commonality in the following section.

5. Commonality drivers

Given evidence of liquidity commonality in the loan market, we examine the drivers of this commonality. Supply-driven explanations imply that investors should maintain liquidity buffers to avoid liquidity-driven negative skewness in returns, and that crises may be related to the funding liquidity of intermediaries (Brunnermeier & Pedersen, 2009). Demand-side explanations focus on movements in investor funds and suggest a focus on investor property rights and transparency or other measures aimed at avoiding investor panic (Karolyi et al., 2012).

Following Karolyi et al. (2012) we measure intra-month commonality using daily liquidity data. More specifically, for each month t, the daily change in loan liquidity is regressed on the daily change in the contemporaneous, leading, and lagged market liquidity,

$$\Delta Liqui\,\square\square\square\square_{i,d,t} = \alpha + \beta_1 \Delta Liquidity_{m,d,t} + \beta_2 \Delta Liquidity_{m,d-1,t} + \beta_3 \Delta Liquidity_{m,d+1,t} + \varepsilon_{i,d,t}, \quad (2)$$

where $\Delta Liquidity_{i,d,t}$ is the change in *Bid-Ask* for loan *i* on day *d* in month *t* and $\Delta Liquidity_{m,d,t}$ is the daily change in sample-wide average *Bid-Ask* weighted by market value. Following Chordia et al. (2000) we include the leading and lagged market liquidity to account for differing rates of adjustment to market movements that is likely to be a feature of daily data. Intra-month commonality is measured in terms of R^2 from Eq. (2). Following Karolyi et al. (2012), we take the log transformation $\ln[R^2_{i,t}/(1-R^2_{i,t})]$ so that our R^2 is not bounded by 0 and 1, where $R^2_{i,t}$ is the R^2 from the regression of loan *i* in month *t*.

Most demand-driven explanations focus on correlated trading by diversified institutional investors. Karolyi et al. (2012) use commonality in turnover to measure correlated trading activity. Such a measure is particularly appropriate in the loan market, given the dominance of diversified institutional investors such as CLOs. We proxy for trading activity using commonality in *Quoted Depth*. Liquidity commonality is regressed on demand and supply factors,

$$RSQ\_Liq_t = \alpha + \beta_1 RSQ\_QuDepth_t + \beta_2 \Delta Funding\ Liquidity_t + \beta_3 \Delta MktPrice_t + \beta_4 \Delta MktLiq_t + \varepsilon_t, \quad (3)$$

where ΔRSQ_Liq_t is the equal-weighted average log transformation of R^2 for each loan from Eq. (2) in month *t* and $\Delta RSQ\_QuDepth_t$ is the equal-weighted average R^2 from a commonality in *Quoted Depth* regression. $\Delta RSQ\_QuDepth_t$ is formulated in the same way as RSQ_LIQ_t in Eq. (2), substituting *Quoted Depth* for liquidity. On the supply-side, we proxy for changes in funding liquidity using three alternative measures. We focus initially on those measures of funding liquidity most closely related to banking sector funding liquidity. Banking sector funding liquidity may be relatively important in the loan market given that banks are the dominant market maker. When secondary loan prices trade below the prices held on bank balance sheets (effectively representing trading losses), the ability of banks to provide liquidity on other positions may reduce (Kyle & Xiong, 2001). Further, loans that trade in the loan market are at the riskier end of bank portfolios (Gatev & Strahan, 2009) and are likely to have relatively high funding liquidity requirements. The risk management practices of banks may also have a more acute impact in over-the-counter markets. For example, value at risk calculations may reflect longer lead times on asset sales, exacerbating any liquidity spiral (Gârleanu & Pedersen, 2007). We include ΔTED, the change in the difference between three month LIBOR, the rate at which banks are willing to lend to each other, and three month Treasury yields and $\Delta LIBOR\_OIS$, the change in the difference between three month LIBOR and the three month overnight index swap. TED is shown to be closely related to banking sector liquidity (Cornett, McNutt, Strahan, and Tehranian, 2011) and similarly $\Delta LIBOR\_OIS$ addresses movements in LIBOR against an alternative index. We also include $\Delta OIS\_Treasury$, the change in the spread between the three month overnight index swap and three month Treasury yields, as an alternative measure of funding liquidity. As the overnight interest rate swap is unaffected by counterparty risk but has, in theory, the same default risk, and as three-month Treasury bills are one of the most liquid instruments in the market, $\Delta OIS\_Treasury$ represents a reasonable proxy for general movements in funding liquidity.[19] To control for market conditions, we include $\Delta MktPrice$, the change in market-weighted average loan prices and $\Delta MktLiq$, the change in market liquidity.

The Brunnermeier and Pedersen (2009) model posits a high correlation between market returns, market liquidity and funding liquidity. Indeed we encounter collinearity issues, in particular due to the high correlation between changes in market liquidity and market prices.[20] We address collinearity issues by making changes in market prices

[19] Krishnamurthy (2010) analyses the flight to liquidity during the GFC using the spread between the overnight index swap and Treasury yields. The floating rate leg of a three month overnight index swap is based on the average overnight federal funds rate over the next three months.

[20] The correlation coefficient between changes in market liquidity and market prices is 0.54. Similarly and as expected, volatility as measured by the standard deviation of changes in mid-quotes

orthogonal to changes in market liquidity and other explanatory variables. At least ten intra-month *Quoted Depth* observations are required to form a meaningful R^2. To avoid bias the same sample is used for both liquidity commonality and the demand-side driver. The advantage of restricting the sample in this way is that firm quotes are more likely to reflect actual trading activity. The restricted sample still includes 2,950 loans and 29,741 months of data.

The regression results for Eq. (3) are presented in Table 6. Market condition variables are significant at the 1% level. Further, the economic significance of market condition variables, as measured by their standardized coefficients, is more than twice that of the banking sector funding liquidity measures, and almost four times general funding liquidity conditions as measured by Δ*OIS_Treasury*. However, funding liquidity may be a critical link in the mutually reinforcing feedback loop described by Brunnermeier and Pedersen (2009). The banking sector funding liquidity variables, Δ*TED* and Δ*LIBOR_OIS*, are significant at the 6% level and 11% level respectively. Changes in general funding liquidity conditions, as measured by Δ*OIS_Treasury*, is significant at the 2% level, although the economic significance of general funding liquidity is lower than the banking sector funding liquidity measures, and comparable to the demand-side driver. The demand-side driver is significant at the 8% level when modelled with Δ*OIS_Treasury*, however its significance drops to below 12% when included with either of the banking sector funding liquidity variables. Demand-side explanations explored by Karolyi et al. (2012) relating to investor property rights and transparency in various global markets are perhaps less significant in the U.S. loan market.

To further assess the relative impact and economic significance of funding liquidity variables and demand-side drivers we run two supplementary models (6 and 7) that include the demand-side driver along with banking sector funding liquidity (Δ*TED* or Δ*LIBOR_OIS*) that are made orthogonal to Δ*OIS_Treasury*. We include orthogonal variables to enable the measurement of the total impact of funding liquidity on liquidity risk, and to address collinearity resulting from correlation between the funding liquidity variables. In both models, the economic and statistical significance of Δ*TED* and Δ*LIBOR_OIS* decline only

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is highly correlated with changes in market prices (coefficient 0.93) and is excluded due to collinearity issues (variance inflation factors in excess of 10).

marginally when they are orthogonalised to Δ*OIS_Treasury*, and their economic significance remains higher than Δ*OIS_Treasury*; indicating that banking sector funding liquidity has residual explanatory power over and above general funding liquidity. The economic significance of general funding liquidity (supply-side) conditions is equal to the demand-side proxy, however, the combined economic significance of banking sector funding liquidity and general funding liquidity is over two times larger the demand-side driver.

[Insert Table 6]

6. Additional Robustness tests

In this section, we conduct robustness testing of liquidity commonality using two alternative measures of liquidity. Liquidity commonality may differ when using alternative measures of liquidity if alternative measures address different facets of liquidity. Specifically, we test for liquidity commonality using *Dispersion* and an aggregated measure of liquidity (denoted *AggLiq*). Dick-Nielsen et al. (2012) form an aggregated measure of liquidity using an equally weighted index of those liquidity measures that load most heavily on the first principal component. Similarly, *AggLiq* is an equally weighted combination of *Bid-Ask*, *Dispersion* and *Gamma*, the variables that load most heavily on the rotated first principal component as shown in Table 4. Each of the variables in *AggLiq* are standardized across loans and months.

Our key empirical results, that liquidity commonality varies substantially across market states, are not changed by the different choice of liquidity measure. Table 7 shows the *Dispersion* results, which are similar to the *Bid-Ask* tests. Liquidity betas are insignificant out of the GFC, however 95% of loans have positive liquidity betas and 78% have significant liquidity betas during the GFC. The commonality regressions using *AggLiq* (see Table 8) also show strong commonality during the GFC; 98% of liquidity betas are positive and 87% are significant using the *AggLiq* measure, and the Newey-West *t*-statistic on liquidity beta is 5.54. Movements in R^2 are similar for all three measures. The similarity between the commonality regressions using *Bid-Ask* and *AggLiq* provide further evidence that *Bid-Ask* is at least as effective as other potential parsimonious measure of liquidity.

One limitation when using *Dispersion* to measure liquidity is a reduction in sample size, as those loan months with only one quoting broker-dealer are excluded from the sample. Focusing on the GFC period, there are 601 loans that have at least 15 months of *Dispersion* data, compared to 1,820 in the *Bid-Ask* commonality regressions. The restricted sample is primarily explained by the observation that just 53% of loans in the GFC period are quoted by one broker-dealer, and an additional 32% are quoted by between one and two dealers at some point. *Bid-Ask* is preferred over *Gamma*, as *Gamma* is formulated ex post, in this case over a one-month period. The authors also recommend *Bid-Ask* to practitioners due to ease of calculation and implementation.

[Insert Table 7 and Table 8]

7. Conclusion

This paper investigates liquidity in the economically significant secondary corporate loan market. Using principal component analysis and canonical correlations to analyze several conventional measures of liquidity, together with novel trading liquidity data from Markit, we find that the proportional bid-ask spread (*Bid-Ask*) parsimoniously measures the level of market liquidity. *Dispersion* is an equally effective alternative measure of liquidity in the loan market, however its usefulness is limited to situations where there are at least two broker-dealers. This finding appears to contrast with evidence provided by Jankowitsch et al. (2011) on the superiority of dispersion in the corporate bond market, although we note the observation by Schestag et al. (2016) that quoted bid-ask spreads are more useful for larger institutional trades, and the loan market is an institutional market.

Liquidity commonality varies significantly across market states, increasing 18-fold during the global financial crisis of 2007-09 compared to the pre-crisis period. This result is robust to the use of *Dispersion* as a measure of liquidity, as well as an aggregate measure comprising *Bid-Ask*, *Dispersion* and a measure comprising negative serial covariance that is similar to Roll (1984). The similarity between commonality regressions when using alternative measures of liquidity provide further support for *Bid-Ask* as an effective parsimonious measure of liquidity. Further, in contrast to many other measures of liquidity, *Bid-Ask* is instantly observable for all quoted loans, and from a practitioner perspective does not require periodic ex post calculations. In keeping with Brunnermeier and Pedersen (2009), changes in liquidity commonality are increasing in changes in market conditions and both general funding liquidity and banking sector funding liquidity. While the results indicate that funding liquidity (supply-side) drivers are more important than demand-side drivers in the loan market during the sample period, the GFC was both a banking crisis and a recession, and demand-side influences may be more important in crisis periods not associated with banking sector weakness. The significant time variation in liquidity commonality may be partially explained by the observation that the loan market is relatively illiquid and subject to significant frictions, such as monopolistic power amongst broker-dealers. Longer time series data that includes greater variability in loan market liquidity commonality and banking sector conditions, or cross-market comparative studies, would provide evidence as to the relative impact of market structure and funding liquidity conditions.

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Table 1

Summary statistics, full sample

This table shows summary statistics over the full sample. *#Loans* is the number of loans. *#Quote Days* is the number of days for which a quote exists. *Size* is the initial par value of the loan. *Initial Life* is the tenor of the loan at inception in years. *Initial Spread* is the spread over LIBOR on issuance date in basis points. *Age* is the current age of the loan in years. *Rem. Life* is the current remaining life of the loan in years. *Quoted Price* is the current mid-quote where par is equal to 100. *Depth* is the daily number of broker-dealers quoting a loan. *Rated Loans* is the number of loans in the sample rated by Moody's. *Rating* is a numerical translation of the Moody's rating. For example, 1=Aaa, …, 13=Ba3, 14=B1, 15=B2, …, and 21=C. Ratings data is only available on the full dataset from January 2007. *Minimum* and *Maximum Rating* are loan-level average ratings across each loan's life. Some negative results for Minimum Age and Minimum Remaining Life are observed when either (i) loans are not repaid by their maturity date or (ii) loans are extended under an existing credit agreement. This impacts 3.6% of observations.

	Mean	Median	Std.Dev.	Skew	Kurtosis	Minimum	Maximum
#Loans	14,952						
#Quote Days	6,273,840						
Size	392	185	734	9.8	212.6	0.1	26,000
ln(Size)	5.2	5.2	1.2	-0.1	0.3	-2.0	10
Initial Life	5.6	6.0	1.6	-0.1	7.2	0.0	30
Initial Spread	360	300	201	1.8	5.3	0.0	2,000
Age	1.5	1.0	1.4	1.8	5.2	-3.5	14.7
Rem. Life	4.1	4.3	1.9	-0.3	4.8	-8.1	28.6
Quoted Price	94.8	99.2	11.9	-3.6	16.0	10.1	141.8
Depth	2.1	1.2	1.9	2.4	6.6	1.0	15.2
Rated Loans	3,717						
Rating	13.6	13.8	1.9	-0.1	1.0	3.0	19.9

Table 2
Summary statistics, annual

This table reports summary statistics for each year in the sample. 2001 is excluded for brevity as it only includes three months of data. *#Loans* is the number of loans. *#Quote Days* is the number of days for which a quote exists. *#Firm Quote Days* is the number of days where a firm quote exists. *% Firm Quote Days* is the percentage of days that have firm quotes. *Size* is the initial par value of the loan. *Initial Life* is the tenor of the loan at inception in years. *Initial Spread* is the spread over LIBOR on issuance date in basis points. *Age* is the current age of the loan in years. *Rem. Life* is the current remaining life of the loan in years. *Quoted Price* is the current mid-quote where par is equal to 100. *Depth* is the daily number of broker-dealers quoting a loan. *Rating* is a numerical translation of the Moody's rating 1=Aaa, …, 13=Ba3, 14=B1,…, and 21=C. *Rated Loans* is the number of loans in the sample rated by Moody's. *% Rated* is the percentage of all loans in the sample that are rated. Ratings data is only available on the full dataset from January 2007. Summary statistics for 2013 are based on data from January to October. Markit data on firm quotes is available from March 2008.

	2002			2003			2004			2005		
	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.
#Loans	1,991			2,383			3,121			3,328		
#Quote Days	327,097			378,293			412,396			493,861		
Size	275	150	431	296	155	468	305	160	500	323	160	553
Initial Life	5.8	6.0	1.8	5.5	6.0	1.8	5.5	5.8	1.7	5.7	6.0	1.6
Initial Spread	290	300	95	302	300	111	303	275	137	302	275	161
Age	2.0	2.0	1.6	1.9	1.3	1.8	1.5	0.6	1.8	1.1	0.7	1.5
Rem. Life	3.8	4.0	1.9	3.7	3.8	2.0	4.1	4.4	2.1	4.5	4.9	2.1
Quoted Price	92	98	14	95	99	12	98	100	10	99	100	8
Depth	1.8	1.0	1.5	2.2	1.2	2.0	2.0	1.1	1.7	1.9	1.0	1.6

	2006			2007			2008			2009		
	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.
#Loans	3,664			4,145			3,122			2,854		
#Quote Days	590,611			645,545			576,983			529,730		
#Firm Quote Days	na			na			60,241			67,568		
% Firm Quote Days	na			na			na			12.8%		
Size	354	160	660	413	175	771	449	200	809	466	200	920
Initial Life	5.8	6.0	1.5	6.0	6.0	1.4	6.0	6.0	1.5	5.9	6.0	1.6
Initial Spread	305	250	168	303	250	166	312	275	182	332	275	200
Age	1.1	0.7	1.4	1.2	0.9	1.2	1.8	1.4	1.4	2.4	2.3	1.4

Rem. Life	4.6	5.0	2.1	4.7	5.0	1.9	4.2	4.5	2.0	3.5	3.7	1.8
Quoted Price	99	100	8	98	99	7	88	91	12	80	84	18
Depth	1.9	1.0	1.8	1.8	1.0	1.8	1.7	1.0	1.7	2.1	1.1	1.9
Rated Loans	na			1,212			1,236			1,293		
% Rated	na			29%			40%			45%		
Rating	na	na	na	13.5	13.0	1.7	13.6	13.5	1.9	13.9	14.0	2.2

Table 2 (continued)
Summary statistics, annual

	2010			2011			2012			2013		
	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	Mean	Median	Std.Dev.
#Loans	3,560			3,619			3,689			3,490		
#Quote Days	596,142			578,716			596,310			501,195		
#Firm Quote Days	123,563			121,778			116,745			113,744		
% Firm Quote Days	20.7%			21.0%			19.6%			22.7%		
Size	412	196	708	443	209	765	459	225	884	490	250	893
Initial Life	5.8	6.0	1.5	5.7	6.0	1.4	5.6	6.0	1.5	5.6	5.9	1.4
Initial Spread	368	325	211	394	350	217	436	400	229	448	400	225
Age	2.5	2.9	1.7	2.3	1.4	2.0	2.0	1.2	2.0	1.8	1.1	1.9
Rem. Life	3.3	3.3	1.7	3.4	3.4	2.0	3.6	3.9	2.1	3.9	4.2	2.1
Quoted Price	91	96	14	94	98	12	95	99	13	96	100	13
Depth	2.7	1.7	2.4	2.6	1.6	2.2	2.5	1.6	2.1	2.6	1.7	2.2
Rated Loans	1,538			1,626			1,598			1,459		
% Rated	43%			45%			43%			42%		
Rating	13.7	13.7	2.1	13.6	13.8	2.0	13.7	14.0	2.0	13.8	14.0	2.0

Table 3

Summary statistics: Market liquidity measures

This table reports monthly market-weighted summary statistics and correlations for each liquidity measure. Panel A shows the market-weighted mean monthly level of market liquidity using each measure of liquidity, and Panel B shows the correlations in monthly changes. *Bid-Ask* is the proportional bid ask spread in basis points. *Zero Trading* is the percentage of trading days where no firm quote occurs. *Gamma* is the square root of negative serial covariance, multiplied by 100. *Dispersion* relates to the difference between daily average and individual mid-quotes, multiplied by 100. *Movers* is the number of dealers that move their quoted price daily. *Quotes Count* is the total number of daily quotes. Q*uoted Depth* is the daily $ volume of firm quotes. *Depth* is the daily number of broker-dealers quoting the loan. Correlations are calculated over the common 67 month period. *Standard Deviation* is the standard deviation of monthly changes in each liquidity measure. *Volatility* is the daily standard deviation of movements in the mid-quote. *Mean Change* is the mean monthly change. *SD Monthly Change* is the standard deviation of monthly changes. Daily measures are averaged over the month. Refer to Section 3 for further detail on each liquidity measure. Summary statistics for 2013 are based on data from January to October.

Panel A: Mean monthly levels

	Bid-Ask	Zero Trading	Gamma	Dispersion	Movers	Quotes Count	Quoted Depth	Depth	*Volatility*
2002	146	na	0.08	0.62	na	na	na	2.74	*0.32%*
2003	121	na	0.06	0.62	na	na	na	3.08	*0.21%*
2004	72	na	0.02	0.33	na	na	na	3.03	*0.08%*
2005	66	na	0.02	0.25	na	na	na	3.14	*0.07%*
2006	64	na	0.01	0.24	na	na	na	3.54	*0.05%*
2007	85	na	0.04	0.32	na	na	na	3.72	*0.15%*
2008	222	65%	0.14	1.00	1.34	6.10	3.43	4.00	*0.70%*
2009	287	63%	0.15	1.13	1.51	11.29	4.12	4.31	*0.73%*
2010	143	52%	0.06	0.54	1.93	13.83	6.24	5.21	*0.26%*
2011	124	53%	0.05	0.37	1.67	12.06	5.67	4.83	*0.25%*
2012	123	59%	0.04	0.33	1.34	10.00	3.57	4.44	*0.17%*
2013	96	58%	0.03	0.24	1.10	9.77	4.00	4.04	*0.13%*
Mean change	0.3%	-0.1%	12.7%	1.6%	1.5%	2.3%	2.5%	1.1%	*9.5%*
SD monthly change	13.1%	6.4%	67.7%	23.3%	17.9%	14.8%	19.3%	7.4%	*72.9%*
Number of months	144	67	144	144	67	67	67	144	*144*

Panel B: Correlations in Monthly Changes

	Bid Ask	Zero Trading	Gamma	Dispersion	Movers	Quotes Count	Quoted Depth	Depth
Zero Trading	0.65							
Gamma	0.54	0.39						
Dispersion	0.82	0.63	0.63					
Movers	0.25	-0.11	0.24	0.32				
Quotes Count	-0.09	-0.53	-0.02	-0.10	0.57			
Quoted Depth	-0.63	-0.82	-0.34	-0.64	0.15	0.67		
Depth	-0.26	-0.37	-0.17	-0.06	0.09	0.16	0.42	
Volatility	0.55	0.54	0.85	0.66	0.41	0.01	-0.46	-0.22

Table 4

Principal component loadings on liquidity measures

The components were extracted using principal components analysis, along with a varimax (orthogonal) rotation. Sign changes were made to ensure that increases in each measure correspond with declines in liquidity.

	Unrotated		Rotated (varimax)	
	1 PC	2 PC	1 PC	2 PC
Bid Ask	0.86	-0.41	0.92	0.24
Zero Trading	0.87	0.22	0.52	0.73
Gamma	0.64	-0.49	0.80	0.04
Dispersion	0.84	-0.40	0.90	0.24
Quotes Count	0.47	0.81	-0.16	0.92
Quoted Depth	0.85	0.45	0.36	0.89
Depth	0.51	0.10	0.32	0.40
% Explained	54.4%	21.1%	40.5%	35.0%
Cum. % Explained	54.4%	75.5%	40.5%	75.5%

Kaiser-Meyer-Olkin measure of sampling adequacy = 0.74

Bartlett's test of sphericity p-value < 0.001 (rejects null that there are no common factors)

Table 5

Liquidity commonality

This table presents commonality for the three sub-periods, each comprising 24 months. The GFC period is the 24 months from July 2007 through June 2009. Monthly changes in an individual loan's *Bid-Ask* are regressed on changes in equal-weighted and market-weighted market liquidity. Panel A reports cross-sectional *median* time series slope coefficients, Newey-West *t*-statistics (2 lags) in square brackets and Adjusted R^2. Panel B reports the *average* coefficients, Newey-West *t*-statistics and Adjusted R^2. Following Chordia et al. (2000) we note '% Positive', being the percentage of individual regressions with positive slope coefficients and '% Significant', being the percentage of *t*-statistics greater than 1.645 (the 5% critical level in a one-tailed test). We require at least 15 monthly observations in any sub-period to facilitate a meaningful regression analysis.

	Market Weighted			Equally Weighted		
	Pre GFC	GFC	Post GFC	Pre GFC	GFC	Post GFC
	July 05 June 07	July 07 June 09	July 09 June 11	July 05 June 07	July 07 June 09	July 09 June 11
Panel A: Medians						
Intercept	0.00	0.02	-0.01	0.00	-0.01	-0.01
	[0.10]	[0.56]	[-0.35]	[-0.27]	[-0.28]	[-0.35]
Coefficient	0.04	0.84	0.37	0.11	0.99	1.08
	[0.37]	[2.78]	[1.01]	[0.66]	[2.88]	[0.87]
Adjusted R^2	-0.02	0.35	-0.01	-0.02	0.36	0.00
Panel B: Averages						
Intercept	0.01	0.05	0.00	0.00	0.00	0.00
	[0.13]	[0.29]	[-0.41]	[-0.30]	[-0.38]	[-0.44]
Coefficient	0.63	0.86	0.49	1.05	1.01	0.98
	[0.23]	[4.04]	[1.32]	[0.48]	[3.70]	[1.24]
Adjusted R^2	0.02	0.36	0.07	0.02	0.35	0.06
% Positive	56%	90%	70%	63%	91%	73%
% Significant	18%	66%	36%	21%	72%	35%
# Loans	1,468	1,820	1,652	1,468	1,820	1,652

Table 6
Liquidity commonality drivers

This table reports monthly time-series regressions of liquidity commonality on demand and supply-side drivers for the sample period March 2008 through October 2013. Newey-West *t*-statistics (2 lags) are reported in square brackets. The dependent variable, RSQ_Liq, is liquidity commonality, where liquidity commonality is measured as the equal-weighted average log transformation of R^2 from the commonality regression in month t. The demand proxy is RSQ_QuDepth, the average log transformation of R^2 from the commonality in *Quoted Depth* regression. The bank supply proxy is either (i) ΔTED, the change in the 3-month TED spread, or (ii) ΔLIBOR_OIS, the change in LIBOR over the overnight index swap. The proxy for general funding liquidity conditions is ΔOIS_Treasury, the change in the overnight index swap over Treasuries. Control variables include the change in loan market liquidity as measured by the aggregate bid-ask spread (ΔMktLiq) and the change in loan market prices as measured by the change in the mid-quote (ΔMktPrice, orthogonalized to other explanatory variables). We require at least 10 monthly observations for a loan to be included in the R^2 calculation. Other than the average R^2 measures all variables are market-weighted. To facilitate comparisons each observation is standardized by subtracting the sample mean and dividing by standard deviation.

	(1)	(2)	(3)	(4)	(5)	(6)
Loan Market Conditions						
ΔMktLiq	1.88	1.96	1.67	1.58	1.71	1.71
	[11.01]	[11.38]	[6.61]	[5.06]	[6.53]	[6.53]
ΔMktPrice (orthogonalized)	1.76	1.74	1.76	1.76	1.75	1.75
	[5.17]	[5.75]	[5.73]	[5.13]	[5.83]	[5.83]
Supply and demand factors						
RSQ_QuDepth		0.46	0.46	0.45	0.46	0.46
		[1.79]	[1.57]	[1.50]	[1.63]	[1.63]
ΔLIBOR_OIS				0.76		
				[1.61]		
ΔLIBOR_OIS (orthogonalized to ΔOIS_Treasury)					0.74	
					[1.55]	
ΔTED			0.77			
			[1.88]			
ΔTED (orthogonalized to ΔOIS_Treasury)						0.64
						[1.48]
ΔOIS_Treasury		0.46			0.44	0.45
		[2.35]			[2.54]	[2.74]
Adjusted R^2	0.47	0.49	0.52	0.52	0.52	0.52

Months	68	68	68	68	68	68

Table 7

Liquidity commonality using dispersion

This table replicates Table 5, this time using *Dispersion* to measure liquidity. *Dispersion* relates to the difference between daily average and individual mid-quotes, multiplied by 100. Refer to Appendix A for a detailed definition of *Dispersion* and Table 5 for other definitions. Panel A and Panel B report median and mean intercepts, coefficients and R^2 respectively.

	Market weighted			Equally weighted		
	Pre GFC	GFC	Post GFC	Pre GFC	GFC	Post GFC
	July 05 June 07	July 07 June 09	July 09 June 11	July 05 June 07	July 07 June 09	July 09 June 11
Panel A: Medians						
Intercept	0.03	0.00	0.01	0.07	-0.05	-0.04
	[0.22]	[0.04]	[0.15]	[0.52]	[-0.38]	[-0.36]
Coefficient	0.31	0.96	0.69	0.08	0.87	0.72
	[0.40]	[3.08]	[0.88]	[0.13]	[3.18]	[0.90]
Adjusted R^2	-0.03	0.34	0.00	-0.04	0.34	-0.01
Panel B: Means						
Intercept	0.08	0.10	0.09	0.00	0.02	0.00
	[0.05]	[-0.03]	[-0.05]	[0.25]	[-0.46]	[-0.56]
Coefficient	0.89	1.11	0.86	1.01	1.03	1.10
	[0.38]	[3.79]	[1.19]	[0.22]	[3.89]	[1.04]
Adjusted R^2	0.02	0.34	0.06	0.01	0.34	0.05
% Positive	61%	95%	72%	55%	96%	73%
% Significant	16%	78%	34%	14%	78%	32%
# Loans	482	601	879	482	601	879

Table 8

Liquidity commonality using an aggregate measure of liquidity

This table replicates Table 5, this time using *AggLiq* to measure liquidity. *AggLiq* is an equally weighted combination of *Bid-Ask*, *Dispersion* and *Gamma*. Panel A and Panel B report median and mean intercepts, coefficients and R^2 respectively.

	Market weighted			Equally weighted		
	Pre GFC	GFC	Post GFC	Pre GFC	GFC	Post GFC
	July 05 June 07	July 07 June 09	July 09 June 11	July 05 June 07	July 07 June 09	July 09 June 11
Panel A: Medians						
Intercept	0.00	0.00	0.00	0.00	-0.01	-0.04
	[-0.00]	[0.08]	[-0.24]	[-0.08]	[-0.32]	[-0.17]
Coefficient	0.48	0.99	0.47	0.26	0.88	0.97
	[0.45]	[4.90]	[1.25]	[0.28]	[4.30]	[1.30]
Adjusted R^2	-0.02	0.36	0.05	-0.02	0.36	0.01
Panel B: Means						
Intercept	0.00	0.02	0.00	0.00	0.00	0.00
	[0.02]	[0.05]	[-0.24]	[-0.08]	[-0.31]	[-0.21]
Coefficient	0.87	1.14	0.54	1.01	1.01	1.00
	[0.42]	[5.54]	[1.87]	[0.33]	[5.15]	[1.37]
Adjusted R^2	0.02	0.35	0.07	0.01	0.35	0.06
% Positive	62%	98%	73%	58%	98%	77%
% Significant	17%	87%	43%	16%	87%	41%
# Loans	482	601	879	482	601	879

Table 9

Variation in liquidity (Bid-Ask) and loan characteristics

This table reports results from monthly cross-sectional regressions where coefficients and *t*-statistics are averaged across the sample period. *Size* is the natural log of par value in millions of dollars. *Age* is the period in years since the loan was issued. *Maturity* is the period in years until the loan is due for repayment. *Rating*^{2} is *Rating* squared, where *Rating* is a numerical translation of the Moody's rating 1=Aaa, …,13=Ba3, 14=B1,…, and 21=C. *TLA* is a dummy variable that takes the value 1 when the loan is either a term loan A or a revolver. *TLB* is a dummy variable that takes the value 1 when the loan is a term loan B. *t*-statistics are reported in square brackets. Results for the full sample and the GFC period are presented. The GFC period covers July 2007 through June 2009. The full sample period begins with the availability of rating data in January 2007 through October 2013, comprising 2,045,144 quote days for 3,717 loans. Economic significance is the impact on *Bid-Ask* (in basis points) of a one standard deviation increase, calculated as the coefficient multiplied by the square root of the average monthly cross-sectional variance for the relevant sample period. *t*-statistics are computed from standard errors that are heteroskedastic-consistent, following White (1980).

	Full Sample			GFC			*Economic Significance*					
								Full Sample			*GFC*	
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Intercept	0.68	1.22	0.78	1.35	1.60	1.62						
	[2.25]	[3.82]	[3.16]	[2.74]	[3.41]	[3.36]						
Size	-0.18	-0.18	-0.12	-0.45	-0.44	-0.44	*-20*	*-20*	*-14*	*-49*	*-48*	*-48*
	[-3.82]	[-3.77]	[-3.73]	[-6.01]	[-5.67]	[-6.02]						
Age	-0.04	-0.03		0.03	0.04		*-5*	*-4*		*4*	*5*	
	[2.11]	[2.54]		[0.07]	[0.40]							
Maturity			-0.06			-0.07			*-10*			*-12*
			[-2.32]			[-0.51]						
Rating^2	0.01	0.01	0.01	0.02	0.02	0.02	*47*	*41*	*45*	*127*	*123*	*128*
	[5.78]	[4.46]	[5.76]	[8.14]	[7.59]	[8.29]						
TLA	0.55		0.56	0.22		0.20	*24*		*24*	*9*		*9*
	[6.26]		[5.58]	[2.87]		[2.62]						
TLB		-0.41			-0.30			*-20*			*-15*	
		[-5.04]			[-2.92]							
Adjusted R^2	0.23	0.20	0.19	0.20	0.20	0.20						

Table 10
Summary Statistics: Ratings

This table summarizes the percentage of loans in each Moody's rating category during each year and the average proportional bid-ask spread (*Bid-Ask*) in basis points by rating category. Markit maps Moody's ratings to all loans in the sample from January 1, 2007.

	2007	2008	2009	2010	2011	2012	2013	Bid-Ask
Baa2 or higher	0.8%	1.1%	1.8%	1.8%	1.5%	1.8%	1.2%	115
Baa3	3.2%	3.6%	3.7%	3.9%	5.0%	3.2%	3.7%	115
Ba1	6.6%	7.4%	5.6%	6.6%	7.7%	8.0%	7.3%	110
Ba2	14.8%	13.7%	14.1%	16.6%	15.1%	12.6%	11.7%	120
Ba3	27.3%	23.7%	18.4%	19.4%	19.7%	20.2%	19.1%	136
B1	24.4%	23.7%	21.0%	22.0%	22.9%	25.0%	26.3%	164
B2	11.7%	13.3%	11.7%	10.8%	12.3%	12.1%	13.8%	208
B3	4.3%	5.2%	9.9%	8.5%	7.4%	6.9%	6.0%	262
Caa1	5.3%	5.6%	7.6%	5.3%	5.3%	5.9%	5.8%	309
Caa2	1.6%	2.0%	4.1%	3.1%	2.0%	3.0%	3.4%	402
Caa3 or lower	0.0%	0.6%	2.1%	1.9%	1.1%	1.3%	1.5%	540

Appendix A

Calculation of liquidity measures

Following is additional detail on *Gamma* and *Dispersion*.

Adjusted serial covariance (Gamma)

Motivated by Bao et al. (2011) and Roll (1984) we take the square root of the negative covariance,

$$\gamma_{i,m} = \sqrt{-\,Cov\,(\Delta P_{i,t}, \Delta P_{i,t-1})}$$

where $\gamma_{i,m}$ is liquidity in month *m* for loan i, and $Cov\,(\Delta P_{i,t}, \Delta P_{i,t-1})$ is the serial covariance in daily average mid-quote changes. Following Dick-Nielsen et al. (2012), we discard positive covariance results as the calculation is undefined. We calculate $\gamma_{i,m}$ for each month and formulate a market-weighted average. At least 15 observations are required. Market values are estimated by the mid-quote multiplied by issuance.

Dispersion

Jankowitsch et al. (2011) calculate dispersion as the volume-weighted difference between individual broker-dealer quotes and market consensus valuations provided by Markit. Less liquid loans will display greater dispersion. Houweling et al. (2005) measure liquidity as the standard deviation of quoted yield differences amongst broker-dealers relative to their mean. We follow the Houweling et al. (2005) measure, replacing yield with offer quote.[21] *Dispersion* is calculated as follows,

$$Dispersion_{i,t} = \sqrt{\frac{1}{n_{i,t}-1}\sum_{s=1}^{n_{bt}}\left(\frac{p_{i,t,s} - \bar{p}_{i,t}}{\bar{p}_{i,t}}\right)^2}$$

where $n_{i,t}$ is the number of quotes for loan *i* on day *t*, $p_{i,t,s}$ is the offer quote from broker-dealer *s*, and $\bar{p}_{i,t}$ is the average offer quote across all broker-dealers. To calculate *Dispersion*

[21] Yield data adjusts for amortization however yield data is only available on an aggregated daily basis. Given that spreads will move inversely with prices the results should be almost identical.

we require at least two quotes on any day. To the extent that loans with a single quote are more likely to be illiquid, we may understate market illiquidity. We may overstate illiquidity to the extent that intraday quotes are nonsynchronous.

Appendix B

Cross Sectional Characteristics of Liquidity

Similar to corporate bonds, the level of liquidity should vary by loan characteristic. Chen et al. (2007) and Ericsson and Renault (2006) find that the level of liquidity is increasing in credit quality. However, Gupta et al. (2008) show that lower quality loans have *higher* liquidity. Gupta et al. (2008) use a binary measure of liquidity, defined as whether or not a loan trades in the secondary market. Our measure of liquidity is more granular than the binary measure used by Gupta et al. (2008). Additionally, our measure is used only for loans traded in the secondary loan market. In essence, we are investigating the relative differences in liquidity for the liquid loans as defined by Gupta et al. (2008). Larger bonds also tend to have greater liquidity and liquidity declines as bonds age (Bao et al., 2011). We also expect loan liquidity to be increasing in size, as larger loans should trade more often. Higher liquidity on short-dated securities may be due to deliberate market-making activity by broker-dealers or gradual absorption into buy-and-hold portfolios (Houweling et al., 2005). These are plausible influences on the loan market; however, the impact may be limited by the relatively short tenor of loans. Loan type may also be influential. Term Loan B (TLB) are designed to appeal to institutional investors. Compared to revolving loans or Term Loan A (TLA) facilities, which are often held by banks, TLBs are fully funded, have longer maturities and minimal amortization (Culp, 2013). We test for cross-sectional differences in the level of liquidity in the loan market using the following equation,

$$Liquidity_i = \alpha + \beta_1 Size_i + \beta_2 Age_i + \beta_4 Rating_i^2 + \beta_4 Loan\,Type_i + \beta_4 Industry_i + \varepsilon_i, \quad (4)$$

where $Liquidity_i$ is *Bid-Ask* for loan *i*, *Size* is the log of the amount issued, Age is loan age, $Rating^2$ is the Moody's credit rating squared, $Loan\,Type$ is a dummy variable for loan type, $Industry$ is a dummy variable for industry, and ε is a random error term. Eq. (4) is estimated for each month for the cross-section of loans.[22] We initially exclude $Industry$ and discuss the results separately.

Average coefficients and *t*-statistics from monthly cross-sectional OLS regressions across the sample period are presented in Table 9. Model (1) includes as $Loan\ Type$ a dummy variable for those loans that either TLA or revolving facilities. The size of a loan is a significant influence on liquidity; a one standard deviation increase in *Size* decreases *Bid-Ask* by 20 basis points across the full sample and by 49 basis points during the GFC. Credit quality is the dominant determinant of cross sectional differences in liquidity. Consistent with the findings of Gupta et al. (2008), less than 5% of loans that trade in the secondary market are rated investment grade (refer Table 10 for the distribution of loans by Moody's rating). In the secondary loan market, similar to the corporate bond market, we find that lower quality loans have lower liquidity. The contrast in cross-sectional relationships between GFC and non-GFC periods is unlikely to be due to changes in the distribution of loans amongst different credit ratings, as the distribution is relatively stable over, evidenced by the large concentration of loans rated between Ba2 and B2 in each year of the sample. $Loan\ Type$ has a significant influence on liquidity. Revolvers and TLB loans have lower liquidity than other loans. Similarly, in Model (2), TLBs have higher liquidity than other loans after controlling for other cross-sectional differences in characteristics. The average coefficient for *Age* has an unexpected sign and is economically insignificant. TLB loans tend to be longer-dated than revolvers and TLA loans. To test whether $Loan\ Type$ is driven by higher liquidity on short-dated loans, we replace *Age* with $Maturity$, the time until maturity.[23] In contrast with the bond market, as loans get closer to maturity liquidity *increases*, perhaps reflecting the expectation that liquidity will crystallize through repayment at par in the short term. However, the low economic significance of $Maturity$ across the full sample and insignificance of $Maturity$ during the GFC suggests that tenor is of little importance to the level of liquidity in the loan market. Finally, we include $Industry$ in the model (results not shown). None of $Industry$ coefficients are significantly different from

[22] Squaring the rating variable captures the non-monotonicity in the liquidity term structure (refer Table 10). The results are very similar when we model a linear relationship, however there is a slight improvement in goodness of fit when we use the squared rating variable.
[23] *Maturity* and *Age* are not included in the same regression due to collinearity (ccorrelation coefficient -0.78).

the reference industry. However, adjusted R^2 increases and the partial F-test indicates that the industry dummies are jointly different from zero.[24] This suggests that cross-sectional differences in the level of liquidity are influenced by industry. The coefficients on the other explanatory variables are very similar to the regressions that exclude the $Industry$ dummy variables.

[Insert Table 9]

[Insert Table 10]

[24] For example, in Model (3) R^2 increases from 0.19 to 0.28 and the partial F-test statistic is 15.857 (p-value 0.000), so we reject the null that the industry variables are jointly zero.