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Dealer Balance Sheets and Bond Liquidity Provision

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Abstract

Do regulations decrease dealer ability to intermediate trades? Using a unique data set of dealer-bond-level transactions, we link changes in liquidity of individual U.S. corporate bonds to dealers' transaction activity and balance sheet constraints. We show that, prior to the financial crisis, bonds traded by more levered institutions and institutions with investment-bank-like characteristics were more liquid but this relationship reverses after the financial crisis. In addition, institutions that face more regulations after the crisis both reduce their overall volume of trade and have less ability to intermediate customer trades.

Key words: bond liquidity, regulation, dealer constraints

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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 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 take first steps to remedy this gap in the academic literature, and study the relationship between corporate bond market liquidity and dealer balance sheets and document 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 to capture dealers' trading activity. TRACE collects detailed trade information from securities brokers and dealers that are members of the Financial Industry Regulatory Authority (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.

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

The client's identity is not entered to the system, and as such it is unknown.

Using the transactions data, we compute the first principal component of several liquidity measures that are commonly used in the corporate bond liquidity literature, creating a summary measure of bond liquidity. We link variation in bond-level liquidity to variation in the constraints faced by active traders in the market. Using the identities provided in the supervisory TRACE dataset, we match FINRA members to the balance sheets of their parent bank holding companies (BHCs), collected through the FR Y-9C report. The match to BHCs is done using the organization structure information of BHCs collected through the FR Y-10 report, as described in greater detail in Cetorelli and Stern (2015). We use Y-9C information to construct measures of institution-level constraints. We then construct bond-level measures of constraints as the total-volume-weighted average of metrics of constraints of institutions that trade in the bond. This allows us to quantify cross-sectionally the extent to which a tightening of constraints faced by market participants leads to a decline in bond liquidity.

In the full sample, we find that bonds trade by more levered and systemic institutions – those with higher leverage, higher repo borrowing and higher vulnerability (as measured by CoVaR) – and bonds traded by institutions more akin to investment banks – BHCs with smaller risk-weighted-assets to assets, smaller allocation to loans, and higher trading revenues – are less liquid. These results hold across bonds with different credit rating, issued by companies in different industries, with different issuance sizes, and different prior levels of liquidity, suggesting that institutional constraints impact the liquidity of the corporate bond market as a whole. We further show that these results are not driven by non-random assignment of bonds to institutions: there is significant overlap between bonds traded by constrained and unconstrained institutions, and, moreover, constrained and unconstrained institutions have similar portfolio allocations to bonds across the credit rating spectrum.

The relationship between bond liquidity and institution-level constraints changes significantly over time. We find that, prior to the crisis, bonds traded by institutions with higher leverage, higher ROA, lower risk-weighted assets, lower reliance on repo funding, and lower CoVaR were more liquid. During the rule implementation period (starting in January 2014), these relationships reverse, with bonds traded by institutions with lower leverage, higher risk-weighted assets, more reliance on repo funding and lower ROA are more liquid. That is, the relationship between bond (il)liquidity and dealer constraints that we see in the full sample is primarily driven by that same relationship in the post-crisis period.

What then causes the relationship between bond market liquidity and dealer constraints to change over time? We show that, after the crisis, institutions with higher leverage and higher trading revenues have lower overall transaction volume while, prior to the crisis these same institutions had higher overall trading volumes. This pattern reversal is consistent with more stringent leverage regulation and more regulation of investment banks reducing institutions' ability to provide liquidity to the market overall. More importantly, we find that, during the rule implementation period, institutions with higher repo funding, trading revenue, LSR and CoVaR and lower allocation to loans are less able to intermediate customer trades, where we measure the ability to intermediate trades as the ratio between customer and dealer trading volume. That is, institutions more impacted by post-crisis regulation are less able to intermediate customer trades.

Finally, we show that, while, in general, constraints faced by buyers in the market have a similar impact on bond liquidity as the constraints faced by the sellers, bonds bought by institutions with higher CoVaR during the rule implementation period are more liquid, while the bonds sold by institutions with higher CoVaR are less liquid. This result is consistent with regulation aimed at reducing the risk of systemic institutions, such as the Basel III accord, impacting the willingness of these institutions to hold corporate bond positions.

The rest of the paper is organized as follows. Section 2 provides a brief summary of the post-crisis regulations most relevant for the behavior of supervised institutions in the corporate bond market. Section 3 then reviews the prior empirical literature on corporate bond market liquidity and, in particular, the literature on the changes in corporate bond market liquidity after the crisis. We describe our sample construction in Section 4 and present our results in Section 5. Section 6 concludes.

2 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. While some regulations focus on the general health of regulated entities, others directly restrict certain types of trading activities. This section provides a brief overview of the regulations that might have impacted the trading of corporate bonds. We return to the assessment of the impact of these regulations later in the paper.

2.1 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 (VaR) 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 VaR requirement based on a one-year loss horizon, calculated in addition to the VaR 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).

2.2 Basel III Capital Requirements

The Basel III capital framework aims to strengthen 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. This 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%, with the largest U. S. institutions subject to an addition 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 central clearing counterparties (CCPs) (CGFS, 2014).

Finally, the macroprudential surcharge aims to reduce the probability of failure of globally systemically important banks (GSIBs) by increasing their going-concern loss absorbency. The extent and impact of failure of G-SIBs is further reduced by improving global recovery and resolution frameworks (see BCBS, 2013b).

2.3 Basel III Liquidity Regulation

In addition to the capital regulation improvements described above, Basel III also introduced two pillars of liquidity regulation: the liquidity coverage ratio (LCR) and the net stable funding ratio (NSFR) (see BCBS, 2013a, 2014). The goal of 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, while the NSFR aims to reduce funding risk over a longer time horizons by requiring banks to fund their activities with sufficiently stable sources of funding in order to mitigate the risk of future funding stress.

2.4 Total Loss Absorbing Capacity (TLAC)

The aim of TLAC, which was finalized in December 15, 2016, is to reduce both the probability and impact of failure of GSIBs. TLAC provides recapitalization capacity available in resolution in an orderly resolution. See FSB (2015) for an overview.

2.5 Stress Tests

The Federal Reserve conducts stress tests for the largest 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 Dodd-Frank Act (DFA) requires the Federal Reserve to conduct annual stress tests (DFAST) 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 firm-wide 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.

2.6 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 Theoretical Predictions and Empirical Evidence

We now review the literature on corporate bond market liquidity, and the existing evidence of the post crisis reforms on dealer behavior and market liquidity.

3.1 Evidence on Corporate Bond Market Liquidity

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. This was a major evolution in the corporate bond market. 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, declined significantly for high yield bonds. Bessembinder and Maxwell (2008) provide an overview of the impact of the increase in transparency on the market.

The 2007-2009 financial crisis highlighted the need to better understand corporate bond market liquidity. Friewald et al. (2012) document that liquidity explains about one third of the variation in the aggregate market corporate yield spread in the time-series, and about half during the crisis. Direct measures of trading activity, such as trade volume, and other commonly-used liquidity measures, do not show significant explanatory power. In the cross-section, they find that the overall liquidity of bonds issued by financial firms is higher on average, than those of industrial firms. Dick-Nielsen et al. (2012) document that liquidity deteriorated for both investment grade and high yield bonds, but it was slow and persistent for the first and short-lived for the latter. Moreover, they find consistent evidence with flight-to-quality only for AAA-rated bonds. Bao et al. (2011) calculate the *Roll* liquidity measure at the bond-level and then aggregate the liquidity measure across individual bonds. Using the aggregate measure they find that the aggregate illiquidity doubled relative to its pre-crisis average when the credit problem first broke out in August 2007, and subsequently tripled in March 2008 when Bear Stearns collapsed. Their measure peaks in October 2008, after Lehman's default and the bailout of AIG, and slowly declines thereafter.

Beyond the traditional measures of liquidity, some papers have focused on the network of client-dealer and dealer-dealer relationships. Hendershott et al. (2015) show that execution costs in the corporate bond market depends strongly on insurers' trading relationships. 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. Using a similar data to what we use in this paper, Di Maggio et al. (2015) show that more central dealers are able to pay lower spreads but charge significantly higher spreads to their counterparties. During periods of distress, dealers tend to provide liquidity to the counterparties with whom they have the strongest ties.

3.2 Preliminary Evidence of Regulatory Reforms' Impact

Much of the theoretical literature of the impact of regulations on intermediation activity is focused on banks. Furlong and Keeley (1989) show that mean-variance optimizing banks with deposit insurance will reduce risk taking when capital regulation is tightened. Similarly, in Keeley (1990), capital regulation limits excessive risk taking due to deposit insurance. However, increased competition can raise risk taking incentives, even in the presence of capital regulation, as competition lowers charter value. Thakor (2014) provides a review of the literature on bank capital regulation. Recent literature focuses on the impact of regulation in dynamic, general equilibrium settings. This literature shows that there is a trade-off between trend growth and long-run stability of financial institutions (see, e.g. Adrian and Boyarchenko, 2012; He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014). Of course, the focus of the current paper is on market making, not commercial banking.

CGFS (2014) takes stock of the impact of the post crisis 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, Basel 2.5 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.

Adrian et al. (2016) document the post crisis dealer behavior and the evolution of market liquidity. Furthermore, Adrian et al. (2015) and Adrian et al. (2016) exhibit a dramatic stagnation of dealer balance sheets in the post crisis period. This stagnation of balance sheets occurred contemporaneously with dealer deleveraging. However, traditional market liquidity metrics in US Treasury and corporate bond markets, where dealers are the most important market makers, indicate robust market liquidity. The metrics that the authors focus on include bid-ask spreads, price impact, and depth. Adrian et al. (2016) also point out that some funding liquidity metrics show an increase of balance sheet costs since the crisis (interest rate swap spreads and the CDS-bond basis), while others indicate ample liquidity (e.g. yield curve fitting errors). Even three market stress events in the post-crisis era (the 2013 Taper tantrum, the 2014 Treasury flash rally, and the 2015 liquidation of 3rd Avenue) did not trigger widespread liquidity dislocations, and the degree of deterioration in market liquidity was within historical norms.

Boyarchenko et al. (2016) examine the evolution of funding liquidity metrics in corporate bond markets in more detail. They look at three explanations of credit market arbitrage trade dislocations: increased idiosyncratic risks, strategic positioning by some market participants, and regulatory changes. They document increased idiosyncratic risk during the relevant period but limited evidence of asset managers' changing their positioning in derivative products. The relative changes in idiosyncratic risk levels and in asset managers' derivatives positions appear small relative to the post-crisis increase in cost of capital. The authors link the CDS-bond arbitrage trade to return-on-equity (ROE) calculations of a stylized dealer balance sheet and argue that given current levels of regulatory leverage, the CDS-bond basis would need to be significantly more negative relative to pre-crisis levels to achieve the same ROE target.

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. They find that capital allocation has shifted from bank affiliated dealers to independent dealers since the passage of DFA and Basel III. Bao et al. (2016) document that the illiquidity of bonds that were recently downgraded from investment grade to high yield rating has increased after the Volcker Rule. For this subset of bond events, dealers regulated by the Volcker rule have decreased their market-making activities while non-Volcker-affected dealers have stepped in to provide some additional liquidity. However, Volcker-affected dealers that are not constrained by Basel III and CCAR also change their behavior, which the authors interpret as inconsistent with the effects being driven by these latter regulations. In contrast, Trebbi and Xiao (2015) find that post-crisis U.S. regulatory intervention does not appear to have produced structural deteriorations in market liquidity. We add to this body of evidence by providing a direct analysis of how constraints faced by institutions that are active traders in a bond impact its liquidity, and the trading activity of these institutions. Given the clustering of the timing of many of the regulations, our empirical methodology is similar to Bessembinder et al. (2016) and Bao et al. (2016), yet our paper considers a different dimension of dealers' willingness to intermediate compared to Bessembinder et al. (2016), and a much broader set of bonds compared to Bao et al. (2016).

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 TRACE, which contains – for almost all US corporate bonds – the uncapped trade size, price, buyer and seller identities. FINRA members are identified by a designated Market Participant Identifier, MPID, which is linked to the firm's legal name and, at times, to its "doing business as" (DBA) name.[2] Non-FINRA members are identified either as "C", or as "A". Our trades dataset spans from July 2002, when TRACE was introduced, to December 2015. Real-time, public dissemination of trades was staggered, and its full implementation was completed

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

on February 7, 2005, when all bonds, except the TRACE-eligible Rule 144A bonds, were subject to dissemination. 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. Therefore, we exclude trades prior January 2005 and we only keep secondary market trades or primary market trades executed at market price (Trading Market Indicator = S1), which includes 103.2 million trade records and 111,812 bond issues.

Before calculating flows and liquidity measures using the traded price, we address several data issues. First, we remove cancelled trades and use the amended version of the trade record if a 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 correction and cancellation records. Specifically, when possible, we use the identity of the buyer and seller when matching the correction/cancellation to its original, erroneous record, as well as a linking field between the correction/cancellation to its original record, even if it was not submitted on the same execution date. 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.[3] An example of a give-up is a clearing firm that reports on behalf of its correspondent firms. The clearing firm 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 the one that is required to

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

cancel/correct the record for the correspondent.

Third, towards the end of our sample, in November 2, 2015, FINRA addressed an issue that has become more prevalent, a FINRA-member transferring a bond to an affiliate firm[4] that is not a registered-FINRA member, for bookkeeping purposes. Prior to the change, such 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. The new rule requires firms to distinguish trades with its affiliates from trades with its clients by identifying the counterparty as "A" for the former case, and as "C" for the latter. Therefore, such trade between FIRNA member and its non-member affiliate trades are excluded, using the flag and using a matching algorithm prior to the existence of this flag.

Beyond the aforementioned filtering, we also exclude trades that are reported on a non-business day, and 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 weekly buy, sell, and net order flows for each member transacted in a specific bond issue. To capture the multi-facity of illiquidity, we calculate bond-level 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. The calculation of each of the measures is detailed in the Online Appendix.

[4]An affiliate is a non-member entity that controls, is controlled by, or is under common control with a FINRA member. 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."

We use Mergent FISD to get the characteristics of the bonds. We exclude bonds with foreign currency, agency backed, private placements, unit deals, perpetual, and preferred. We also drop bonds with a maturity of less than one year, and unrated bonds. We exclude trades of bonds 30 days prior to default, and if the bond is reinstated then we exclude the first 30 days after it was reinstated.

Table 1 reports the number of trades and number of 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 10,111,881 transactions and 12,782 bond issues, and covers the time period from January 2005 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.[5] 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.[6] 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 (Cetorelli and Stern, 2015). 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.

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

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

FR Y9-C collects financial statements for U. S. based BHCs, 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 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 earnings structure of the institution (ROA and trading revenue). The details of these measures are described in the Online Appendix.

4.3 LSR and CoVaR

The balance sheet measures of constraints described above consider one dimension of balance sheets at a time. We supplement these measures with two summary measures: Bai et al. (2015) liquidity mismatch measure, LSR, and Adrian and Brunnermeier (2016) measure of vulnerability, CoVaR. LSR calculates the potential liquidity shortfall of BHCs during a liquidity stress scenario. The LSR consists of two parts: The numerator is the liquidity-adjusted sum of liabilities and off-balance-sheet exposures; the denominator consists of liquid assets subject to similar liquidity adjustments. CoVaR is defined as the VaR 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. 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 Empirical Results

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

In our baseline specification, we consider the impact of constraints faced by institutions that are active traders in a bond on that bond's future evolution of liquidity, controlling for observable time-varying bond characteristics and bond fixed effects. That is, our baseline specification investigates whether characteristics of institutions that are active in the bond have additional explanatory power for the evolution of bond liquidity. This specification requires us to translate dealer-level measures of constraints into bond-level measures of constraints.

Given the total volume of the buy-side transactions done by institution d in bond b in week t, $B_{d,b,t}$, and the total volume of sell-side transactions, $S_{d,b,t}$, we define the overall trading volume of institution d in bond b in week t as

$$V_{d,b,t} = B_{d,b,t} + S_{d,b,t}. \tag{1}$$

We define the bond-level measure of constraint as the volume-weighted average of institution-level constraints

$$\text{Constraint}_{b,t} \equiv \sum_{d \in \mathcal{D}_{bt}} \frac{V_{d,b,t}}{\sum_{d \in \mathcal{D}_{bt}} V_{d,b,t}} \text{Constraint}_{d,t}, \tag{2}$$

where $\mathcal{D}_{bt}$ is the set of institutions trading bond b in week t, and $\text{Constraint}_{d,t}$ is one of the proxies of financial constraints of institution d at the end of the prior quarter. By measuring the institution-level constraint as of the previous quarter, we avoid issues of reverse causality, with the liquidity of the institution's bond portfolio affecting the measures of constraints. The volume-weighting insures that the constraints faced by more active traders in the bond in a given week have a larger impact on the liquidity of the bond.

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

$$\text{Illiquidity}_{b,t} = \alpha_t + \delta \text{Illiquidity}_{b,t-1} + \beta \text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}, \tag{3}$$

where $\text{Illiquidity}_{b,t}$ is the illiquidity 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 week t.[7] The coefficient β measures the marginal impact of institutional constraints on bond liquidity. When β is positive, bonds that are more heavily traded by institutions with larger values of the characteristic 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

[7] 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, an indicator for callability of the bond and an industry fixed effect.

magnitude remains similar. This finding suggests 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, or bonds with different liquidity in the previous week, or have a differential impact across high and low uncertainty periods.

Consider first the full sample estimates of the impact of balance sheet characteristics, reported in the first row of Table 2. Bonds traded by institutions with higher leverage, more reliance on repo funding, and with higher trading revenue (relative to the size of their balance sheet) are less liquid than the average bond. At the same time, bonds traded by institutions with higher risk-weighted assets, more illiquid assets (in the form of loans), higher ROA, and greater maturity mismatch are more liquid than the average bond. Intuitively, 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). Similarly, more levered institutions are less likely to be able to provide liquidity to the corporate bond markets. Overall, the full sample estimates suggest that bonds traded by more levered and systemic institutions – those with higher leverage, higher repo borrowing and higher CoVaR – and bonds traded by institutions more akin to investment banks – BHCs with smaller RWA-to-assets, smaller allocation to loans, and higher trading revenue – are less liquid than the average bond.

Turning next to the breakdown by credit rating, we see that the effect of constraints on bond liquidity is larger for high yield bonds. That is, while investment grade bonds traded by more levered and systemic institutions and institutions more similar to investment banks are less liquid than the average investment grade bond, the impact on high yield bonds of these constraints is two to four times as large.[8]

Table 2 also shows that the effect of constraints is similar across terciles of original

[8]Notice that, even though the impact on high yield bonds is larger, there are more investment grade bonds in our sample, so that the full sample estimates are closer to the estimates for the investment grade bonds.

issuance size – small and large bonds alike traded by more levered institutions are less liquid – and across different sectors, with the impact of balance sheet constraints the largest for bonds issued by firms in the manufacturing sector. Finally, constraints have a similar impact on bond liquidity during both high (with VIX above its full sample median) and low (with VIX below its full sample median) uncertainty periods. Liquidity mismatch and CoVaR are exceptions in this case, with bonds traded by institutions with higher LSR and higher CoVaR more liquid during low uncertainty periods and less liquid during high uncertainty periods. This may reflect the fact that less liquid and more systemic institutions suffer more during periods of high uncertainty.

Even though regression specification 3 controls for bond characteristics, it is possible that less liquid bonds are systematically traded by different institutions than more liquid ones are. The bottom panel of Table 2, however, shows that the impact of bond-level constraints on bond liquidity is similar across illiquidity quintiles, with the illiquidity quintile computed as of the prior week. Though the constraints do have the largest impact on the least liquid bonds (in the top quintile of the illiquidity metric the previous week), the coefficients remain significant even for the most liquid bonds (in the bottom quintile of the illiquidity metric the previous week).

5.2 Dealer-bond match

The above results show that bonds that are actively traded by constrained institutions are less liquid. Though we control for standard bond characteristics and show that our results hold in different subsamples, the non-random assignment of bonds to dealers may still be a concern. We now investigate whether the bonds held by constrained institutions are systematically different from the bonds held by unconstrained institutions.

Figure 2 plots the fraction of bonds each week traded by both constrained and unconstrained institutions in black, the fraction traded by only institutions above the median in grey, and the fraction traded by only the institutions below the median in white. Three features of the data become apparent. First, across all measures of institutional constraints, there is a substantial fraction of bonds every week that are traded by both constrained and unconstrained institutions. Thus, even at the individual bond level, there is significant overlap in the portfolios trade by constrained and unconstrained institutions. Second, larger institutions – that is, those with higher leverage, higher repo borrowing, higher ROA and higher CoVaR – and institutions more akin to investment banks – those with a lower fraction of risk-weighted assets and loans to assets, higher trading revenue and higher LSR – trade a larger number of bonds. Indeed, Figure 2i shows that institutions with a higher fraction of non-commercial bank subsidiaries trade a larger number of bonds. Finally, while institutions that trade a large number of bonds have higher ROA and trading revenue during normal periods, unsurprisingly, they have lower overall returns and lower trading revenue during the financial crisis.

Turning next to the overall trading portfolio of the institutions, Figure 3 shows the fraction of trading allocated to AAA, non-AAA investment grade and high yield bonds by constrained institutions (above the positive line) and unconstrained institutions (below the positive line). The figure shows that constrained and unconstrained institutions allocate a similar fraction of their trading activity to bonds across all four credit rating buckets. Thus, even though larger and investment-bank like institutions trade a higher absolute number of bonds, they make similar trading activity allocation decisions.

Overall, these results show that there are no systematic differences between bonds traded by constrained and unconstrained institutions. Instead, bonds more actively traded by more constrained institutions are less liquid, even controlling for liquidity in previous week, bond characteristics, and time fixed effects. We next investigate how the relationship between liquidity and constraints has changed over time.

5.3 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 bond liquidity and institutional constraints. Indeed, as can be seen from Figure 5, which plots the coefficient β estimated in 12 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.

Many of the regulations described in Section 2 were introduced, finalized and implemented concurrently. Figure 4 plots the dates at which selected regulations were either introduced, passed or phased in, showing this clustering over time. Furthermore, some institutions responded to regulations in advance of the rules being finalized, as the broad contours of the reforms was often known beforehand. These considerations make an event study approach to measuring the impact of regulations impossible. Instead, we follow prior literature (see e.g. Bessembinder et al., 2016) and compare outcomes in different subperiods.

In Table 3, we split our sample into four subperiods – pre-crisis (January 1, 2005 – 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. Overall, constraints faced by institutions in the rule implementation period have a dramatically different impact on bond liquidity than in the pre-crisis period. Prior to the crisis, bonds traded by institutions with higher leverage, higher ROA and lower CoVaR were more liquid while bonds traded by institutions with higher risk-weighted assets and more reliance on repo funding were less liquid. During the rule implementation period, these relationships reverse, with bonds traded by institutions with lower leverage, higher risk-weighted assets, more reliance on repo funding and lower ROA more liquid.

These changes are both statistically and economically significant. A simple back-of-the-envelope computation shows that, in the pre-crisis period, bonds falling in the top 10 percent of the bond-level leverage distribution in a week, on average, had bid-ask spreads 300 bps lower than bonds falling in the bottom 10 percent of the distribution. In contrast, during the rule implementation period, bonds in the top 10 percent of the constraint distribution had bid-ask spreads 32 bps higher than bonds in the bottom 10 percent.

Finally, Table 3 shows that, while some of these changes are trends that started during the financial crisis period, others only manifest in the rule writing and rule implementation periods. Thus, for example, the relationship between reliance on repo funding and bond liquidity only becomes positive in the rule writing period and statistically significantly only during the rule implementation period.

What causes then the relationship between constraints and liquidity to change over time? Table 4 studies the relationship between the institutions' trading activity and constraints faced by the institutions. In particular, Table 4a estimates the relationship between monthly gross trading volume in bond b by institution d, controlling for month and institution fixed effects, bond characteristics and lagged volume

$$\text{Volume}_{b,d,t} = \alpha_t + \alpha_d + \sum_{l=1,2} \delta_l \text{Volume}_{b,d,t-l} + \beta \text{Constraint}_{d,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,d,t}. \quad (4)$$

Comparing the coefficients β across different subperiods, we see that, prior to the crisis, more levered and systemic institutions – those with higher leverage and higher repo borrowing – and institutions more akin to investment banks – BHCs with smaller RWA-to-assets, smaller allocation to loans, and higher trading revenue – have, on average, higher gross trading volumes. These relationships reversed during the crisis but retained their statistical significance. In the rule implementation period, only the negative relationship between leverage and volume and the negative relationship between trading revenue and volume have remained statistically significant. That is, in the post-crisis period, institutions with higher leverage and higher trading revenue have lower overall transaction volume. This reversal relative to the pre-crisis period is consistent with more stringent leverage regulation, through, for example, the supplemental leverage ratio (SLR), and with investment banks subject to more regulation overall.

Table 4b then considers whether these reductions in the overall trading volume by constrained institutions is due to changes in the volume traded with customers or with other dealers and estimates the relationship between ratio of customer volume to dealer volume in bond b by institution d, controlling for month and institution fixed effects, bond characteristics and lagged volume

$$\frac{\text{Volume}^{C}_{b,d,t}}{\text{Volume}^{D}_{b,d,t}} = \alpha_t + \alpha_d + \sum_{l=1,2} \delta_l \frac{\text{Volume}^{C}_{b,d,t-l}}{\text{Volume}^{D}_{b,d,t-l}} + \beta \text{Constraint}_{d,t} + \sum_{k} \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,d,t}. \quad (5)$$

The customer-to-dealer ratio captures the ability of institutions to intermediate customer trades; when this ratio is larger, the institution is able to accommodate the same volume of customer order flow while transacting with fewer other dealers. Prior to the crisis, institutions with higher reliance on repo funding, higher trading revenues, greater maturity mismatch (higher LSR) and higher vulnerability (higher CoVaR) – that is, institutions more like investment banks – were better able to intermediate customer trades. During the rule implementation period, these same institutions are less able to intermediate customer trades, as shown by the negative relationship between the customer-to-dealer ratio and repo funding, trading revenue, LSR and CoVaR, and the positive relationship between the customer-to-dealer ratio and the fraction of assets held as loans. These results are consistent with institutions more impacted by post-crisis regulations being less able to intermediate customer trades.

Overall, Tables 3 and 4 show that post-crisis regulation has had an adverse impact on bond market liquidity. More levered institutions and institutions that behave like investment banks have reduced their overall transaction volume in corporate bonds. More importantly, institutions that face more regulations after the crisis are less able to intermediate customer trades and accommodate the same volume of customer order flow by transacting more with other dealers.

5.4 Constrained buyers vs constrained sellers

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

$$\text{Liquidity}_{b,t} = \alpha_t + \delta \text{Liquidity}_{b,t-1} + \beta^B \text{Constraint}^B_{b,t} + \beta^S \text{Constraint}^S_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}, \tag{6}$$

where $\text{Constraint}^B_{b,t}$ and $\text{Constraint}^S_{b,t}$ are the buy-flow-weighted and sell-flow-weighted bond-level measures of constraints, 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 5a reports the impact of constraints faced by buyers across various measures of constraints, for both the full sample and subsamples over time, while Table 5b reports the impact of constraints faced by sellers. Across all measures of constraints, in the full sample, buyers' and sellers' constraints have a similar impact on bond liquidity.

Comparing the coefficients across sub-periods, we see that the relationship between buy-flow-weighted (sell-flow-weighted) constraints changes over time, with bonds bought (sold) by institutions with higher leverage, lower risk-weighted assets, lower reliance on repo funding, lower trading revenue and greater maturity mismatch less liquid during the rule implementation period. Interestingly, during the rule implementation period, CoVaR of buyers has a differential impact than CoVaR of sellers, with bonds bought by institutions with higher CoVaR *more liquid* and bonds sold by institutions with higher CoVaR *less liquid*. Intuitively, regulation aimed at reducing the risk of systemic institutions impacts the willingness of these 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.[9] More generally, aggregate trading VaRs of banks have been reduced dramatically since the financial crisis, and aggregate dealer balance sheet size has stagnated.[10]

6 Conclusion

Market participants and analysts have argued that post-crisis regulatory reforms have increased balance sheet costs for dealer participants and thus have had adverse consequences on the level of market liquidity. Despite anecdotal evidence of reduced market liquidity, establishing a causal link between regulations and market liquidity has proven challenging. In this paper, we investigate how constraints faced by institutions that are active traders in the U. S. corporate bond market have affected bond-level liquidity and institutions' ability to intermediate customers' trades.

By linking bond transaction to the balance sheets of individual institutions, we find that post-crisis regulation has had an adverse impact on bond market liquidity. Specifically, we find that prior to the crisis bonds traded by institutions with higher leverage, higher ROA and lower CoVaR were more liquid while bonds traded by institutions with higher risk-

[9] See, for example, the unwinding of the formerly largest trading floor **in pictures**.
[10] See an investigation of **the stagnation of dealer balance sheets**.

weighted assets and more reliance on repo funding were less liquid. As intermediaries have had to comply with more regulations, these relationships reversed, with bonds traded by institutions with lower leverage, higher risk-weighted assets, more reliance on repo funding and lower ROA are more liquid.

From the intermediaries' perspective we find that, prior to the crisis, more levered and systemic institutions – those with higher leverage and higher repo borrowing – and institutions more akin to investment banks – BHCs with smaller RWA-to-assets, smaller allocation to loans, and higher trading revenue – have, on average, higher gross trading volumes. In the post-crisis period, however, we find that institutions with higher leverage and higher trading revenue have lower overall transaction volume. This evidence is consistent with more stringent leverage regulation, through, for example, the SLR, and with investment banks subject to more regulation overall. We show that the decrease in their overall trading activity is related to their reduced ability to share risk with other intermediaries in the market. We capture the risk sharing among intermediaries by the ratio of customer-to-dealer flows, and we show that, during the rule implementation period, institutions with greater reliance on repo funding, higher trading revenues, greater maturity mismatch and higher vulnerability, and institutions with lower fraction of assets held as loans were less able to intermediate customer trades and, instead, have to tap the interdealer market more to accommodate the same volume of customer flows.

To our knowledge, our paper is the first to provide direct empirical evidence on the impact of post-crisis regulations on the ability of more constrained intermediaries to provide liquidity in the corporate bond market. To evaluate the full welfare 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 Trades	Number of Issues
Raw regulatory TRACE	103,237,129	111,812
Exclude primary trades	100,135,428	95,815
Exclude non-business days, size and/or price outliers, and non-member affiliate – principal transactions	99,963,281	95,224
Exclude bonds with 10 or fewer observations over the entire sample	99,877,060	71,982
Merge with Mergent FISD and exclude foreign, perpetual, preferred, unit deals, private palcements, remaining maturity $<$ 1 year, and MTNs	70,510,012	44,920
Sample used in the analysis (condition on a match of FINRA-members' MPIDs to RSSD IDs)	10,111,881	12,782

Table 2: **Bond liquidity and dealer constraints**. This table reports the estimated coefficient β from the regression
$\text{Illiquidity}_{b,t} = \alpha_t + \delta\text{Illiquidity}_{b,t-1} + \beta\text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}$,
for the full sample as well as the credit rating, industry, original issuance amount, liquidity and uncertainty 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 and industry 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	Repo	Loans	ROA	Trading rev.	LSR	CoVaR
Full sample	0.030	-0.085	0.026	-0.069	-0.066	0.022	-0.018	0.014
	[7.316]***	[-28.232]***	[5.824]***	[-24.875]***	[-6.561]***	[8.258]***	[-2.170]**	[1.432]
Credit Rating								
IG	0.023	-0.071	0.022	-0.057	-0.072	0.017	-0.018	0.017
	[5.579]***	[-23.292]***	[4.672]***	[-19.977]***	[-7.013]***	[6.495]***	[-2.020]**	[1.743]*
HY	0.086	-0.199	0.082	-0.152	-0.123	0.054	0.006	0.060
	[6.815]***	[-18.546]***	[10.949]***	[-17.066]***	[-3.849]***	[7.797]***	[0.639]	[3.736]***
D	0.048	-0.124	-0.067	-0.062	0.157	-0.018	-0.122	-0.092
	[1.179]	[-3.122]***	[-2.741]***	[-1.787]*	[2.017]**	[-0.718]	[-3.605]***	[-2.322]**
Sector								
Energy	0.026	-0.119	0.033	-0.097	-0.105	0.027	-0.072	0.001
	[1.408]	[-7.426]***	[2.929]***	[-7.361]***	[-2.380]**	[2.864]***	[-3.415]***	[0.051]
Financials	0.012	-0.051	-0.007	-0.036	-0.031	0.010	-0.033	-0.011
	[1.633]	[-10.732]***	[-1.101]	[-8.383]***	[-1.887]*	[2.361]**	[-3.125]***	[-0.757]
Manufacturing	0.073	-0.132	0.087	-0.100	-0.118	0.034	0.064	0.047
	[4.866]***	[-11.151]***	[9.448]***	[-9.030]***	[-3.464]***	[4.001]***	[4.422]***	[2.393]**
Utilities	0.033	-0.096	0.071	-0.097	-0.064	0.035	0.002	0.053
	[1.747]*	[-6.306]***	[6.116]***	[-7.245]***	[-1.434]	[3.493]***	[0.094]	[2.614]***
Other	0.037	-0.093	0.056	-0.081	-0.089	0.030	0.014	0.037
	[7.463]***	[-21.734]***	[16.815]***	[-20.919]***	[-7.714]***	[10.506]***	[3.064]***	[6.126]***
Issuance tercile								
Smallest (T1)	0.028	-0.096	0.017	-0.073	-0.008	0.031	-0.035	0.002
	[4.285]***	[-17.151]***	[2.510]**	[-13.210]***	[-0.545]	[5.961]***	[-3.840]***	[0.124]
T2	0.026	-0.075	0.046	-0.066	-0.110	0.022	0.027	0.035
	[5.320]***	[-18.018]***	[14.906]***	[-17.561]***	[-8.654]***	[7.809]***	[6.009]***	[5.420]***
Largest (T3)	0.026	-0.077	0.046	-0.067	-0.154	0.021	0.034	0.033
	[4.735]***	[-19.095]***	[14.545]***	[-19.053]***	[-9.640]***	[7.370]***	[6.650]***	[4.581]***
VIX above/below median								
Below median	0.027	-0.059	-0.008	-0.046	-0.011	0.013	-0.065	-0.023
	[3.550]***	[-13.180]***	[-1.370]	[-11.562]***	[-0.652]	[2.929]***	[-7.419]***	[-1.700]*
Above median	0.026	-0.051	0.030	-0.044	-0.051	0.010	0.014	0.027
	[5.042]***	[-11.875]***	[8.605]***	[-11.516]***	[-4.362]***	[3.659]***	[2.525]**	[4.411]***
Illiquidity previous week quintiles								
Most liquid (Q1)	0.027	-0.059	-0.008	-0.046	-0.011	0.013	-0.065	-0.023
	[3.550]***	[-13.180]***	[-1.370]	[-11.562]***	[-0.652]	[2.929]***	[-7.419]***	[-1.700]*
Q2	0.026	-0.051	0.030	-0.044	-0.051	0.010	0.014	0.027
	[5.042]***	[-11.875]***	[8.605]***	[-11.516]***	[-4.362]***	[3.659]***	[2.525]**	[4.411]***
Q3	0.034	-0.068	0.033	-0.056	-0.039	0.016	0.007	0.034
	[5.721]***	[-14.243]***	[8.607]***	[-13.203]***	[-2.607]***	[4.655]***	[1.130]	[4.352]***
Q4	0.025	-0.078	0.043	-0.065	-0.084	0.020	0.020	0.029
	[3.669]***	[-14.181]***	[9.586]***	[-13.173]***	[-5.099]***	[5.401]***	[3.084]***	[3.315]***
Least liquid (Q5)	0.030	-0.132	0.079	-0.116	-0.164	0.048	0.053	0.049
	[2.843]***	[-15.178]***	[11.095]***	[-14.612]***	[-6.696]***	[8.099]***	[5.524]***	[3.970]***

Table 3: **Subsample regressions**. This table reports the estimated coefficient β from the regression
$\text{Illiquidity}_{b,t} = \alpha_t + \delta\text{Illiquidity}_{b,t-1} + \beta\text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}$,
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 and industry 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	Repo	Loans	ROA	Trading rev.	LSR	CoVaR
Pre-crisis	-0.049	0.045	0.030	-0.012	-0.359	-0.010	-0.007	0.142
	[-5.625]***	[3.821]***	[3.430]***	[-0.912]	[-10.174]***	[-0.915]	[-0.802]	[5.166]***
Crisis	0.035	-0.096	0.044	-0.058	0.047	0.040	-0.019	-0.048
	[5.184]***	[-10.693]***	[6.774]***	[-6.514]***	[2.335]**	[6.032]***	[-2.720]***	[-3.170]***
Rule writing	0.035	-0.053	-0.002	-0.026	0.168	0.024	-0.051	-0.112
	[5.196]***	[-7.160]***	[-0.306]	[-3.343]***	[7.829]***	[3.744]***	[-6.603]***	[-7.368]***
Implementation	0.029	-0.018	-0.038	0.018	0.147	-0.014	0.073	-0.005
	[4.610]***	[-2.577]***	[-7.157]***	[2.479]**	[6.892]***	[-2.310]**	[10.876]***	[-0.337]
F-tests relative to pre-crisis coeffficients								
$F(\beta_{Pre} = \beta_{Crisis})$	37.476	52.898	1.055	5.115	59.790	8.347	1.005	21.432
p-val	0.000	0.000	0.304	0.024	0.000	0.004	0.316	0.000
$F(\beta_{Pre} = \beta_{Writing})$	37.613	32.143	6.008	0.548	95.257	3.970	10.465	38.108
p-val	0.000	0.000	0.014	0.459	0.000	0.046	0.001	0.000
$F(\beta_{Pre} = \beta_{Imp.})$	35.563	13.956	29.014	2.579	88.427	0.053	43.615	12.147
p-val	0.000	0.000	0.000	0.108	0.000	0.817	0.000	0.000

Table 4: **Trading and dealer constraints**. This table reports the estimated coefficient β from the regression
$\text{Flow}^k_{b,d,t} = \alpha_t + \alpha_d + \delta_1 \text{Flow}^k_{b,d,t-1} + \delta_2 \text{Flow}^k_{b,d,t-2} + \beta \text{Constraint}_{d,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,d,t}$,
where $k \in$ {Gross volume, customer-to-dealer ratio}. T-statistics based on standard errors clustered at the year-issuer level reported below point estimates; all regressions include month, entity and industry 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) Gross volume

	Raw lev.	RWA	Repo	Loans	ROA	Trading rev.	LSR	CoVaR
Pre-crisis	3.226	-1.816	1.288	-1.458	0.535	2.838	0.545	-3.842
	[3.890]***	[-3.449]***	[3.205]***	[-2.652]***	[0.836]	[3.881]***	[0.824]	[-3.369]***
Crisis	-1.206	1.957	-1.282	1.849	0.236	-1.371	-1.462	0.121
	[-2.725]***	[2.709]***	[-2.464]**	[2.478]**	[0.304]	[-1.876]*	[-2.351]**	[0.094]
Rule writing	-1.178	0.041	0.259	-0.231	1.622	-0.708	-0.090	1.475
	[-2.186]**	[0.093]	[0.585]	[-0.404]	[2.383]**	[-1.574]	[-0.157]	[1.051]
Implementation	-2.208	-0.314	-0.365	-0.031	-0.718	-1.247	0.041	1.451
	[-3.905]***	[-0.683]	[-1.008]	[-0.058]	[-0.786]	[-3.054]***	[0.108]	[1.102]
F-tests relative to pre-crisis coefficients								
$F(\beta_{Pre} = \beta_{Crisis})$	33.844	11.431	14.081	8.003	0.085	9.760	13.441	4.393
p-val	0.000	0.001	0.000	0.005	0.771	0.002	0.000	0.036
$F(\beta_{Pre} = \beta_{Writing})$	11.854	12.459	3.594	3.784	1.990	14.004	0.519	8.433
p-val	0.001	0.000	0.058	0.052	0.158	0.000	0.471	0.004
$F(\beta_{Pre} = \beta_{Imp.})$	17.940	11.129	11.324	5.087	0.877	20.617	0.659	8.727
p-val	0.000	0.001	0.001	0.024	0.349	0.000	0.417	0.003

(b) Customer-to-dealer ratio

	Raw lev.	RWA	Repo	Loans	ROA	Trading rev.	LSR	CoVaR
Pre-crisis	-2.256	2.914	2.285	-2.627	-7.544	7.863	2.537	12.852
	[-0.698]	[2.189]**	[2.013]**	[-1.619]	[-2.460]**	[3.468]***	[2.115]**	[3.157]***
Crisis	-1.135	2.953	0.087	3.458	1.622	-2.574	-0.057	-0.867
	[-0.763]	[2.697]***	[0.080]	[2.592]***	[0.646]	[-1.893]*	[-0.039]	[-0.339]
Rule writing	2.349	0.036	1.150	3.007	-0.365	-3.428	2.734	-1.902
	[1.935]*	[0.026]	[1.420]	[1.989]**	[-0.169]	[-2.862]***	[2.610]***	[-0.790]
Implementation	0.769	0.865	-2.507	3.665	5.432	-5.183	-4.203	-11.993
	[0.530]	[0.693]	[-2.695]***	[2.722]***	[1.515]	[-3.848]***	[-3.212]***	[-3.575]***
F-tests relative to pre-crisis coefficients								
$F(\beta_{Pre} = \beta_{Crisis})$	0.063	0.000	1.191	6.722	4.841	9.445	1.203	5.813
p-val	0.802	0.985	0.275	0.010	0.028	0.002	0.273	0.016
$F(\beta_{Pre} = \beta_{Writing})$	1.381	2.200	0.881	5.806	3.783	11.395	0.039	6.659
p-val	0.240	0.138	0.348	0.016	0.052	0.001	0.843	0.010
$F(\beta_{Pre} = \beta_{Imp.})$	0.501	1.188	12.534	7.293	4.416	14.035	28.438	12.344
p-val	0.479	0.276	0.000	0.007	0.036	0.000	0.000	0.000

Table 5: **Constraints of buyers and sellers**. This table reports the estimated coefficients β^B and β^S from the regression

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

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 and industry 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) Buyers' constraints

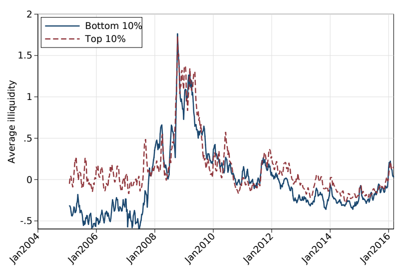
	Raw lev.	RWA	Repo	Loans	ROA	Trading rev.	LSR	CoVaR
Full sample	0.013	-0.044	0.013	-0.036	-0.024	0.014	-0.011	-0.003
	[3.412]***	[-16.167]***	[4.269]***	[-14.298]***	[-2.904]***	[6.182]***	[-2.211]**	[-0.378]
Pre-crisis	-0.042	0.030	0.014	0.007	-0.225	-0.008	-0.002	0.107
	[-5.078]***	[2.892]***	[2.137]**	[0.656]	[-8.488]***	[-0.741]	[-0.407]	[5.417]***
Crisis	0.018	-0.055	0.028	-0.042	0.019	0.020	0.008	-0.034
	[2.794]***	[-6.435]***	[5.045]***	[-4.944]***	[1.176]	[3.271]***	[1.305]	[-2.964]***
Rule writing	0.022	-0.024	-0.003	-0.012	0.114	0.017	-0.028	-0.071
	[3.429]***	[-3.603]***	[-0.617]	[-1.720]*	[6.461]***	[2.967]***	[-4.138]***	[-6.143]***
Implementation	0.028	-0.016	-0.022	0.004	0.107	-0.005	0.024	-0.032
	[4.601]***	[-2.530]**	[-5.101]***	[0.652]	[6.163]***	[-0.932]	[4.042]***	[-2.480]**
F-tests relative to pre-crisis coefficients								
$F(\beta_{Pre} = \beta_{Crisis})$	21.307	23.097	1.697	7.145	38.764	2.963	1.206	23.171
p-val	0.000	0.000	0.193	0.008	0.000	0.085	0.272	0.000
$F(\beta_{Pre} = \beta_{Writing})$	24.276	12.811	3.088	1.376	68.082	2.518	5.571	36.552
p-val	0.000	0.000	0.079	0.241	0.000	0.113	0.018	0.000
$F(\beta_{Pre} = \beta_{Imp.})$	31.434	9.775	15.176	0.034	66.355	0.024	8.260	20.034
p-val	0.000	0.002	0.000	0.854	0.000	0.877	0.004	0.000

(b) Sellers' constraints

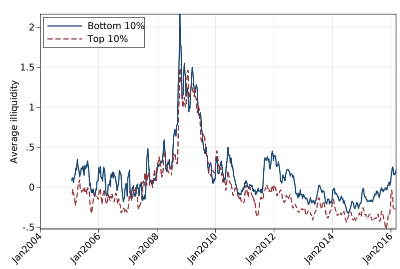
	Raw lev.	RWA	Repo	Loans	ROA	Trading rev.	LSR	CoVaR
Full sample	0.015	-0.053	0.015	-0.042	-0.043	0.011	-0.011	0.016
	[4.158]***	[-18.232]***	[4.798]***	[-16.033]***	[-4.926]***	[5.278]***	[-2.093]**	[2.520]**
Pre-crisis	-0.025	0.023	0.023	-0.015	-0.203	-0.001	-0.001	0.061
	[-3.207]***	[2.110]**	[3.624]***	[-1.360]	[-6.882]***	[-0.111]	[-0.235]	[3.013]***
Crisis	0.018	-0.058	0.026	-0.030	0.044	0.025	-0.026	-0.033
	[2.819]***	[-6.779]***	[4.662]***	[-3.635]***	[2.453]**	[4.218]***	[-4.179]***	[-2.788]***
Rule writing	0.021	-0.037	-0.002	-0.017	0.085	0.009	-0.029	-0.065
	[3.300]***	[-5.195]***	[-0.545]	[-2.470]**	[4.474]***	[1.681]*	[-4.113]***	[-5.370]***
Implementation	0.011	-0.003	-0.029	0.018	0.078	-0.015	0.051	0.027
	[1.851]*	[-0.473]	[-6.619]***	[2.795]***	[4.147]***	[-2.692]***	[8.326]***	[2.029]**
F-tests relative to pre-crisis coefficients								
$F(\beta_{Pre} = \beta_{Crisis})$	12.187	19.586	0.064	0.686	31.536	2.815	6.322	9.763
p-val	0.000	0.000	0.800	0.408	0.000	0.093	0.012	0.002
$F(\beta_{Pre} = \beta_{Writing})$	13.810	13.457	7.436	0.015	40.158	0.489	5.898	17.108
p-val	0.000	0.000	0.006	0.903	0.000	0.484	0.015	0.000
$F(\beta_{Pre} = \beta_{Imp.})$	9.349	2.748	32.260	4.388	38.698	0.846	30.181	1.150
p-val	0.002	0.097	0.000	0.036	0.000	0.358	0.000	0.284

Figure 1: **Bond-level illiquidity 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.

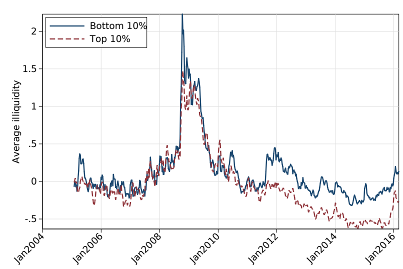
(a) Raw leverage



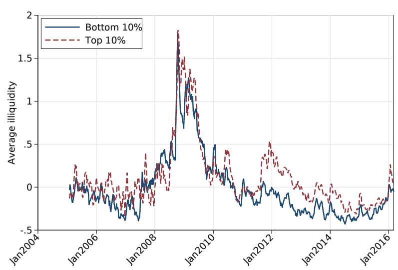
(b) RWA



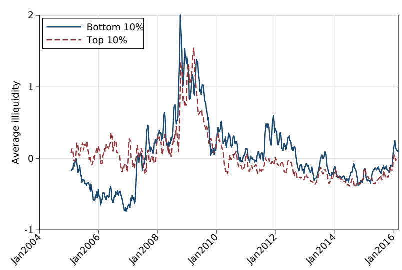
(c) Loans



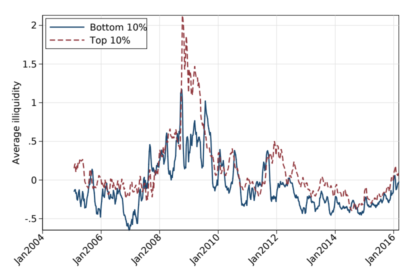
(d) Repo



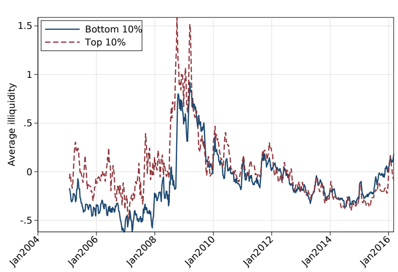
(e) ROA



(f) Trading revenue



(g) LSR



(h) CoVaR

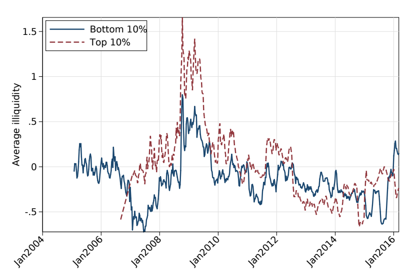


Figure 2: **Fraction of bonds traded by constrained and unconstrained institutions.** This figure plots the time series of the fraction of bonds each week traded both by institutions above and below the median of the constraints (black), only by institutions above the median of the constraint (grey), and only by institutions below the median of the constraint (white).

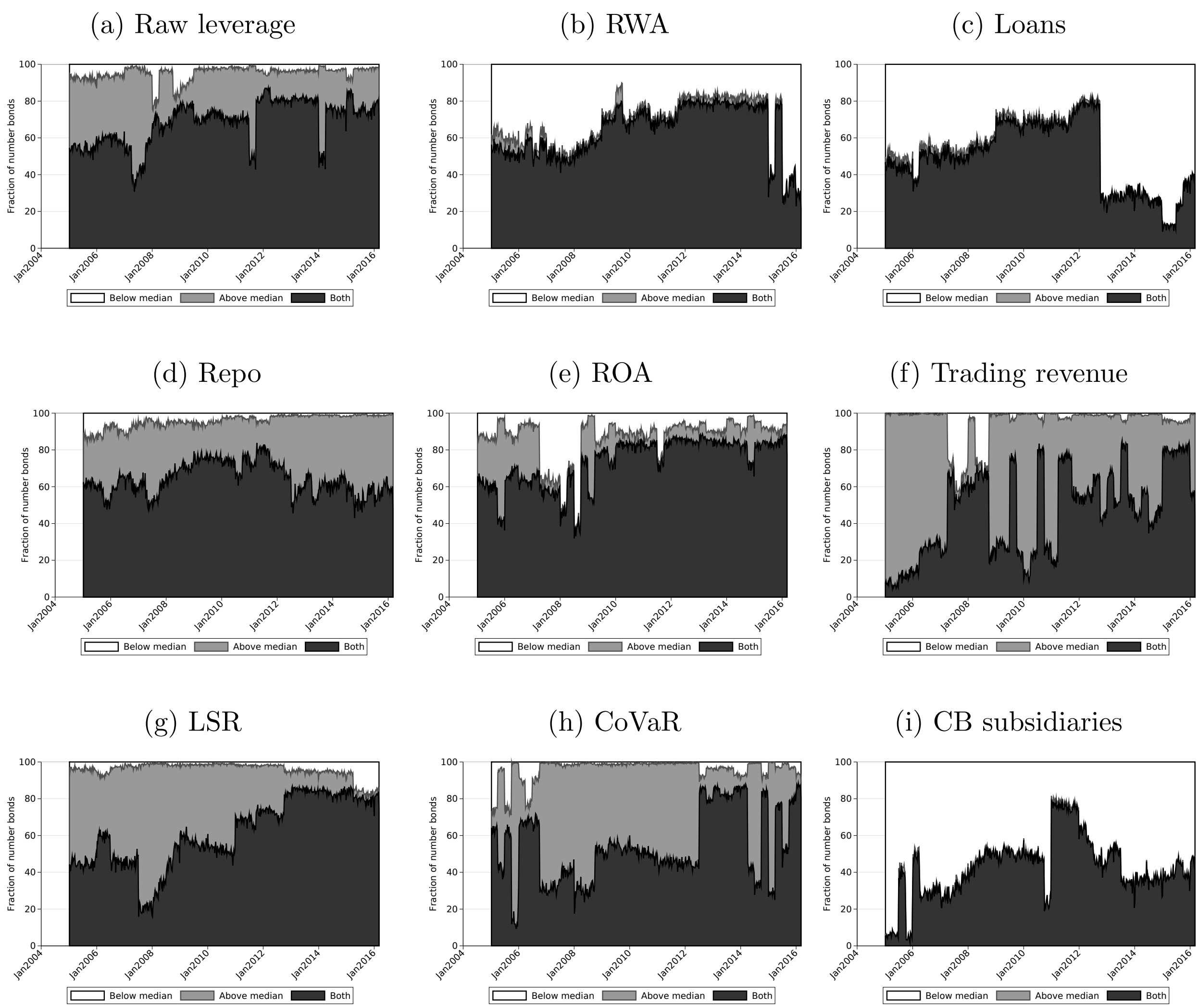


Figure 3: **Fraction of trading volume in different credit ratings by constrained and unconstrained institutions.** This figure plots the median within a quarter of the fraction of the trading activity done by an institution in a given week accounted for by trades in different credit rating buckets. Diamonds represent institutions that are above the median of the constraint distribution in the previous quarter; squares represent institutions that are below the median.

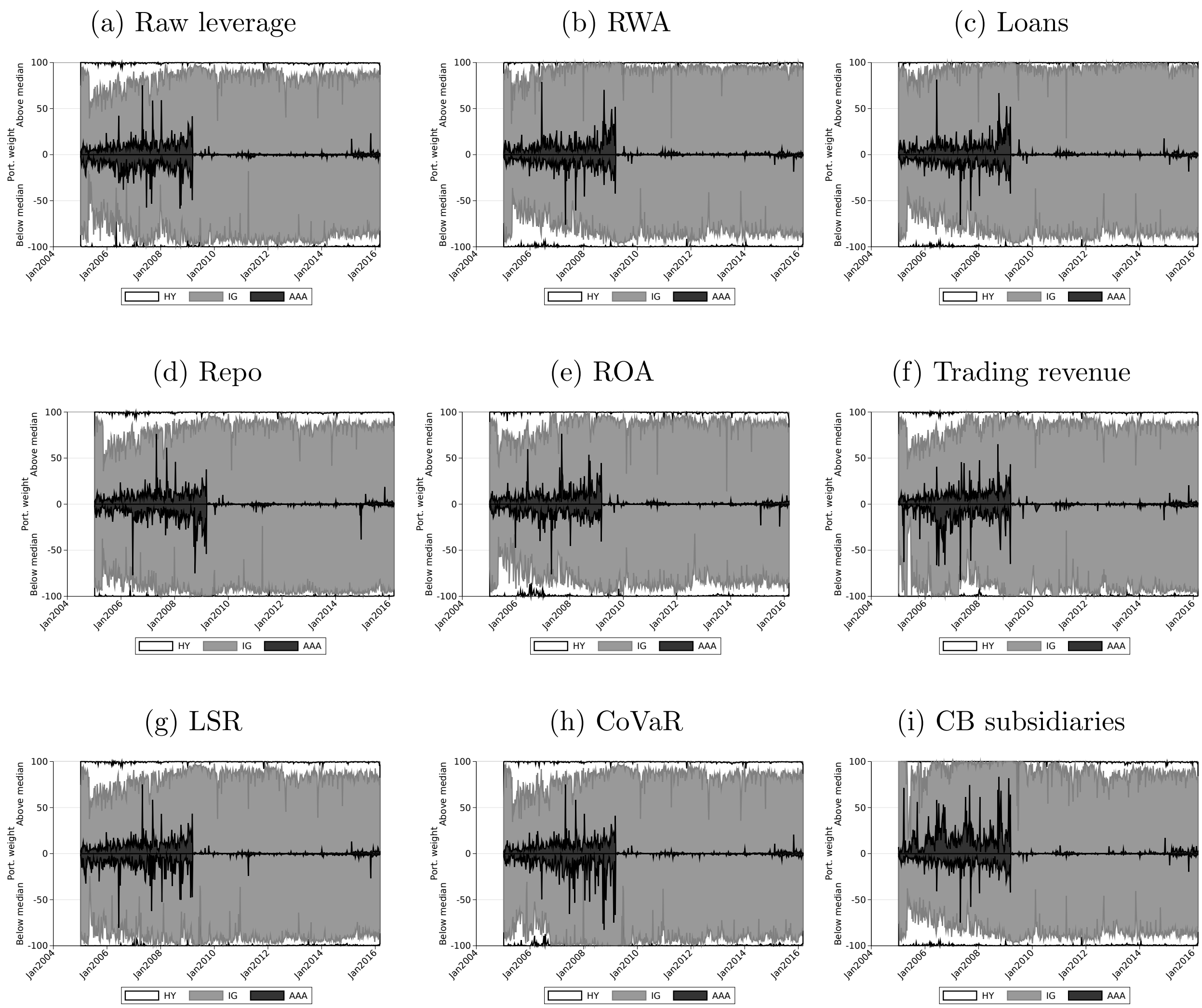


Figure 4: **Timeline of regulation implementation.** This figure plots the dates at which selected regulations were either introduced, passed or phased in.

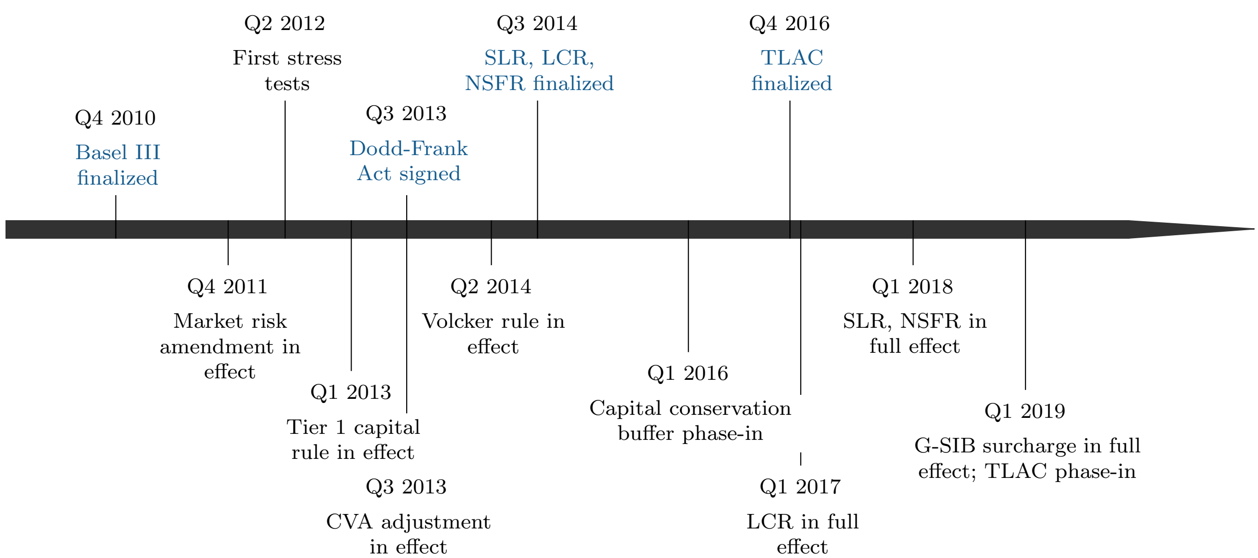
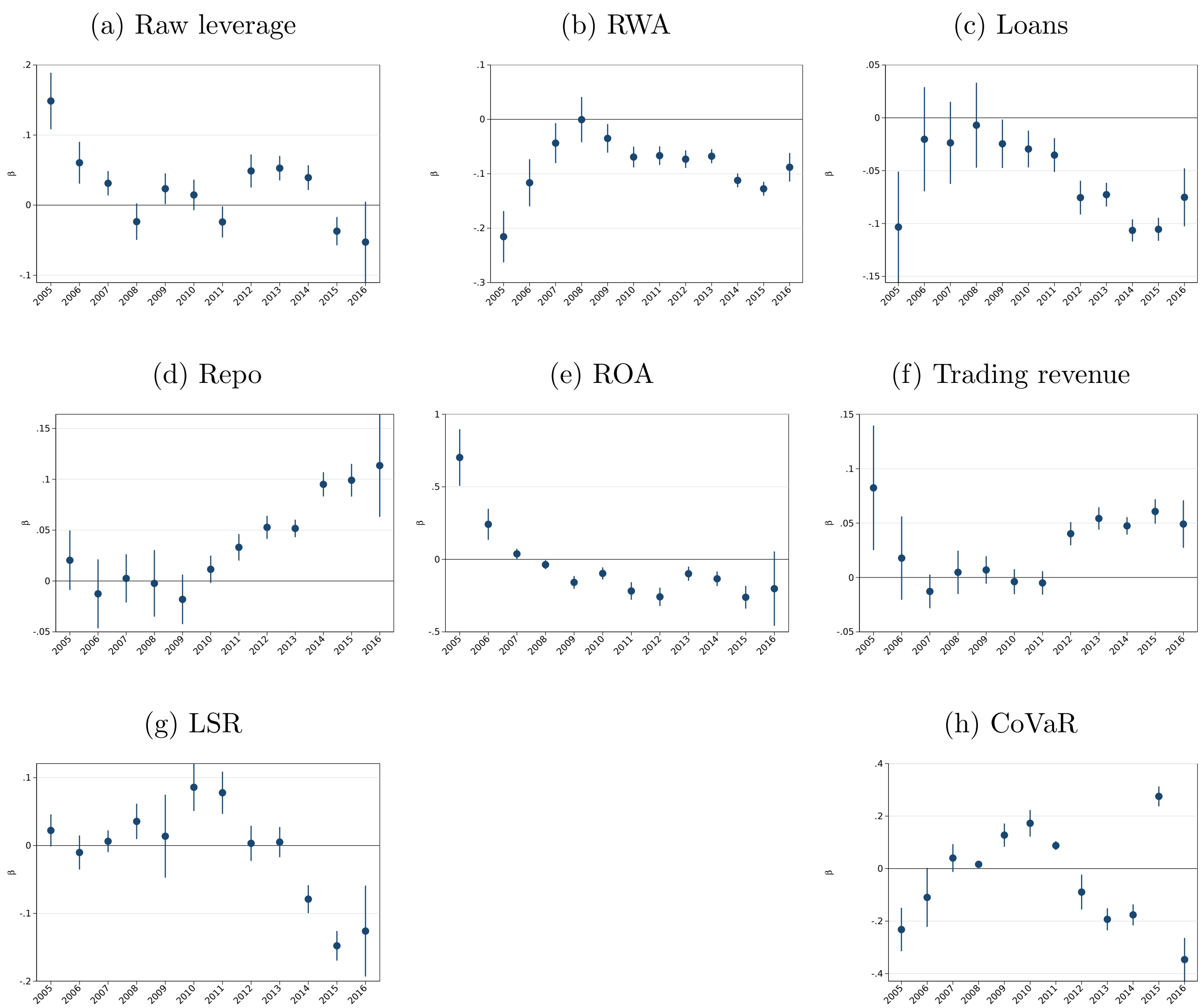


Figure 5: **Baseline regression coefficients over time.** This figure plots the estimated coefficient β from the regression
$\text{Illiquidity}_{b,t} = \alpha_t + \delta\text{Illiquidity}_{b,t-1} + \beta\text{Constraint}_{b,t} + \sum_k \gamma_k \text{Char}_{b,k,t} + \epsilon_{b,t}$,
for the sample split 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 and industry 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 Data

A.1 Calculating Bond Illiquidity Measures

In the paper we calculate the bond-level illiquidity proxy as the first principal component of various illiquidity measures (PC1) at the weekly level. The illiquidity measures that underlie the PCA include: Amihud, effective bid-ask spread, imputed round-trip cost, and a combination of zero return days and no-trade days. In this section we detail the exact calculation of each measure.

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.

The imputed round-trip cost (IRC) is based on Feldhütter (2012). First, we identify whether transaction is 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. Then, for each IRT, the imputed round-trip cost (IRC) is 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 for IRC 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 a combination of two "zero measures", as suggested by Lesmond et al. (1999). The first measure is zero return days (ZRD), which proxies for bonds whose prices is unchanged over a long period. The second measure is zero trade days (ZTD), which proxies for bonds that do not trade for a long period. The two measures are then combined to one measure as

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

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

A.2 Calculating 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 institution's systemic risk contribution. A firm's 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 firm's 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