Dealer Balance Sheets and Bond Liquidity Provision*

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Abstract

Do regulations decrease dealer incentives to intermediate trades? Using a unique dataset of dealer-bond-level transactions, we construct the interdealer intermediation chain for the U. S. corporate bond market. Unlike prior studies, the transactions that we observe are uncapped in size and include the identity of dealer counterparties to the transaction. The granular nature of our data allows us to link changes in liquidity of individual corporate bonds to dealer transaction activity. We show that, in the full sample, bond-level liquidity is higher when institutions that are active traders in the bond are more levered, have higher trading revenue, have higher liquidity mismatch, are more vulnerable, have lower risk-weighted assets, less reliance on repo funding, and fewer illiquid assets. In the rule implementation period (post January 2014), bonds traded by more vulnerable institutions and institutions with greater liquidity mismatch are less liquid, suggesting that prudential regulations may be having an effect on bond market liquidity.

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1 Introduction

Regulatory reform efforts since the financial crisis, including the Dodd-Frank Act in the U. S. and the Basel Committee's Basel III bank regulations, have aimed at making the financial system safer and severe financial crises less likely. These regulations impair the ability of regulated institutions to increase their balance sheet size and thus might reduce the overall intermediation capacity of the financial system, even during normal times. The decreased intermediation capacity may lead to decreased liquidity in markets where the regulated institutions intermediate a large fraction of the trading activity. Recent commentary by market participants suggests that this is indeed the case, with a recent Wall Street Journal article[1] noting that "*Three-quarters of institutional bond investors say that liquidity provided by bond dealers has declined in the past year.*"

While much of the commentary by market participants has attributed these reported declines in liquidity to post-financial crisis changes in the regulatory environment faced by the dealers in these markets, the evidence on the link between dealer balance sheets and bond market liquidity, as well as between regulation and market liquidity, has been scarce. In this paper, we make first steps to remedy this gap in the academic literature, and study the relationship between corporate bond market liquidity and dealer balance sheets and how this relationship changes over time.

We use the supervisory version of the Trade Reporting and Compliance Engine (TRACE) to construct trade-based measures of bond market liquidity and dealer positions of corporate bonds. TRACE collects detailed trade information from securities brokers and dealers that are members of FINRA, including the date and time at which the transaction took place, the price and quantity of the bond traded, dealer/client flags for the two parties to the transaction, and a buy/sell indicator. Unlike the academic version of TRACE, the record for each trade in the supervisory version also includes the full name of the reporting FINRA member, and the uncapped size of the trade. The client's identity is not entered to the

[1] Wall Street Journal (3/31/2016), "Big Bond Investors Say Liquidity Has Declined in Past Year"

system, and as such it is unknown.

Using the transactions data, we calculate several liquidity measures that are commonly used in the corporate bond liquidity literature. In particular, we employ an effective bid-ask spread as the difference between the weighted average of the buy and sell prices, where the weights are the dollar value of the transaction (Hong and Warga, 2000 and Chakravarty and Sarkar, 2003); imputed roundtrip costs of finding trades close in time that are likely to be a buy and a sell, and calculating $\frac{P_{\max}-P_{\min}}{P_{\max}}$, where $P_{\max}$ and $P_{\min}$ are the largest and smallest prices, respectively, in the trades cluster (Feldhütter, 2012); Roll (1984) measure as two times the square root of minus the covariance between consecutive returns (Bao et al., 2011); zero-trading days (Chen et al., 2007); and the Amihud (2002) measure as the daily ratio of the absolute return to its dollar trading volume.

Next, we link bond-level liquidity to the constraints faced by active traders in the market. Using the dealer identities provided in the supervisory TRACE dataset, we match FINRA members to the balance sheets of their parent bank holding companies, collected through the FR Y-9C report. Y9-Cs contain basic balance sheet information for U. S.-based bank holding companies, which can be used to monitor the financial condition of the holding companies. In particular, we can use Y9-C information to measure the balance sheet capacity of dealers. We construct bond-level measures of constraints as the absolute net flow weighted average of metrics of constraints of institutions that trade in the bond. This allows us to quantify the extent to which a tightening of constraints faced by market participants leads to a decline in market liquidity. The rich nature of the data allows us to use cross-sectional differences in the rate at which intermediaries facing differential constraints trade in the cross-section of bonds to estimate precisely the magnitude of the effect of tightening of constraints on market liquidity. While Comerton-Forde et al. (2010) document that NYSE specialists' inventory has a significant impact on *equity* market liquidity, this is the first study of these effects in the setting of OTC-traded corporate bonds.

We find that bonds that are more actively traded by institutions with higher (raw) leverage, with higher trading revenue, higher liquidity mismatch and higher vulnerability (as measured by CoVaR) are all more liquid than the average bond. At the same time, bonds that are traded by institutions with higher ratio of risk-weighted assets to assets, greater reliance on repo funding, more illiquid assets (in the form of loans) and higher ROA are less liquid than the average bond. Intuitively, institutions that are able to maintain a higher level of leverage and that have a higher trading revenue overall are able to devote more resources to their trading activity overall, while institutions with less liquid assets are less likely to provide liquidity to the bond market. Similarly, institutions more reliant on repo funding are also less likely to provide liquidity to the corporate bond market as long positions in corporate bonds are usually repo financed as well. Comparing the impact of constraints faced by buyers to the impact of constraints faced by sellers in the market, we find that the tightening of sellers' constraints leads to larger declines in market liquidity.

Finally, we investigate whether this link between participants' constraints and market liquidity has changed over time. We use a difference-in-difference approach to quantify the impact of both market events (the financial crisis) and regulatory reform on the relationship between institutions' constraints and bond liquidity. The detailed nature of the transactions dataset allows us to use variability across institution-bond transaction pairs over time to quantify to what extent liquidity, risk weight, and leverage regulations are associated with changes in market liquidity provision by dealers that are relatively more constrained, and for bonds that are relatively less liquid. We find that during the post-crisis reform implementation period (post January 2014), the relationship between bond liquidity and vulnerability switches signs, with bonds that are more actively traded by more vulnerable institutions or institutions with a larger liquidity mismatch between their assets and liabilities less liquid. This suggests that regulatory reforms do have an impact on the incentives of constrained institutions to provide liquidity in the corporate bond market.

Overall, we describe the recent trends in corporate bond liquidity and the impact that post-crisis capital and liquidity regulations have had on dealers' incentives to provide liquidity in OTC markets. More broadly, fixed income securities perform a crucial role in the transmission of monetary policy. A tightening in monetary policy raises the cost of funding for financial institutions. When secondary market liquidity is impaired, this funding shock is amplified as intermediaries are also compensated for the increased costs of selling primary issuance to the secondary market. Thus, the overall funding costs for the real sector increase, which may lead to increased fragility.

2 Literature Review

Corporate bonds used to be traded in an opaque environment where quotes were only available to market professionals and transaction prices were not made public. In 2002, the Transaction Reporting and Compliance Engine (TRACE) was introduced, requiring all trades in publicly issued corporate bonds to be reported to the National Association of Security Dealers, which in turn made transaction data available to the public. The subsequent literature generally finds that public traders benefited significantly from the price transparency due to TRACE. Goldstein et al. (2007) find that transparency has either a neutral or a positive effect on liquidity, finding a decline of spreads for large and newly issued bonds, and no impact for very infrequently traded bonds. Edwards et al. (2007) find that transaction costs decrease significantly with trade size, and that highly rated bonds, recently issued bonds, and bonds close to maturity tend to have lower transaction costs. Bessembinder and Maxwell (2008) provides an overview of the impact of the increase in transparency on the market. Mahanti et al. (2008) and Feldhütter (2012) propose new liquidity metrics computed from TRACE.

Dick-Nielsen et al. (2012) construct the spread contribution from illiquidity during the financial crisis of 2007-09. The increase in the illiquidity spread is slow and persistent for investment grade bonds and stronger but more short-lived for speculative grade bonds. Bonds become less liquid when financial distress hits a lead underwriter and the liquidity of bonds issued by financial firms dries up under crises. During the crisis, flight-to-quality is only detected for AAA-rated bonds.

Harris (2015) compares TRACE trades to contemporaneous quotes from electronic venues to measure transaction costs between December 15, 2014 and April 15, 2015. He identifies Riskless-Principal-Trades (RPTs) by finding all adjacent trade reports with the same size. A potential RPT is an adjacent pair involving a customer trade and an interdealer trade, or two customer trades on opposite sides. He reports that 42% of all trades are potential RPT pairs for which the time between trades is less than 1 minute; less than 2 seconds separate the trades in 73% of the potential RPT pairs.

Hendershott et al. (2015) show that execution costs in the corporate bonds market depend strongly on insurers' trading network and who are they connected to. across insurance firms, the largest holders of corporate debt. While both large and small insurers trade with large dealers, large insurers form more relations than small ones, leading to better execution by fostering price competition among dealers.

Babus and Hu (2015) argue that concentrated intermediation (a star network) is both a constrained efficient and a stable structure, when linking is costly. The center agent in a star network can receive a higher fee than any intermediary in other classes of networks.

Di Maggio et al. (2015) investigate the network of relationships between dealers in the corporate bond market. Dealers tend to provide liquidity during periods of distress to the counterparties with whom they have the strongest ties. Highly connected and systemically important dealers exploit their connections at the expense of peripheral dealers and their clients, charging them higher markups than to other core dealers, especially during high-uncertainty periods. The failure of a major dealer in 2008 lead institutions with stronger ties to that dealer to route their trades through longer intermediation chains, increasing transaction costs.

Our paper is closely related to Bessembinder et al. (2016) and Bao et al. (2016).Bessembinder et al. (2016) study bond liquidity as a function of dealers' willingness to commit capital to bond trading, and focus on whether post-crisis banking reforms have affected liquidity provision in the corporate bond market by examining results separately for those dealers who are affiliated with a bank holding company and dealers that are not bank-affiliated. Bao et al. (2016) document that the illiquidity of stressed bonds has increased after the Volcker Rule. Dealers regulated by the rule have decreased their market-making activities while non-Volcker-affected dealers have stepped in to provide some additional liquidity. Furthermore, even Volcker-affected dealers that are not constrained by Basel III and CCAR regulations change their behavior, inconsistent with the effects being driven by these other regulations. In contrast, Trebbi and Xiao (2015) finds that post-crisis U.S. regulatory intervention does not appear to have produced structural deteriorations in market liquidity.

3 Post-Crisis Regulatory Changes: Background

The financial crisis of 2007-09 unearthed shortcomings in the regulatory framework of banks and dealers. Institutions experienced both solvency and liquidity problems during the crisis, motivating subsequent regulatory reforms. Additionally, some regulations directly restrict certain activities. This section provides a brief overview of the regulations that impact the trading of corporate bonds.

3.1 Basel 2.5 Market Risk Amendment

In 2010, the market risk amendment—commonly referred to as Basel 2.5—was introduced (see BCBS, 2010). The value-at-risk based trading book framework is supplemented with an incremental risk capital charge which includes default risk as well as migration risk for credit products. The incremental risk capital charge reduces the incentive for regulatory arbitrage between the banking and trading books. The framework also introduces a stressed value-at-risk requirement based on a one-year loss horizon, calculated in addition to the value-at-risk based on the most recent one-year observation period. The incremental risk capital and the stressed VaR put forward in the Basel 2.5 market risk framework significantly impact the balance sheet costs for trading credit products, particularly for corporate bonds (CGFS, 2014).

3.2 Basel III Capital Requirements

The Basel III capital framework strengthens the resilience of the banking sector by improving the regulatory capital framework. The reforms raise both the quality and quantity of the regulatory capital base and enhance the risk coverage of the capital framework. They are underpinned by a leverage ratio that serves as a backstop to the risk-based capital measures, is intended to constrain excess leverage in the banking system and provide an extra layer of protection against model risk and measurement error.

Basel III requires the predominant form of Tier 1 capital to be in the form of common shares and retained earnings. Common tier 1 equity has to be at least 4.5% of risk weighted assets at all times. The total risk weighted tier 1 plus tier 2 capital requirement is 8%. Furthermore a capital conservation buffer of 2.5% was introduced that can be drawn down in periods of stress. The buffer aims to reduce procyclicality by allowing institutions to use the capital buffer in times of stress.

Banks must determine their capital requirement for counterparty credit risk using stressed inputs for counterparty credit exposures arising from banks' derivatives, repo and securities financing activities. Banks are subject to a capital charge for potential mark-to-market losses, referred to as credit valuation adjustment (CVA) associated with a deterioration in the credit worthiness of a counterparty.

The leverage ratio requirement constrains leverage in the banking sector, thus helping to mitigate the risk of the destabilizing deleveraging processes. Furthermore, the leverage ratio provides a safeguard against model risk and measurement error by supplementing the risk-based measure with measure independent of risk. The leverage ratio requirement is 3%, and the largest U.S. institutions additionally a 2% supplement. The leverage ratio requirement reduces low-margin, balance sheet intensive businesses such as market-making in highly rated sovereign bonds and repo, likely providing incentive to move such businesses to CCPs (CGFS, 2014).

The macroprudential surcharge reduces the probability of failure of GSIBs by increasing their going-concern loss absorbency. The extent and impact of failure of G-SIBs was reduced by improving global recovery and resolution frameworks (see BCBS, 2013b).

3.3 Liquidity Regulation

The Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR, see BCBS, 2013a, 2014) aims to prevent funding shortages during times of stress. The LCR is to promote the short-term resilience of the liquidity risk profile of banks by ensuring that banks have an adequate stock of liquid assets that can be used to meet liquidity needs for a thirty-day stress scenario. The NSFR is to reduce funding risk over a longer time horizon by requiring banks to fund their activities with sufficiently stable sources of funding in order to mitigate the risk of future funding stress. The NSFR is defined as the amount of available stable funding relative to the amount of required stable funding.

3.4 Total Loss Absorbing Capacity (TLAC)

The aim of TLAC is to reduce both the probability and impact of failure of GSIBs. TLAC provides recapitalization capacity available in resolution in an orderly resolution. The quantitative TLAC requirements have not yet been finalized. See FSB (2015) for an overview.

3.5 Stress Tests

The Federal Reserve conducts stress tests for the largest bank holding companies (BHCs) and designated systemically financial institutions (SIFIs). Stress testing is a tool that helps bank supervisors measure whether a BHC has enough capital to support its operations throughout periods of stress. The DFA requires the Federal Reserve to conduct an annual stress tests to evaluate whether BHCs and SIFIs have sufficient capital to absorb losses resulting from adverse economic conditions. The stress tests are based on a hypothetical, severely adverse scenario designed by the Federal Reserve. The Federal Reserve's annual Comprehensive Capital Analysis and Review (CCAR) is an assessment of the capital adequacy and capital planning processes of large U.S. BHCs. Through CCAR, the Federal Reserve seeks to ensure that large BHCs have strong processes for assessing their capital needs that are supported by effective firmwide practices to identify, measure, and manage their material risks; strong internal controls; and effective oversight by boards of directors and senior management. CCAR also promotes greater resiliency by requiring each BHC to support its capital management decisions with forward-looking comprehensive analysis that takes into account the BHC's risk profile and activities.

3.6 Volcker rule

Section 619 of DFA, the Volcker rule, prohibits insured depository institutions and any company affiliated with an insured depository institution from engaging in proprietary trading and from acquiring or retaining ownership interests in, sponsoring, or having certain relationships with a hedge fund or private equity fund. While the rule directly impacts market-makers' capacity to provide liquidity, the overall market liquidity in normal times might not be hampered as some of the lost market-making capacity might be filled by existing non-bank firms such as hedge funds or insurance companies (Duffie, 2012).

3.7 Post-trade transparency

Required post-trade reporting, phased-in starting July 2002, was a major evolution in the corporate bond market. Not only that institutions are required to report their trades through the TRACE system, the information is also publicly disseminated shortly after. The impact of transparency on liquidity and on dealers' propensity to provide liquidity have been debated, but most academic papers find that the implementation of TRACE benefited clients over all, lowering transaction costs (Bessembinder et al. (2006), Goldstein et al. (2007),Edwards et al. (2007), Asquith et al. (2013)). Asquith et al. (2013), however, find that market activity as measured by trading volume divided by issue size for bonds with credit ratings high yield that trade infrequently.

3.8 Preliminary Evidence of Regulatory Reforms' Impact

CGFS (2014) take stock of the impact of those regulations for the business model of dealers, and market making more generally. The regulatory changes since 2010 are likely to affect dealers' balance sheets and profitability. Market participants expect the cost of market making to rise. Risk weights and credit risk charges make trading of corporates and credit derivatives more expensive. In particular the incremental risk capital charge and the stressed VaR add to inventory costs of corporate bonds. Furthermore, less liquid corporate bonds are ineligible for the liquidity coverage ratio, which is expected to reduce the willingness of banks to warehouse these assets. The leverage ratio increases the balance sheet cost of repos, including repos backed by corporates and structured credit. This creates a constraint on dealers' ability to manage inventory risk.

CGFS (2016) provides results of an informal survey of market participants. Survey participants provided estimates of the relative importance of different cost drivers including regulatory capital requirements as well as trading and operational costs using two highly stylized portfolios: one of sovereign bonds and one of corporate bonds. The survey results suggest that the P&L impact of recent regulatory changes has been differentiated. For sovereign bonds, both the Basel III leverage ratio and higher risk-weighted capital requirements were considered as having the largest impact on regulatory capital charges and, hence, dealers' profits. For the corporate bond example, by comparison, revisions to the Basel II market risk framework (Basel 2.5) were seen to have had the largest impact on regulatory charges. The survey responses imply that the gross revenue required to yield a return on capital of 8% under a fully phased-in Basel III framework would have resulted in returns above 20% given the requirements pertaining under Basel II. For corporate bonds, CGFS (2016) reports that survey respondents indicated that, on average, revisions to the Basel II market risk framework (Basel 2.5) had had the largest impact on regulatory charges. In line with this, respondents suggested, on average, that capital charges would have had increased significantly for this pricing example, when moving from Basel II to current requirements. The remaining phase-in of the Basel III requirements, in turn, was expected to have only a minor impact. Assuming constant revenues and a return on capital of 8% annually under the fully phased-in Basel III framework, survey responses suggest that for this example the return on capital would have amounted to about 26% annually under Basel II requirements.

Bessembinder et al. (2016) study bond liquidity as a function of dealers' willingness to commit capital to bond trading and show that trading capital allocation has shifted from bank affiliated dealers to independent dealers since the passage of DFA and Basel III. Bao et al. (2016) show that the illiquidity of stressed bonds has increased after the Volcker Rule and that Volcker rule affected dealers provide relatively less liquidity than non-Volcker-affected dealers since the passage of the rule. Trebbi and Xiao (2015) finds that post-crisis U.S. regulatory intervention does not appear to have produced structural deteriorations in market liquidity.

3.9 Empirical Predictions about Regulations' Impact

The above described regulations have been, or are in the process of being, phased in concurrently. The Dodd Frank Act and Basel III were passed in July 2010, at the same time as the Basel 2.5 market risk amendment was phased in. Since 2010, various rules of DFA and Basel III were drafted, commented on, and finalized. Hence the announcement days of final rules were not necessarily news to the market, as much of the rule making process revealed more or less of the details of the rules before finalization. Rule making for the Volcker rule was in 2010-12, and the rule was fully phased in in 2014. The rules for the Basel III capital requirements were drafted in 2010-12, and the phase in period is from 2013-2018, with a the fully phased in capital requirements only coming into effect in 2019. The Dodd Frank and CCAR stress tests started in 2011 for the twelve largest, and the universe of banks was expanded significantly to include all banks with assets of at least $50 Billion in 2016. Furthermore, each vintage of stress tests features a different scenario design. The liquidity coverage ratio is phased in from 2015 to 2019, and the net stable funding ratio is not expected to be phased until 2019. Therefore, many regulations were phased in concurrently. Furthermore, some institutions started to adapt to expected rules prior to their finalization, as the broad contours of the reforms was often known in advance.

Three regulations are expected to have the strongest impacts on the corporate bond market. The CVA and stress VaR of the Market Risk Amendment increase the balance sheet costs of credit risk relative to other asset classes in the trading book. Furthermore, risk weights on credit risk were increased relatively strongly by Basel III capital requirements. Finally, the Volcker rule prohibits proprietary trading of credit products in general, and corporate bonds in particular.

The CCAR and DFAST stress test scenarios do incorporate credit market stresses, but do not necessarily impact corporate bonds relatively stronger than other asset classes. However, banks that are subject to stress tests, relative to banks that are not subject to those tests, likely do have higher balance sheet costs for the entire trading book.

Other regulations have large impacts on trading, but not necessarily on corporate bonds. The leverage ratio is an unweighted capital requirement that is particularly costly for low risk assets such as Treasury securities or reverse repos. The liquidity coverage ratio does not have any particular impact on corporate bonds, as they do not qualify as high quality liquid assets. The NSFR and TLAC are not yet phased in.

4 Data Description and Sample Construction

For the empirical analysis we use information both about the dealers' trading activity in the corporate bond market as well as their balance sheet constraints. This section details the different data sources that we use to construct the daily dataset at the bond-dealer-level for the period from January 2005 to December 2015.

4.1 Corporate bond transactions

Corporate bond transaction data is sourced from a supervisory version of the Trade Reporting and Compliance Engine (TRACE), which contains transaction level data for almost all US corporate bonds. TRACE was introduced in July 2002 by the Financial Industry Regulatory Authority (FINRA)[2]. Real-time, public dissemination of trades was staggered, and since February 7, 2005, all bonds, except the TRACE-eligible Rule 144A bonds, are subject to dissemination.[3] As the number of bonds with disseminated trade information was expanded, FINRA also reduced the time delay for trade reporting from 75 minutes on July 1, 2002, to 45 minutes on October 1, 2003, to 30 minutes on October 1, 2004, and to 15 minutes on July 1, 2005. On January 9, 2006, the time delay for dissemination was eliminated.

Under FINRA Rule 6700, all broker/dealers who are FINRA member firms are required to enter trades in eligible fixed income securities into TRACE. If two members trade, both buying and selling members have to report. If a member and a non-member or a customer trade, only the member is required to report. FINRA Rule 6730 (Transaction Reporting) describes the specific items of information required to be provided in the trade report, including the identity of the other side (contra-party) for each transaction.

In most publicly available versions of TRACE, the identities of the buyer and seller is

[2]FINRA, which is a non-governmental regulator of the entire securities industry, was formed in the summer of 2007 from the NYSE and the NASD

[3]Agency debentures were added in March of 2010 and are subject to real-time dissemination. On November 12, 2012, FINRA began disseminating transaction information for agency pass-through mortgage-backed securities traded to-be-announced (TBA). FINRA began disseminating information for so-called specified pool transactions in agency pass-through mortgage-backed securities and SBA-backed securities in July 2013.

masked, and at best it is indicated whether the reporting member traded with a dealer (D) or with a customer (C). We, however, use a supervisory version of TRACE. Beyond the price and uncapped size information, the supervisory version also includes the identities the buyer and seller identities if they are FINRA members. The firms are identified using a designated Market Participant ID (MPID), or "C" for customer, if the firm is a non-member. The MPID is linked to the firm's legal name and, at times, to its "doing business as" (DBA) name.[4] The dataset starts in July 2002 and ends in December 2015. We only keep secondary market trades or primary market trades executed at market price (Trading Market Indicator = S1), which includes 167.6 million records and 123,600 bond issues.

Before calculating flows and liquidity measures using the traded price, we address several data issues. First, since TRACE is a real-time reporting system, it is prone to manual mistakes in entering the trade terms. When a trade is amended or cancelled, a correction or a cancellation record is entered, respectively, in addition to the existing original, erroneous trade record. We remove cancelled trades and using the amended version of the trade record if correction to the trade was submitted. Although in the literature many follow Dick-Nielsen (2009), the supervisory version of TRACE allows us to better address some of the issues resulting from the double reporting of corrections and cancellations. Specifically, we use the identity of the buyer and seller when matching the correction/cancellation to its original, erroneous record. Moreover, in the supervisory TRACE version, there is a special field that link the correction to its original record. As it will become clear in the following data issue, it is important to note that only the firm whose identifier is in the Reporting Party field of the trade report can subsequently correct or cancel that trade report.

Second, we properly account for "give-up" trades, in which a trade is reported by a member on behalf of another member who has a reporting responsibility.[5] An example of a give-up is a clearing firm that reports on behalf of its correspondent firms. The clearing firm

[4]The DBA is a fictitious name under which a firm does business that's different from its legal name.

[5] A "Uniform Service Agreement" is required for every firm for which the reporting firm will submit a give-up trade.

reports the trade by "giving up" the name of the correspondent in the "Reporting Party Give Up" field. Therefore, we associate the trade with correspondent firm rather than with the reporting firm. If the correspondent realizes a mistake was made, the correspondent will have to notify the clearing firm and the clearing firm would be required to the cancels and corrections for the correspondent.

Third, in November 2015, FINRA addressed an issue that has become more prevalent, a FINRA-member transferring a bond to an affiliate firm that is not a registered-FINRA member, for bookkeeping purposes. An affiliate is a non-member entity that controls, is controlled by or is under common control with a FINRA member.[6] Up to November 2015, a transfer between a member to a non-member affiliate and a customer-dealer trade were indistinguishable, and both were reported as a customer-dealer trade. The affiliate trade, however, does not constitute an actual transfer of risk between a dealer and a client, and does not provide investors with useful pricing information. The transfer is often preceded by an actual client-dealer trade with the same size and same price, and often only seconds apart, which contains the pricing information. Since November 2, 2015, firms are required to use a "non-member affiliate – principal transaction indicator" when reporting a transaction to TRACE in which both the member and its non-member affiliate act in a principal capacity, and where such trade occurs within the same day, at the same price and in the same security as a transaction between a member and another contra-party. When a transaction is identified as a non-member affiliate trade, FINRA suppresses dissemination of the transaction from public dissemination.

Fourth, we exclude trades that are not executed during normal system operating hours, between 8:00 am and 6:30 pm ET, or when reported on a non-business day whether it is a weekend of a bond market holiday.[7] As it is observed from Figure A.3 that exhibits the

[6] FINRA Rule 6710 states that "For the purposes of this definition, "control," along with any derivative thereof, means legal, beneficial, or equitable ownership, directly or indirectly, of 25 percent or more of the capital stock (or other ownership interest, if not a corporation) of any entity ordinarily having voting rights. The term "common control" means the same natural person or entity controls two or more entities."

[7] The TRACE system is open 8:00 am through 6:30 pm ET, while the market open from 8:00 am through 5:15 pm ET. See page 20 in TRACE OTC Corporate Bonds and Agency Debt User Guide – version 4.5,

distribution of trade execution time through out TRACE operating hours, and outside the normal hours less than 5 percent of number of trades and less than 10 percent of volume traded take place outside the normal operating hours. We also exclude trades with abnormal sizes (e.g., a trade with more than the amount outstanding), and abnormal prices (e.g., close to 0).

Once TRACE data issues are addressed, we aggregate the transactions information to construct the weekly net order flow each member transacted in a specific bond issue. That is, each week we sum the amount the member bought and subtract that amount it sold in a specific bond issue.

Using the transactions data we also calculate bond-level illiquidity. Since illiquidity can be measured in multiple ways, in this paper, we calculate an illiquidity proxy as the first principal component of various illiquidity measures (PC1) at the weekly level. The illiquidity measures include Amihud, effective bid-ask spread, imputed round-trip cost, and a combination of zero return days and no-trade days. Specifically, the weekly Amihud's measure is computed as the median of the daily measure calculated as follows:

$$\text{Amihud}_{b,t} = \frac{1}{N_{b,t}} \sum_{j=1}^{N_{b,t}} \frac{|r_{b,j}|}{v_{b,j}} \times 10^6,$$

where $N_{b,t}$ is the number of returns for bond b on day t, $r_{b,j}$ is the return of consecutive transactions, and $v_{b,j}$ is the dollar volume of a trade. The effective bid-ask is the difference between the dollar weighted average price of the buy trades and the dollar weighted average price of the sell trades (see Hong and Warga (2000) and Chakravarty and Sarkar (2003)):

$$\text{BAS}_{b,t} = \sum_{n=1}^{N} P_n^B W_n^B - \sum_{m=1}^{M} P_m^S W_m^S.$$

The measure requires at least one buy and one sell transaction each day.

To calculate the imputed round-trip cost (IRC) we follow Feldhütter (2012). The author

`http://www.finra.org/sites/default/files/TRAQS-CA-user-guide-v4.5.pdf` for further details.

classifies a transaction as part of an imputed round-trip trades (IRT) if two or three trades in a given bond with the same trade size occur on the same day, and there are no other trades with the sam size on that day. For each IRT, the imputed round-trip cost (IRC) is then defined as

$$IRC_{b,t} = \frac{P_{\max} - P_{\min}}{P_{\min}} \times 100,$$

where $P_{\max}$ is the highest price within an IRT and $P_{\min}$ is the lowest price within an IRT. The daily estimate of the roundtrip cost is the average IRC for all IRTs in a day and the weekly IRC is the median daily observation.

All the aforementioned illiquidity measures require at least two dealer-client observation for each day. Many corporate bond issues do not satisfy this condition, and would be dropped from the analysis. Therefore, we also calculate to measure illiquidity using a combination of two zero measures, as suggested by Lesmond et al. (1999). The measure zero return days (ZRD) proxies for bonds whose prices is unchanged over a long period, while the measure zero trade days (ZTD) proxies for bonds that do not trade for a long period. The two measures are then combined to one measure as

$$\text{Zeros}_{b,t} = \frac{\text{Zero Return Days}_{b,t} + \text{Zero Trade Days}_{b,t}}{\text{Trading Days}_t} \times 100.$$

Before applying PCA, we normalize all measures by subtracting their respective mean and dividing by their respective standard deviation.

We use Mergent FISD to get the characteristics of the bonds. We exclude bonds with special features that might affect their prices or frequency of trading. Specifically, we exclude all bonds with options, floating rates, odd frequent of coupon payments, medium-term notes, and inflation-indexed bonds. We also drop bonds with a maturity of less than one year, and unrated bonds.

Table 1 reports the number of observations and number of bond issues that were excluded in each step in the filtering process and due to the merge with Mergent FISD. The sample that is used in our benchmark analysis includes 9,352,641 transactions and 45,405 bond issues, and covers the time period from January 2003 to December 2015.

4.2 Balance sheet-based measures of constraints

To measure the funding and liquidity constraints faced by FINRA members, we first need to match them to companies that file financial statements. As mentioned before, the institutions that are required to report to TRACE are U. S. registered broker-dealers who are FINRA members. Members can report their trades under multiple MPID-s.[8] Many of these large broker-dealers are also U. S. BHCs themselves or subsidiaries of a BHC that are required to submit quarterly FR Y9-C forms.[9] This precludes us from matching U. S. broker-dealers who are affiliated with foreign BHCs. The match between the U. S. broker-dealers that report to TRACE and the U. S. BHCs that submit FR Y9-C is based on schedule FR Y-10 that includes the organizational structure of BHCs, savings and loans holding companies (SLHCs), and other institutions supervised by the Federal Reserve System.[10] We use the information on the institutional high holders to link to financial statements filed by them. We then aggregate the trading activity to the institutional high-holder level (usually BHCs in our sample).

We use FR Y9-C fillings to construct measures of constraints along multiple dimensions. FR Y9-C collects financial statements for U. S. based bank holding companies, including income statements, balance sheets and measures of off-balance sheet exposures. We group the characteristics into three categories: measures of the funding structure of the institution (raw leverage and net repo funding as a fraction of total assets), measures of the asset structure of the institution (loans as a fraction of total assets and risk-weighted assets as a fraction of total assets), and measures of the earning structure of the institution (ROA and trading revenue). The details of these measures are described in Appendix A.2.

[8]Only firms operating an Alternative Trading System are required to use a single, unique MPID when reporting transactions.

[9]Goldman Sachs and Morgan Stanley became BHCs in the middle of our sample, on September 2008.

[10]We thank Nicola Cetorelli for providing the panel data on real-time BHC organizational structure.

4.3 CoVaR

The balance sheet measures of constraint described above can only be constructed at a quarterly frequency. We supplement these measures with Adrian and Brunnermeier (2016) measure, CoVaR, which can be constructed at higher frequencies. CoVaR is defined as the Value-at-Risk of the financial system, conditional on the distress of a particular financial institution. Hence, it can be interpreted as an index of firm-level financial vulnerability that emphasizes the importance of the firm to systemic risk.

Empirical results presented in Appendix A.3 demonstrate that CoVaR is a useful summary metric of financial vulnerability. At a quarterly frequency, it correlates strongly with measures of leverage, maturity and liquidity transformation, and risk taking. Furthermore, CoVaR can also be interpreted as a measure of interconnectedness, as it is constructed to capture the tail correlation of firms with the financial system as a whole.

5 Bond Level Liquidity and Constraints

In this section, we focus on the link between bond-level liquidity and the constraints faced by intermediaries that are active traders in the bond.

5.1 Aggregate trends

We begin by translating institution-level constraints into bond-level measures of constraints. In our baseline specification, we compute an absolute net flow weighted average of institution-level constrains amongst institutions that have a non-zero net flow in a particular bond in a given week:

$$\text{Constraint}_{b,t} \equiv \sum_{d \in \mathcal{D}_{bt}} \frac{|\text{Flow}_{b,d,t}|}{\sum_{d \in \mathcal{D}_{bt}} |\text{Flow}_{b,d,t}|} \text{Constraint}_{d,t},$$

where $\text{Flow}_{b,d,t}$ is the net transaction flow of dealer d in bond b in week t, $\mathcal{D}_{bt}$ is the set of dealers trading bond b in week t, and $\text{Constraint}_{d,t}$ is one of the proxies of financial constraints of dealer d at the end of the prior quarter. When constrained institutions account for a larger fraction of the net transaction flow, the bond-level measure of constraints $\text{Constraint}_{b,t}$ is higher. In addition to the net flow weighted measures of constraints, we also construct the buy-flow and sell-flow weighted measures of bond-level constraints

$$\text{Constraint}^{B}_{b,t} \equiv \sum_{d \in \mathcal{D}^{B}_{bt}} \frac{\text{Buy flow}_{b,d,t}}{\sum_{d \in \mathcal{D}^{B}_{bt}} \text{Buy flow}_{b,d,t}} \text{Constraint}_{d,t}$$
$$\text{Constraint}^{S}_{b,t} \equiv \sum_{d \in \mathcal{D}^{S}_{bt}} \frac{\text{Sell flow}_{b,d,t}}{\sum_{d \in \mathcal{D}^{S}_{bt}} \text{Sell flow}_{b,d,t}} \text{Constraint}_{d,t}.$$

The buy-flow weighted constraint measures the constrains faced by the active buyers in the market, while the sell-flow weighted constraint measures the constraints faced by the active sellers in the market. If buyers and sellers in the market have disparate bargaining power in corporate bond transactions, constraints faced by buyers may impact bond liquidity differently than constraints faced by sellers. We investigate this potential asymmetry in section 5.3.

Figure 1 plots the time series of the average liquidity of the bonds in the top 10 and bottom 10 percent of constrained bonds across various measures of constraints. Three features are striking in the plots. First, average liquidity fluctuates over time for both the most and the least constrained bonds. Second, the relative liquidity of most constrained and least constrained bonds fluctuates over time, with the most constrained bonds sometimes more liquid than the least constrained bonds. Finally, different constraints impact the liquidity of constrained and unconstrained bonds disparately. CoVaR is the conditioning variable that has the strongest correlation with liquidity: bonds traded by dealers with low CoVaR are consistently less liquid than bonds traded by dealers with high CoVaR. Raw leverage, net repo, and the liquidity stress index also exhibit consistent relationships with liquidity: bonds tend to be less liquid if they are traded by dealers with lower leverage, higher net repo, and less liquidity stress. The other characteristics—RWA, loans, ROA, and trading revenue exhibit a time varying relationship with market liquidity.

We now examine the link between constraints and liquidity more formally and estimate the following regression

$$\text{Liquidity}_{b,t} = \alpha_t + \delta \text{Liquidity}_{b,t-1} + \beta \text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}, \tag{1}$$

where $\text{Liquidity}_{b,t}$ is the (il)liquidity of bond b at week t, $\text{Constraint}_{b,t}$ is the bond-level measure of constraints as defined above, and $\{\text{Char}_{b,k,t}\}_k$ are characteristics of bond b at date t.[11] The coefficient β measures the marginal impact of institutional constraints on bond liquidity. When β is positive, bonds that are more heavily traded by constrained institutions are more illiquid.

Table 2 reports the estimated coefficient β from the above regression for the full sample, as well as for subsamples split along various bond characteristics, using the first principal component of the liquidity measures as the measure of bond liquidity. The table shows that, although the statistical significance of the bond-level measure of constraints as an explanatory variable for variation in bond liquidity fluctuates in subsamples, the economic magnitude remains similar, suggesting that institutional constraints impact the liquidity of the bond market as a whole, and not just those with a particular credit rating, or in a particular industry group, or with issuances of particular size.

Consider now the full sample estimates for the coefficient, reported in the first row of Table 2. Bonds that are more actively traded by institutions with higher (raw) leverage, with higher trading revenue, higher liquidity mismatch and higher vulnerability (as measured by CoVaR) are all more liquid than the average bond. At the same time, bonds that are traded by institutions with higher ratio of risk-weighted assets to assets, greater reliance on repo funding, more illiquid assets (in the form of loans) and higher ROA are less liquid than the

[11]We include the following bond characteristics: log age, coupon, log total amount outstanding, log initial offering amount, log time to maturity (in years), an indicator for investment grade (or high yield) rating, and an indicator for callability of the bond.

average bond. Intuitively, institutions that are able to maintain a higher level of leverage and that have a higher trading revenue overall are able to devote more resources to their trading activity overall, while institutions with less liquid assets are less likely to provide liquidity to the bond market. Similarly, institutions more reliant on repo funding are also less likely to provide liquidity to the corporate bond market as long positions in corporate bonds are usually repo financed as well (see Boyarchenko et al., 2016, for further details).

The breakdown by credit ratings shows that results for the investment grade bonds are generally more significant. For raw leverage, net repo, and trading revenue the effects are larger for investment grade than for high yield bonds. The unrated/defaulted bonds only show significant effects for raw leverage, ROA, the liquidity stress ratio, and CoVaR. The signs of the estimated effects are consistent across the ratings classes.

Turning to the industry classifications, Table 2 shows that the estimated coefficients are generally larger and more significant for industries 1-3 than for industries 4-5. Estimated signs are again consistent with the baseline specification across all industries. Finally, comparing bonds with different initial offering amounts, we see that the estimated effects of constraints faced active traders in the bonds are of similar magnitude and statistical significance across initial offering terciles.

The above effects are both economically and statistically significant: a one standard deviation increase in raw leverage increases bond liquidity by 6 percent. In unreported results, we also show that these conclusions are robust to using individual liquidity measures, rather than the first principal component of all liquidity measures, and to including bond issue fixed effects, rather than controlling for time-invariant bond characteristics.[12]

5.2 Changes over time

Both the market and the regulatory environment have changed substantially since the introduction of TRACE in 2002. These changes could have impacted the relationship between

[12]In the regression with bond issue fixed effects, we still control for the log age, log time to maturity, log amount outstanding and credit rating of the bond, as these characteristics change over time.

bond liquidity and institutional constraints. Indeed, as can be seen from Figure 2, which plots the coefficient β estimated in 15 annual subsamples over time, the relationship between measures of constraints and bond liquidity fluctuates over time and, for a number of measures of constraints, even switches sign. Thus, for example, while there was a negative relationship between the institution's reliance on repo funding and bond liquidity at the start of the sample, the relationship became positive and statistically significant immediately preceding the financial crisis and has remained positive since. On the other hand, the relationship between trading revenue and bond liquidity is negative throughout the sample except during the crisis when it becomes positive, albeit not statistically significant.

Table 3 tests this differences over time more formally. In particular, we split our sample into four subperiods – pre-crisis (start of sample to December 31, 2006), crisis (January 1, 2007 – December 31, 2009), rule writing (January 1, 2010 – December 31, 2013), and rule implementation (January 1, 2014 – end of sample) – and conduct F-tests of the coefficients being equal across the four subperiods. The relationship between raw leverage and bond liquidity is the most stable over time: the F-test fails to reject that the relationship in the crisis and the rule implementation periods is different from the relationship in the pre-crisis period. During the rule writing period, however, the relationship between raw leverage and bond liquidity switches signs, with bonds more heavily traded by levered institutions less liquid. This may reflect institutional uncertainty during this period about the exact nature of planned changes to capital regulation.

The relationship between bond liquidity and institutional constraints exhibits statistically significant variation across subperiods for most of the other measures of constraints. Importantly, in the rule implementation period (that is, post January 1, 2014), bonds traded by more vulnerable institutions and institutions with greater liquidity mismatch are less liquid,[13] suggesting that prudential regulations may be having an effect on bond market liquidity. Consistent with the Market Risk Amendment having a greater impact on the corporate

[13]Recall that, in the full sample, bonds traded by more vulnerable institutions and institutions with greater liquidity mismatch are *more* liquid.

bond book, the relationship between bond liquidity and risk-weighted assets as a fraction of total assets also switches signs in the rule implementation period, and becomes negative, so that bonds that are more heavily traded by institutions that have a greater fraction of risky assets are more liquid. The CoVaR measure of vulnerability also switches signs in the implementation period relative to the earlier periods, showing that bonds traded by more vulnerable institutions tend to be less liquid now relative to the pre crisis period.

Overall, Table 3 shows that the relationship between bond liquidity and constraints faced by active traders in the market is not static. Rather, market events, such as the financial crisis, and anticipated and implemented regulatory changes have a significant impact on the willingness of constrained institutions to provide market liquidity. It is important to emphasize that our measure of bond-level constraints uses lagged measures of balance sheet constraints; thus, trading activity by institutions that are constrained in the previous quarter impacts bond liquidity in the current quarter.

5.3 Constrained buyers vs constrained sellers

We conclude this section by investigating the asymmetry between buyers and sellers in the corporate bond market and estimate the following regression

$$\text{Liquidity}_{b,t} = \alpha_t + \delta \text{Liquidity}_{b,t-1} + \beta^B \text{Constraint}^B_{b,t} + \beta^S \text{Constraint}^S_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}, \tag{2}$$

where $\text{Constraint}^B_{b,t}$ and $\text{Constraint}^S_{b,t}$ are the bond-level measure of constraints faced by buyers and sellers, respectively. The coefficient β^B measures the marginal impact of buyers' constraints on bond liquidity, while the coefficient β^S measures the marginal impact of sellers' constraints. When $\beta^B = \beta^S$, the constraints faced by either side to the transaction have an equal impact on bond illiquidity. When $\beta^B > \beta^S$, buyers' constraints have a greater impact on bond liquidity than do the constraints faced by the sellers in the market.

Table 4a reports the full sample estimated coefficients β^B and β^S across various measures of constraints, together with the F-test of the buyers' constraints having the same impact as the sellers' constraints ($\beta^B = \beta^S$). Across all measures of constraints, the sellers' constraints have a greater (in magnitude) impact on bond liquidity, with the difference in coefficients statistically significant at at least the 10 percent level for all measures except the ratio of risk weighted assets to assets. Intuitively, institutional constraints impact the willingness of institutions to hold corporate bond positions and, in particular, may induce constrained institutions to liquidate their corporate bond portfolio, reducing liquidity in the market. Dealers owned by European banks have reportedly reduced their trading operations significantly, particularly with respect to credit trading.[14] More generally, aggregate trading VaRs of banks have been reduced dramatically since the financial crisis, and aggregate dealer balance sheet size has stagnated.[15]

Table 4b tests whether the impact of buyers' and sellers' constraints has changed over time. Similarly to the relationship between net-flow-weighted constraints and bond liquidity, the relationship between buy-flow-weighted (sell-flow-weighted) constraints changes over time, with bonds bought (sold) by more vulnerable institutions and institutions with greater maturity mismatch less liquid during the rule implementation period, while bonds that are sold by institutions with greater ratio of risk-weighted to total assets more liquid during the rule implementation period.

Thus, Table 4a and 4b shows that, while there are important asymmetries in the impact that constraints faced by buyers and sellers in the corporate bond market have on bond liquidity, market and regulatory changes have similar implications for both sides of the market.

[14] See, for example, the unwinding of the formerly largest trading floor **in pictures**.

[15] See an investigation of **the stagnation of dealer balance sheets**.

6 Portfolio Liquidity

The previous section studied the impact that constraints faced by institutions that are active participants in the corporate bond market have on the liquidity of bonds they trade in. We now consider whether institution-level constraints have a significant impact on the liquidity of the portfolio of bonds traded by a particular institution. Similarly to the bond-level measure of constraints, we measure portfolio-level liquidity as the flow-weighted average of the liquidity of the bonds traded by the institution in a given quarter

$$\begin{aligned}
\text{Liquidity}_{dt} &\equiv \sum_{b\in\mathcal{B}_{dt}} \frac{|\text{Flow}_{b,d,t}|}{\sum_{b\in\mathcal{B}_{dt}} |\text{Flow}_{b,d,t}|}\text{Liquidity}_{b,t} \\
\text{Liquidity}^{B}_{dt} &\equiv \sum_{b\in\mathcal{B}^{B}_{dt}} \frac{\text{Buy flow}_{b,d,t}}{\sum_{b\in\mathcal{B}^{B}_{dt}} \text{Buy flow}_{b,d,t}}\text{Liquidity}_{b,t} \\
\text{Liquidity}^{S}_{dt} &\equiv \sum_{b\in\mathcal{B}^{S}_{dt}} \frac{\text{Sell flow}_{b,d,t}}{\sum_{b\in\mathcal{B}^{S}_{dt}} \text{Sell flow}_{b,d,t}}\text{Liquidity}_{b,t},
\end{aligned}$$

where $\mathcal{B}_{d,t}$ is the set of bonds traded by institution d in quarter t, $\mathcal{B}^{B}_{d,t}$ is the set of bonds bought and $\mathcal{B}^{S}_{d,t}$ is the set of bonds sold.

To study the relationship between institution constraints and the liquidity of their corporate bond portfolios, we estimate the following regression

$$\text{Liquidity}_{dt} = \alpha_t + \alpha_d + \delta\text{Liquidity}_{d,t-1} + \beta\text{Constraint}_{d,t} + \epsilon_{d,t}. \tag{3}$$

The coefficient β measures the impact of institutional constraints on the liquidity of the bonds traded by the institution. When β is positive, more constrained institutions trade in less liquid bonds; when β is negative, more constrained institutions trade in more liquid bonds.

Table 5a reports the estimated coefficient β from the above regression for the full sample, using the first principal component of the liquidity measures, weighted by absolute net flow (first row), buy flow (second row) and sell flow (third row). Consistent with the bond-level liquidity results in section 5, institutional constraints have a greater (in magnitude) impact on sell-flow-weighted portfolio liquidity. Unlike the bond-level liquidity results, however, only raw leverage and CoVaR have a statistically significant impact on portfolio liquidity, with institutions that have a higher raw leverage ratio or that are more vulnerable trading more actively in less liquid bonds, both as buyers and sellers.

Table 5b shows the results by sub-periods (pre-crisis, crisis, rule writing, and implementation). During the implementation phase (2014 - 2016), the RWA, loans, trading revenue, liquidity stress, and CoVaR are all significant. When those coefficients are tested against the pre-crisis levels, only trading revenue and the liquidity stress ratio show a significant difference. While trading revenue is associated with better liquidity pre crisis (it has a negative coefficient), that relationship flips in the implementation phase so that trading revenue is associated with less portfolio liquidity. A similar switch in the relationship occurs for the liquidity stress ratio: a higher ratio is associated with more liquidity pre crisis, and less liquidity in the most recent implementation sample. These results are consistent with the notion that banks' business model has changed significantly.

7 Conclusion

Post-crisis regulatory reform, such as the Dodd-Frank Act in the U. S. and the Basel Committee's Basel III regulations, has aimed to increase the stability of the global financial system and to improve the resilience of asset markets to episodes of stress. Market participants and analysts alike have however argued that these reform efforts have increased balance sheet costs for dealer participants and thus have had adverse consequences on the level of market liquidity during "normal" times. Prudential regulators may thus face a risk-return tradeoff in terms of regulations affecting liquidity: while these measures may improve market liquidity during periods of stress, these potential benefits should be weighted against potentially reduced liquidity during normal times.

Despite anecdotal evidence of reduced market liquidity, establishing a causal link between regulations and market liquidity has proven challenging. In this paper, we used detailed data on bond transactions linked to the balance sheets of individual institutions to study both how constraints faced by institutions influence bond-level liquidity and to what extent the relationship between bond liquidity and constraints faced by institutions that are active traders in the bonds changes over time. We find that, prior to the crisis, bonds traded by institutions with higher leverage, higher trading revenue, higher liquidity mismatch, that are more vulnerable, with lower risk-weighted assets, less reliance on repo funding, and fewer illiquid assets are more liquid. Constraints faced by traders in the market have significant time variation in their impact on market liquidity. During the implementation of post-crisis regulation (since January 2014), the impact of trading by vulnerable institutions and institutions with greater maturity mismatch has reversed, with bonds more actively traded by vulnerable institutions or institutions with higher liquidity mismatch less liquid. Furthermore, constraints faced by institutions that are active sellers in the market have a larger impact on bond liquidity than constraints faced by buyers.

Our findings suggest three important implications for theoretical models of corporate bond liquidity. First, constraints faced by active traders in the market do have an economically and statistically significant effect on bond liquidity. Moreover, funding constraints, such as reliance on repo funding, have a different impact than capital constraints, suggesting that market participants manage funding risks separately from capital risks. Our findings are consistent with the notion that changes in institutions' business models – as captured by measures of the structure of their balance sheet and income statements – do impact corporate bond liquidity. Second, there is a marked asymmetry between constraints faced by buyers and constraints faced by sellers in the market. This asymmetry may either arise from differential market power of buyers and sellers or from differential willingness to trade. Finally, market shocks and regulatory reforms do change the willingness of some participants to provide liquidity in the corporate bond market; however, these changes seem to affect buyers and sellers in a similar fashion. Thus, regulatory changes seem to impact both sides of the market to an equal extent.

Overall, our paper provides a first estimate of the costs associated with regulation changing the incentives of constrained institutions to provide liquidity in the corporate bond market. To evaluate the full impact of regulation, however, one would need to also be able to evaluate whether regulatory reforms have decreased liquidity losses during periods of market stress.

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Table 1: **Sample construction**. This table details the steps that were applied to construct the sample. In each step we detail the remaining number of transactions and corporate bond issues.

	Number of Transactions	Number of Issues
Raw Regulatory TRACE	27,708,555	96,215
Merged Clean Regulatory TRACE and Mergent FISD	17,697,165	54,541
Exclude bonds with special features	15,906,305	54,353
Exclude bonds with remaining maturity $<$ 1 year	13,545,989	50,761
Sample used in the analysis	93,52,641	45,405

Table 2: **Bond-level regressions**. This table reports the estimated coefficient β from the regression
$\text{Liquidity}_{b,t} = \alpha_t + \delta \text{Liquidity}_{b,t-1} + \beta \text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}$,
for the full sample as well as the credit rating, industry and original issuance amount subsamples. Each column corresponds to a different measure of institution-level constraints. Bond liquidity measured by the standardized first principal component of Amihud, BAS, IRC and Zeros liquidity measures. T-statistics based on standard errors clustered at the quarter-issuer level reported below point estimates; all regressions include week fixed effects, and controls for log age, coupon, log total amount outstanding, log initial offering amount, log time to maturity (in years), an indicator for investment grade (or high yield) rating, and an indicator for callability of the bond. *** significant at 1%, ** significant at 5%, * significant at 10%.

	Raw lev.	RWA	Net repo	Loans	ROA	Trading rev.	LSR	CoVaR
Full sample	-0.0629	0.0297	0.0402	0.0449	0.0517	-0.0327	-0.0320	-0.0079
	[-30.801]***	[16.557]***	[30.849]***	[28.411]***	[11.356]***	[-31.127]***	[-15.152]***	[-2.276]**
Credit rating								
IG	-0.0634	0.0280	0.0413	0.0422	0.0450	-0.0341	-0.0244	-0.0044
	[-27.568]***	[13.713]***	[26.594]***	[23.011]***	[8.829]***	[-26.958]***	[-10.775]***	[-1.053]
HY	-0.0488	0.0335	0.0352	0.0494	0.0904	-0.0280	-0.0576	-0.0263
	[-11.184]***	[9.130]***	[15.472]***	[16.097]***	[8.898]***	[-15.842]***	[-11.157]***	[-4.266]***
NR/Def	-0.0664	0.0035	0.0190	0.0152	0.0849	0.0035	-0.0936	-0.0474
	[-1.854]*	[0.114]	[0.773]	[0.591]	[2.217]**	[0.212]	[-3.373]***	[-2.874]***
Industry								
1	-0.0691	0.0333	0.0493	0.0498	0.0592	-0.0386	-0.0334	-0.0170
	[-26.349]***	[15.420]***	[30.455]***	[25.644]***	[10.550]***	[-31.949]***	[-12.504]***	[-4.774]***
2	-0.0669	0.0368	0.0299	0.0470	0.0498	-0.0263	-0.0309	-0.0087
	[-20.470]***	[11.044]***	[12.572]***	[15.991]***	[6.290]***	[-13.105]***	[-10.066]***	[-1.540]
3	-0.0578	0.0262	0.0376	0.0376	0.0808	-0.0312	-0.0566	-0.0281
	[-6.316]***	[3.635]***	[7.549]***	[6.031]***	[4.261]***	[-8.370]***	[-6.025]***	[-2.485]**
4	-0.0482	0.0416	0.0121	0.0099	0.0217	0.0277	-0.0187	0.0542
	[-0.664]	[0.492]	[0.198]	[0.150]	[0.133]	[0.687]	[-0.108]	[0.335]
5	0.0228	0.0395	0.0127	0.0279	0.1847	-0.0050	-0.0182	-0.1532
	[0.702]	[1.700]*	[0.993]	[1.518]	[2.502]**	[-0.403]	[-0.386]	[-2.094]**
Initial offering tercile								
1	-0.0490	0.0172	0.0135	0.0326	0.0229	-0.0208	-0.0451	-0.0178
	[-10.886]***	[4.485]***	[3.958]***	[8.352]***	[3.159]***	[-6.625]***	[-12.464]***	[-3.444]***
2	-0.0752	0.0370	0.0457	0.0545	0.0554	-0.0407	-0.0455	-0.0345
	[-22.441]***	[13.510]***	[22.239]***	[21.422]***	[8.332]***	[-23.893]***	[-14.500]***	[-7.574]***
3	-0.0524	0.0305	0.0377	0.0400	0.0631	-0.0265	-0.0206	-0.0069
	[-19.100]***	[12.653]***	[22.989]***	[19.446]***	[10.566]***	[-20.415]***	[-7.462]***	[-1.824]*

Table 3: **Bond-level subsample regressions**. This table reports the estimated coefficient β from the regression
$\text{Liquidity}_{b,t} = \alpha_t + \delta \text{Liquidity}_{b,t-1} + \beta \text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}$,
for the sample split into four subperiods: pre-crisis (start of sample – Dec. 31, 2006), crisis (Jan. 1, 2007 – Dec. 31, 2009), rule writing (Jan. 1, 2010 – Dec. 31, 2013), and implementation (Jan. 1, 2014 – end of sample). Each column corresponds to a different measure of institution-level constraints. Bond liquidity measured by the standardized first principal component of Amihud, BAS, IRC and Zeros liquidity measures. T-statistics based on standard errors clustered at the quarter-issuer level reported below point estimates; all regressions include week fixed effects, and controls for log age, coupon, log total amount outstanding, log initial offering amount, log time to maturity (in years), an indicator for investment grade (or high yield) rating, and an indicator for callability of the bond. *** significant at 1%, ** significant at 5%, * significant at 10%.

	Raw lev.	RWA	Net repo	Loans	ROA	Trading rev.	LSR	CoVaR
Pre-crisis	-0.0338	0.0441	0.0743	0.0095	0.0146	0.0075	-0.0201	-0.0166
	[-10.070]***	[10.923]***	[26.520]***	[2.327]**	[1.708]*	[1.933]*	[-5.910]***	[-2.272]**
Crisis	-0.0337	-0.0029	-0.0171	0.0333	0.1100	-0.0344	-0.0918	-0.1142
	[-9.094]***	[-0.637]	[-4.998]***	[8.103]***	[15.804]***	[-13.852]***	[-22.247]***	[-21.404]***
Rule writing	0.0186	0.0029	-0.0169	0.0102	0.0304	-0.0172	0.0253	-0.0608
	[5.058]***	[0.863]	[-6.390]***	[3.234]***	[3.748]***	[-7.305]***	[5.497]***	[-9.749]***
Implementation	-0.0370	-0.0190	0.0056	-0.0030	-0.0742	-0.0026	0.0365	0.1010
	[-10.668]***	[-5.778]***	[2.400]**	[-0.984]	[-9.799]***	[-1.129]	[8.700]***	[13.341]***
$F(\beta_{Pre} = \beta_{Crisis})$	0.001	36.766	267.226	10.203	58.698	48.729	182.371	102.475
p-val	0.979	0.000	0.000	0.001	0.000	0.000	0.000	0.000
$F(\beta_{Pre} = \beta_{Writing})$	88.699	52.110	487.355	0.014	1.204	17.863	50.928	15.721
p-val	0.000	0.000	0.000	0.906	0.273	0.000	0.000	0.000
$F(\beta_{Pre} = \beta_{Imp.})$	0.388	130.214	377.788	4.802	43.392	3.029	107.299	77.048
p-val	0.534	0.000	0.000	0.028	0.000	0.082	0.000	0.000

Table 4: **Bond-level and constraints of buyers and sellers**. This table reports the estimated coefficients β^B and β^S from the regression
$\text{Liquidity}_{b,t} = \alpha_t + \delta\text{Liquidity}_{b,t-1} + \beta^B\text{Constraint}^B_{b,t} + \beta^S\text{Constraint}^S_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}$, for the full sample and for the sample split into four subperiods: pre-crisis (start of sample – Dec. 31, 2006), crisis (Jan. 1, 2007 – Dec. 31, 2009), rule writing (Jan. 1, 2010 – Dec. 31, 2013), and implementation (Jan. 1, 2014 – end of sample). Each column corresponds to a different measure of institution-level constraints. Bond liquidity measured by the standardized first principal component of Amihud, BAS, IRC and Zeros liquidity measures. T-statistics based on standard errors clustered at the quarter-issuer level reported below point estimates; all regressions include week fixed effects, and controls for log age, coupon, log total amount outstanding, log initial offering amount, log time to maturity (in years), an indicator for investment grade (or high yield) rating, and an indicator for callability of the bond. *** significant at 1%, ** significant at 5%, * significant at 10%.

(a) Full sample

	Raw lev.	RWA	Net repo	Loans	ROA	Trading rev.	LSR	CoVaR
β^B	-0.0288	-0.0016	0.0095	0.0148	0.0132	-0.0142	-0.0240	-0.0055
	[-15.033]***	[-0.976]	[8.108]***	[9.982]***	[3.860]***	[-14.810]***	[-13.301]***	[-2.115]**
β^S	-0.0377	0.0001	0.0137	0.0225	0.0226	-0.0193	-0.0378	-0.0157
	[-19.151]***	[0.046]	[11.269]***	[14.645]***	[5.996]***	[-19.693]***	[-19.720]***	[-5.605]***
$F(\beta^B = \beta^S)$	8.087	0.395	5.224	10.358	2.603	11.989	24.642	6.348
p-val	0.004	0.530	0.022	0.001	0.107	0.001	0.000	0.012

(b) Sub-samples

	Raw lev.	RWA	Net repo	Loans	ROA	Trading rev.	LSR	CoVaR
Pre-crisis, β^B	0.0068	0.0199	0.0429	0.0052	-0.0055	0.0139	0.0065	-0.0125
	[2.048]**	[5.503]***	[17.346]***	[1.378]	[-0.682]	[3.536]***	[1.952]*	[-1.788]*
Crisis, β^B	-0.0232	-0.0166	-0.0140	0.0039	0.0039	-0.0209	-0.0332	-0.0377
	[-6.694]***	[-4.029]***	[-4.367]***	[1.049]	[0.645]	[-8.709]***	[-8.383]***	[-7.461]***
Rule writing, β^B	-0.0010	-0.0023	-0.0136	0.0052	0.0240	-0.0122	-0.0074	-0.0302
	[-0.291]	[-0.738]	[-5.563]***	[1.808]*	[3.242]***	[-5.232]***	[-1.574]	[-5.198]***
Implementation, β^B	-0.0238	-0.0018	0.0012	0.0064	-0.0047	-0.0066	0.0112	0.0480
	[-7.308]***	[-0.614]	[0.576]	[2.280]**	[-0.681]	[-2.829]***	[2.654]***	[6.839]***
Pre-crisis, β^S	-0.0101	0.0392	0.0568	0.0007	-0.0230	0.0172	-0.0182	-0.0135
	[-3.019]***	[10.459]***	[22.275]***	[0.180]	[-2.850]***	[4.608]***	[-5.180]***	[-1.846]*
Crisis, β^S	-0.0311	-0.0111	-0.0146	0.0178	0.0529	-0.0237	-0.0418	-0.0584
	[-8.473]***	[-2.489]**	[-4.384]***	[4.486]***	[8.181]***	[-9.929]***	[-9.370]***	[-11.044]***
Rule writing, β^S	0.0181	-0.0228	-0.0231	0.0009	0.0219	-0.0131	0.0076	-0.0236
	[5.125]***	[-6.975]***	[-9.239]***	[0.308]	[2.810]***	[-5.811]***	[1.555]	[-3.938]***
Implementation, β^S	-0.0296	-0.0152	0.0012	0.0095	-0.0064	-0.0148	-0.0017	0.0403
	[-8.820]***	[-4.809]***	[0.536]	[3.251]***	[-0.896]	[-6.557]***	[-0.398]	[5.535]***
$F(\beta^B_{Pre} = \beta^B_{Crisis})$	30.055	27.407	125.088	0.040	0.680	33.353	67.485	7.190
p-val	0.000	0.000	0.000	0.841	0.410	0.000	0.000	0.007
$F(\beta^B_{Pre} = \beta^B_{Writing})$	2.006	18.975	241.298	0.000	4.717	19.282	4.560	2.779
p-val	0.157	0.000	0.000	0.999	0.030	0.000	0.033	0.096
$F(\beta^B_{Pre} = \beta^B_{Impl.})$	36.457	19.116	188.998	0.047	0.004	11.920	0.735	22.956
p-val	0.000	0.000	0.000	0.829	0.952	0.001	0.391	0.000
$F(\beta^S_{Pre} = \beta^S_{Crisis})$	13.455	45.884	182.237	5.688	43.194	50.041	17.133	20.676
p-val	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000
$F(\beta^S_{Pre} = \beta^S_{Writing})$	26.819	141.202	467.882	0.002	10.613	29.086	15.235	0.845
p-val	0.000	0.000	0.000	0.967	0.001	0.000	0.000	0.358
$F(\beta^S_{Pre} = \beta^S_{Imp.})$	14.538	116.894	317.359	2.603	1.709	32.406	8.900	16.723
p-val	0.000	0.000	0.000	0.107	0.191	0.000	0.003	0.000

Table 5: **Portfolio-level liquidity**. This table reports the estimated coefficient β (β^B, β^S) from the regression
$\text{Liquidity}_{d,t} = \alpha_t + \alpha_d + \delta\text{Liquidity}_{d,t-1} + \beta\text{Constraint}_{d,t} + \epsilon_{d,t}$,
for institution-level liquidity calculated as the absolute net-flow (buy-flow, sell-flow) weighted average of bond liquidity in institution d's portfolio for the full sample and for the sample split into four subperiods: pre-crisis (start of sample – Dec. 31, 2006), crisis (Jan. 1, 2007 – Dec. 31, 2009), rule writing (Jan. 1, 2010 – Dec. 31, 2013), and implementation (Jan. 1, 2014 – end of sample). Each column corresponds to a different measure of institution-level constraints. Bond liquidity measured by the standardized first principal component of Amihud, BAS, IRC and Zeros liquidity measures. T-statistics based on standard errors clustered at the year-institution level reported below point estimates; all regressions include quarter and institution fixed effects. *** significant at 1%, ** significant at 5%, * significant at 10%.

(a) Full sample

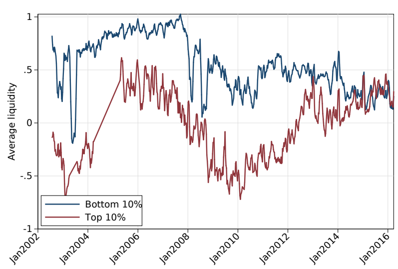
	Raw lev.	RWA	Net repo	Loans	ROA	Trading rev.	LSR	CoVaR
Overall	0.0140	-0.1338	0.0906	-0.1807	0.0152	-0.0304	0.0855	0.0911
	[0.280]	[-1.646]	[1.300]	[-1.400]	[0.403]	[-1.491]	[1.415]	[1.320]
Buyers	0.0526	-0.0605	0.0101	-0.0516	0.0017	0.0016	-0.0222	0.0870
	[1.755]*	[-1.377]	[0.184]	[-0.677]	[0.091]	[0.142]	[-0.533]	[2.028]**
Sellers	0.0545	-0.0513	-0.0089	-0.0243	0.0042	0.0084	0.0113	0.1026
	[1.863]*	[-1.032]	[-0.142]	[-0.285]	[0.231]	[0.702]	[0.256]	[2.416]**

(b) Sub-samples

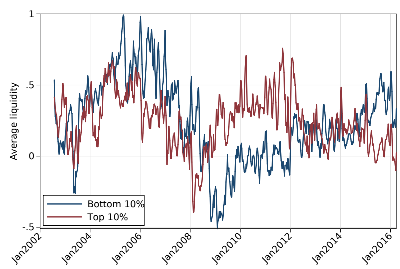
	Raw lev.	RWA	Net repo	Loans	ROA	Trading rev.	LSR	CoVaR
Pre-crisis	-0.0072	-0.1181	0.1143	-0.1142	-0.0017	-0.1559	-0.1683	-0.0175
	[-0.098]	[-2.083]**	[1.490]	[-1.626]	[-0.029]	[-2.637]***	[-2.665]***	[-0.105]
Crisis	0.0711	0.0091	0.0561	0.0188	-0.1521	0.0372	-0.0544	-0.1347
	[1.155]	[0.189]	[0.954]	[0.281]	[-2.981]***	[0.795]	[-0.944]	[-0.879]
Rule writing	0.0344	0.0343	0.0231	-0.0047	0.0111	0.0095	-0.0002	-0.1392
	[0.654]	[0.824]	[0.482]	[-0.080]	[0.147]	[0.283]	[-0.003]	[-1.032]
Implementation	-0.0438	-0.0781	-0.0620	-0.1280	0.0520	0.0972	0.1714	0.2185
	[-0.646]	[-1.708]*	[-1.301]	[-2.207]**	[0.708]	[2.556]**	[2.759]***	[1.775]*
$F(\beta_{Pre} = \beta_{Crisis})$	0.849	3.486	0.407	3.480	6.854	4.195	3.904	0.184
p-val	0.357	0.063	0.524	0.063	0.009	0.041	0.049	0.668
$F(\beta_{Pre} = \beta_{Writing})$	0.147	4.133	0.924	1.653	0.013	3.653	3.317	0.193
p-val	0.702	0.043	0.337	0.199	0.911	0.057	0.069	0.661
$F(\beta_{Pre} = \beta_{Imp.})$	0.085	0.257	3.586	0.022	0.241	7.819	10.982	0.765
p-val	0.771	0.613	0.059	0.883	0.624	0.005	0.001	0.382

Figure 1: **Bond-level liquidity over time.** This figure plots the time series of the average liquidity of bonds in the top decile and bottom decile of the constraint distribution. Bond liquidity measured by the standardized first principal component of Amihud, BAS, IRC and Zeros liquidity measures. Bond-level constraints measured as the absolute net flow weighted average of institution-level constraints for institutions trading in the bond in a given week.

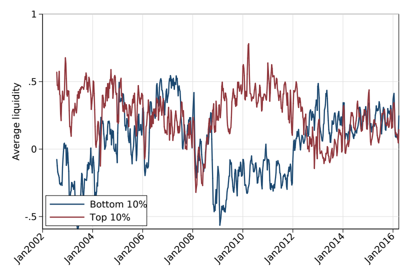
(a) Raw leverage



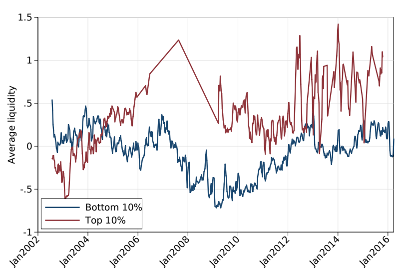
(b) RWA



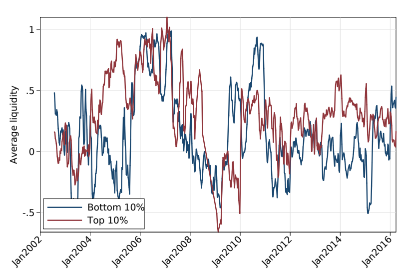
(c) Loans



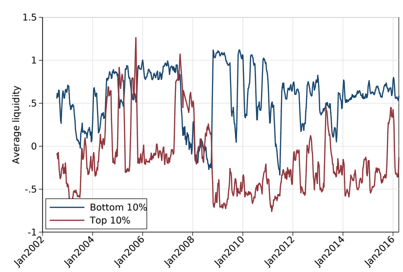
(d) Net repo



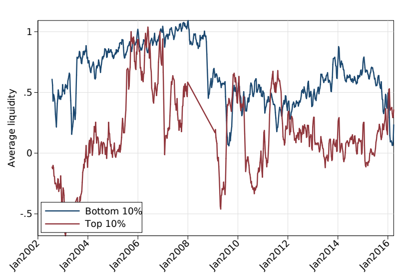
(e) ROA



(f) Trading revenue



(g) LSR



(h) CoVaR

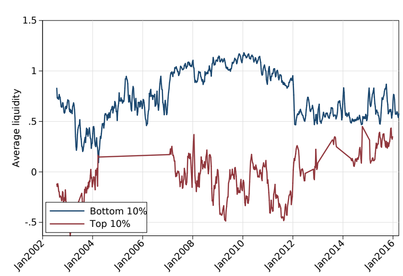
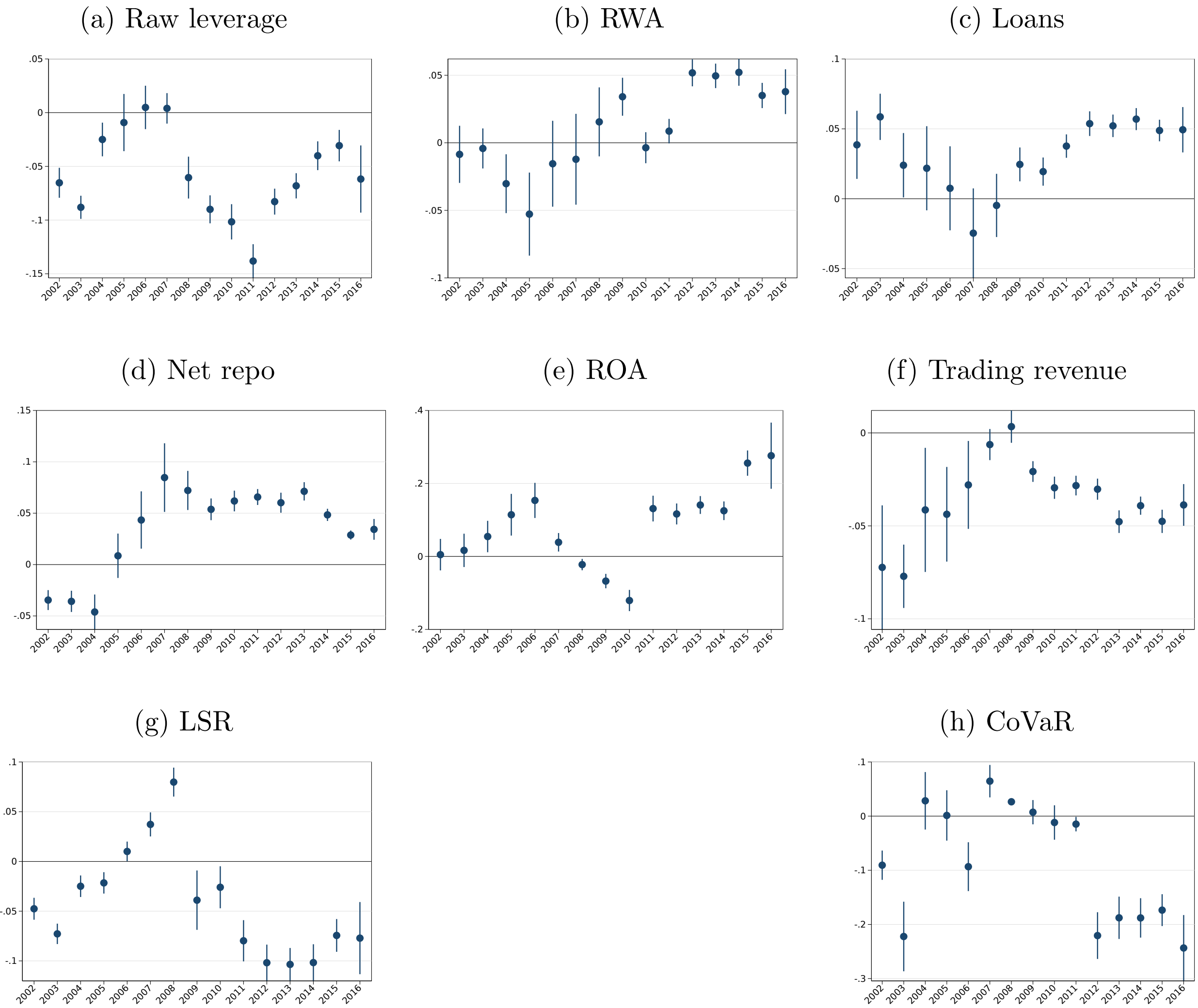


Figure 2: **Baseline regression coefficients over time.** This figure plots the estimated coefficient β from the regression

$$\text{Liquidity}_{b,t} = \alpha_t + \beta \sum_{d \in \mathcal{D}_{bt}} \frac{\left|\text{Flow}_{b,d,t}\right|}{\sum_{d \in \mathcal{D}_{bt}} \left|\text{Flow}_{b,d,t}\right|} \text{Constraint}_{d,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t},$$

for the sample split by year. Each figure corresponds to a different measure of institution-level constraints. Bond liquidity measured by the standardized first principal component of Amihud, BAS, IRC and Zeros liquidity measures. T-statistics based on standard errors clustered at the quarter-issuer level reported below point estimates; all regressions include week fixed effects, and controls for log age, coupon, log total amount outstanding, log initial offering amount, log time to maturity (in years), an indicator for investment grade (or high yield) rating, and an indicator for callability of the bond.



(a) Raw leverage

(b) RWA

(c) Loans

(d) Net repo

(e) ROA

(f) Trading revenue

(g) LSR

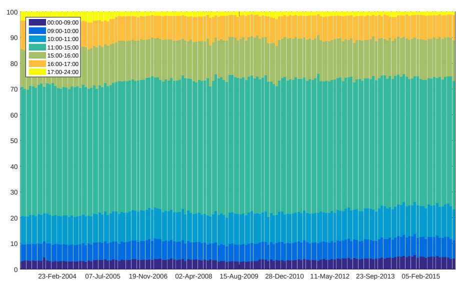
(h) CoVaR

A Data

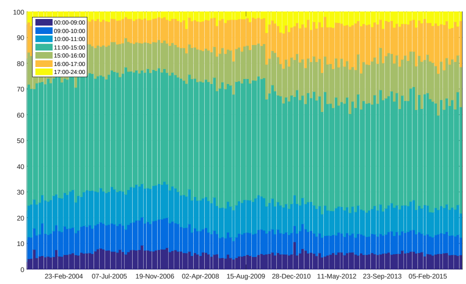
A.1 Supervisory TRACE

Figure A.3: **The two figures show the distribution of execution time of trades over time. To adhere to the trade reporting rules, "normal market hours are from 8:00 am until 5:15 pm ET. Any trade that is executed outside of this time period is considered outside normal market hours. Figure A.3a plots the trade time distribution over time in terms of number of trades. Figure A.3b plots the trade time distribution over time in terms of traded volume.**

(a) Number of Trades



(b) Traded Volume



A.2 Balance Sheet Measures

Measures of the funding structure Our measures of funding structure include leverage (the ratio of book equity to book assets), regulatory leverage (the ratio of risk-weighted asset to Tier 1 capital), the ratio of liabilities repricing within a year net of assets repricing within a year to book assets (as in Landier et al., 2013), the ratio of wholesale funding to book assets, the ratio of retail deposits to book assets, and the ratio of net Federal Reserve balances borrowed and net securities sold under agreements to repurchase to book assets. As is common in the literature, we define retail deposits as the sum of demand deposits, savings deposits and time deposits of less than \$100,000; we define wholesale funding as the sum of time deposits over \$100,000, foreign deposits, securities sold under agreements to repurchase, Federal Reserve balances borrowed, other borrowed money and subordinated debt. The two measures of leverage proxy for the regulatory capital constraints that the institution may be subject to, while the last four measures capture differences in the funding mix between different institutions. Institutions that rely more on runnable funding, such as repo financing and liabilities repricing within a year, are perceived to be more liquidity constrained. Institutions that rely more on wholesale funding are more liquidity constrained during periods of stress (see Huang and Ratnovski, 2011, for a model framework of this effect).

Measures of the asset structure We group the asset side of the institutions' on- and off-balance sheet exposures into the several broad categories, and include the ratio of each of these measures to book assets as asset structure characteristics. In particular, we decompose the asset side of the balance sheet into loans, measured as the total loans made by the BHC; risk-free securities, measured as the sum of U. S. Treasury securities, U. S. government agency obligations, and mortgage-backed securities issued or guaranteed by U. S. Government agencies or sponsored agencies; risky securities, measured as total security holdings net of the risk-free security holdings; unused commitments; and the total gross notional of derivatives held. In addition, we include the ratio of risk-weighted assets to book assets and the ratio of non-performing loans to total loans in our measures of institutions' asset structure.

Measures of the earnings structure We measure the earnings structure of the institutions with return-on-assets (ROA), the ratio of non-interest income to book assets and the ratio of trading revenue to book assets. Institutions with higher ROA are more profitable and thus less likely to be constrained. Non-interest income and trading revenue measure the dependence of the BHC on non-commercial bank sources of income, with the latter measure focusing in particular of how much revenue the BHC derives from it's trading activities.

A.3 CoVaR

CoVaR is a metric for an institutions systemic risk contribution. A firms CoVaR is defined as the increase in the value-at-risk of the financial system conditional on the distress of an institution. The value-at-risk is the loss that occurs at the 95 percent confidence level, i.e., the loss that occurs only in the worst 5 percent of realizations. CoVaR is estimated on daily data for the 1994-2007 sample period by running quantile regressions of bank returns on conditioning variables. See Adrian and Brunnermeier (2016) for details. Bank specific CoVaRs thus vary over time. For the regression analysis, the daily CoVaRs are aggregated to the quarterly frequency.

CoVaR is estimated in the full sample via quantile regressions of firm returns on a fixed set of state variables (the three-month Treasury bill yield, the term spread, the TED spread, the BAA-AAA spread, and the VIX). We follow Adrian and Brunnermeier (2016), and estimate CoVaR via their three step procedure: First, conditional betas (β_t) are obtained for each firm by (quantile) regressing aggregate returns on firm returns and the state variables (for the 5th return percentile). Next, conditional 95 percent value-at-risk (VaR_t) and conditional medians (Med_t) are obtained by (quantile) regressing firm returns on the state variables (for the 5th and 50th return percentiles, respectively). An individual firms time-varying contribution to systemic risk is then $CoVaR_t = -\beta_t (VaR_t - Med_t)$.

Adrian and Brunnermeier (2016) show that CoVaR is systematically related to firm characteristics that measure leverage, maturity transformation, and risk taking. Indeed, Table A.6 shows that CoVaR is tightly linked to the measures of balance sheet constraints in Section 4.2. CoVaR has a 7 percent correlation with Tier 1 leverage, computed as the ratio of risk weighted assets to Tier 1 Common Equity. CoVaR has a 8 percent correlation with the ratio of risk-weighted assets to total assets, a metric of the degree of risk taking of institutions.

An important metric of off balance sheet leverage are unused credit commitments. CoVaR exhibits a 16 percent correlation with unused commitments.

Maturity transformation can be measured via the amount of wholesale funding as a fraction of total assets. Wholesale funding is fragile, thus exposing institutions to rollover and run risk. CoVaR has a 15 percent correlation with this wholesale funding metric. The amount of net repo and federal funds that are used to fund institutions also measures short-term, runnable funds. CoVaR has a 31 percent correlation with these metrics. The fragility of liquidity transformation can be measured by the Liquidity Stress Ratio (Bai et al., 2015). This ratio measures the amount of runnable liabilities as a fraction of liquid assets, using the weights of the Liquidity Coverage Ratio (it is thus inversely related to the LCR). CoVaR exhibits a 25 percent correlation with the Liquidity Stress Ratio.

CoVaR is also positively related to return on assets: higher risk taking along the systemic risk dimension is rewarded through higher returns. Not surprisingly, CoVaR has a high correlation with market beta (75 percent), and with log size (64 percent).

Table A.6: **Correlation between CoVaR and Firm Characteristics**. This table reports panel correlations between Adrian and Brunnermeier (2016) CoVaR and other firm characteristics. All correlations are significant at conventional levels. Correlations computed at a quarterly frequency for the 1985-2015 sample.

	Correlation with CoVaR (%)
Tier 1 Leverage	7.1
RWA to Assets	8.1
Unused Commitments	16.0
Wholesale Funding	14.8
Net Repo and FF	30.9
Liquidity Stress Ratio	24.7
ROA	4.3
CAPM Beta	75.2
Log Assets	64.0