Bank Balance Sheet Constraints and Mutual Fund Fragility

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We develop a methodology to connect individual bonds, dealer banks and mutual funds, utilizing two intuitive and striking patterns: the home bias and the persistence of underwriting relationships. Building on these connections, we show that the introduction of the leverage ratio for European banks had a large impact on bond liquidity. We also show that the bond mutual funds' outflows following the 2020 pandemic outbreak affected substantially more mutual funds with larger exposures to dealer banks' balance sheet constraints. These findings highlight the importance of interactions between the regulation of banks and financial fragility of non-banks.

Keywords: Bond liquidity; market-making; capital requirements; leverage ratio; mutual funds; COVID-19

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1. Introduction

Do regulatory constraints on banks contribute to the fragility of non-banks? In this paper we investigate the role of dealer banks' balance-sheet regulatory constraints on the bond mutual fund run in March 2020. The regulatory overhaul in the aftermath of the 2008 global financial crisis (GFC) raised banks' minimum capitalization requirements and curtailed their broader risk exposure. One of the unintended consequences of these new regulations appeared to be reduced liquidity in the bond markets, as bank-affiliated dealers reduced balance sheet space available for market-making, and costs faced by some counterparties have increased (e.g., Powell, 2015; Duffie, 2016; European Commission, 2017).[1] Indeed, banks' inventories of corporate bond holdings have declined significantly (Figure 1, Panel A).[2] In parallel, the non-bank financial sector more than doubled in size since the GFC and concerns grew both about the build-up of financial fragility in that sector and about the interlinkages between the regulated banks and the less regulated non-banks. The fragility in non-banks manifested itself in runs on mutual funds in early 2020, a dynamic that is believed to have contributed to the broader bond market distress. In this paper, we investigate whether regulatory constraints on dealer banks played a role in exacerbating runs on bond mutual funds.

While critics of the leverage ratio regulation point out its potential negative effects on aggregate bond liquidity, it is hard to argue that regulatory constraints

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[1] In his 2015 speech Jerome Powell stated that: "many point to post-crisis regulation as a key factor driving any recent decline in liquidity (…) I would agree that it is one factor driving recent changes in market making." The European Commission report concludes that "[b]anks and dealers have more limited balance sheet capacity now than prior to the financial crisis. In general, it is more difficult for investors to trade in large sizes. […] Traders that require immediate executions in large size now pay more in price impact because the cost of liquidity has risen post-crisis."

[2] Similar patterns were highlighted for the U.S. in Liberty Street Economics blog, August 21, 2015, "What's Driving Dealer Balance Sheet Stagnation?" by Tobias Adrian, Michael Fleming, Daniel Stackman, and Erik Vogt, https://libertystreeteconomics.newyorkfed.org/2015/08/whats-driving-dealer-balance-sheet-stagnation.html.

were a major impediment to bond market growth. Between 2013 and 2019, the euro area non-financial corporate bond market nearly doubled in size, growing from EUR 1.17 trillion to EUR 2.05 trillion in amounts outstanding, corresponding to roughly a 10% cumulative annual growth (Figure 1, Panel B). Accordingly, in 2014, the Committee on the Global Financial System concluded that "At this stage, there is no conclusive evidence of a widespread rise in trading costs, as a number of factors may be containing the pass-through to clients and issuers."[3]

A way to reconcile these seemingly contradictory facts is to realize that the primary concern with the consequences of the reduced banks' market-making capacity is not the immediate, "normal times" illiquidity costs, but instead the build-up of financial fragility. Bond market growth went hand-in-hand with the growth of mutual funds that invested in bonds (e.g., Goldstein, Jiang, and Ng, 2017; Ma, Xiao, and Zeng, 2020). Figure 1, Panel B illustrates this phenomenon for the European setting. The basic idea behind this concern is that illiquidity and its uneven distribution among portfolio assets expose funds holding such assets to significant outflows. Until 2020, such fragility was largely hypothetical. However, in early 2020, mutual funds in the U.S. and Europe faced significant outflows, leading to fire-sale like dynamics in bond markets. Indeed, the central banks had to intervene in a significant and unprecedented way to stabilize both sovereign and corporate bond markets (e.g., Breckenfelder and Hoerova, 2021).

A run on mutual funds in early 2020, therefore, constitutes a key economic setting to study the role of dealer banks' balance sheet constraints in propagating financial fragility by precipitating the run dynamic. Our study is cross-sectional, and our central contribution is to show that fixed-income funds that were exposed to dealer balance-sheet constraints in their portfolio faced bigger selling pressure. This is consistent with Bao, O'Hara, and Zhou (2018) and Dick-Nielsen and Rossi (2019) who emphasize that liquidity matters the most during market stress or illiquidity

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[3] See Committee on the Global Financial System (2014).

events.

Practitioners and policymakers have specifically cited the Basel III leverage ratio and the Volcker Rule in the U.S. as key drivers of reduced market liquidity.[4] The capacity and willingness of dealers to warehouse securities, especially for the bond market which relies heavily on principal-based market-making services, are essential for liquidity. Because of its non-risk-weighted nature, the leverage ratio—which requires banks to maintain a minimum equity capital as a fraction of its assets—makes it less attractive for banks to engage in low profit margin activities.[5] In line with this idea, the U.S. Federal Reserve temporarily exempted Treasuries and other safe securities from leverage ratio calculations in response to bond market stress in March 2020.[6] For this reason, we will use slack under the leverage ratio as our measure of dealers' balance-sheet constraints.

One important empirical challenge is establishing a connection between bond liquidity and the balance sheet of an individual dealer. To the best of our knowledge, our paper is the first to develop a methodology to do so. In the absence of bond-to-dealer "stickiness," bonds would be transacted through the least constrained dealer, making balance-sheet constraints of individual dealers (and cross-sectional analysis) irrelevant. However, as we will illustrate, individual dealer frictions matter due to (i) a significant home bias among the Eurozone dealers, and (ii) the persistence in dealing activities among bond underwriters. Simply put, we see that the bulk of

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[4] For example, see "The Impact of the Basel III Leverage Ratio on Risk-Taking and Bank Stability," Special Feature in the ECB Financial Stability Review (November 2015). https://www.ecb.europa.eu/pub/pdf/fsr/art/ecb.fsrart201511_01.en.pdf?8dbb0ec8072de08c70002fc0a68ebd81.

[5] This is similar to the intuition in Brunnermeier and Petersen (2009) which links trader's funding liquidity and asset's market liquidity.

[6] See "Federal Reserve Board Announces Temporary Changes to Its Supplementary Leverage Ratio Rule to Ease Strains in the Treasury Market Resulting from the Coronavirus and Increase Banking Organization's Ability to Provide Credit to Households and Businesses", April 1, 2020, https://www.federalreserve.gov/newsevents/pressreleases/bcreg20200401a.htm.

French bonds are likely to be transacted by French dealer banks. Similarly, independently of counterparties' home countries, if a bank was the underwriter of a bond issue, it is very likely that it is also the key dealer for these bonds long after the initial placement. As we elaborate in Section 3, these mechanisms make dealers hard to replace. These salient patterns enable us to use cross-sectional heterogeneity in bond exposure to banks' balance sheet constraints and trace its impact on liquidity. This empirical approach—matching a bond in the secondary market to the dealer—is an alternative measurement of bond liquidity in future studies, as bonds are generally illiquid and lack consistent data. Our methodology effectively provides an insight for measuring liquidity using dealer-level information, and could be used in other contexts as a complementary measure.

Armed with the plausibly exogenous matching between bonds and dealers, we establish a connection between our measure and bond liquidity by looking at the introduction of the leverage ratio for euro area banks. Our results include bond fixed effects; that is, we compare the shift in liquidity for the same bond after the leverage ratio starts to be reported to supervisors. We find that for countries where bank dealers are one percentage point closer to the regulatory requirement (about one standard deviation), the bid-ask spread is 8 basis points higher (about a quarter of the median bid-ask spread in our sample).

Our main results link the outflows and selling behavior of bond mutual funds in Spring 2020 to bond illiquidity caused by dealer bank balance-sheet constraints. In the cross-section of bond mutual funds, we initially demonstrate that, although all funds closely tracked one another in terms of valuations and fund flows prior to the COVID-19 shock, funds more exposed to constrained dealer banks exhibited lower performance and increased outflows after the shock, compared to less exposed funds. At the peak of the crisis, the performance differential between the two groups of funds reached 4 percentage points, and the outflow differential totaled 2 percentage points. This observation is consistent with the notion that fund fragility and fund illiquidity are inherently linked. Promising investors high liquidity while holding illiquid assets can instigate a run-like dynamic among investors, prompting them to withdraw before others do (Chen, Goldstein, and Jiang 2010; Goldstein, Jiang, and Ng, 2017).

Subsequently, we show that to satisfy investor outflows, funds more exposed to illiquidity were compelled to liquidate their safest securities relatively more compared to less exposed funds. Specifically, we document that the holdings of the safest bonds for the more exposed funds dropped by approximately 5 percentage points more compared to the other funds; falling from about 23% holdings of the most liquid securities to approximately 18%. This finding links to literature indicating that mass selling of the safest securities by funds in March 2020 led to disruptions in normally liquid markets, such as those for Treasury bonds or investment-grade corporate bonds (Vissing-Jorgensen, 2021; Haddad, Moreira, and Muir, 2021).

Our paper contributes to and interconnects two strands of research: (i) studies focused on the impact of Basel III regulatory constraints on bond liquidity, and (ii) fragility of bond mutual funds due to illiquidity.

Although, to date, there have been several papers that looked at changes in bond liquidity post GFC, the aggregate impact on market liquidity remains debated. Schultz (2017) shows that after the Volcker Rule was finalized, dealers were more reluctant to take bonds into their inventory and unwound inventory positions more quickly. However, Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018) show that while the bank-affiliated dealers decreased their "capital commitment" in US corporate bond markets, non-bank dealers (unaffected by regulations) have increased their market commitments. According to Bao, O'Hara, and Zhou (2018), the net effect in the aftermath of the bank regulatory adjustment has been negative and, overall, corporate bonds in the US have become less liquid during times of stress. But Trebbi and Xiao (2019), Adrian, Fleming, Shachar, and Vogt (2017) find only limited evidence of a deterioration in market liquidity. Choi, Huh and Shin (2023) point out that customers, rather than dealers, increasingly provide liquidity to other customers. However, for those trades in which dealers do provide liquidity using their inventory capacity, they document an increase in transaction costs after the financial crisis.

We contribute to this debate by (i) showing bond-level evidence; (ii) examining the role of illiquidity tied to bank constraints in the context of the 2020 mutual fund run; and (iii) providing evidence in the European context. As explained earlier, ex-ante, it is not fully clear why individual bank constraints matter for bond intermediation, and much of the literature does not look at it at this level. Adrian, Boyarchenko, and Shachar (2017) is the closest paper to ours in that sense. They link changes in the liquidity of individual US corporate bonds to financial institutions' balance sheet constraints and find that bonds traded by more levered institutions are less liquid, especially after the financial crisis. Their paper takes the assignment of bonds to dealers based on transactional data. Our contribution is to micro-found bond-dealer matching, and establish a source of quasi-exogenous assignment, and to use this assignment to examine the differential impact on mutual funds in 2020.

Bao, O'Hara, and Zhou (2018) and Dick, Nielsen, and Rossi (2019) stress that liquidity matters most during specific market stress or liquidity events. Mutual funds worldwide faced a significant shock with the COVID-19 related economic lockdown. This has been studied by Falato, Goldstein, and Hortaçsu (2021) in the US context.[7] Our specific focus is on the role of the banks' constraints in bond market making and its connection to specific pressures faced by mutual funds. In this sense, our work is closest to O'Hara and Zhou (2021) who also seek to understand the role of frictions among the market makers in driving the bond market turmoil in March of 2020. O'Hara and Zhou (2021) focus, however, on the efficacy of the Federal Reserve's effort to stem the 2020 liquidity crisis in the corporate bond market. The impact of the Federal Reserve corporate credit facilities was also the focus of

[7] Mutual funds in the euro area also faced significant outflows in March 2020; see, e.g., Allaire, Breckenfelder and Hoerova (2022) who study the dynamics of fund runs across different investors in mutual fund shares.

Boyarchenko, Kovner, and Sharchar (2022) and Gilchrist, Wei, Yue, and Zakrajsek (2021). Li, O'Hara and Zhou (2023) study instead how dealers' perceptions of fragility risks posed by mutual funds affected their liquidity provision in the US municipal bond market during the COVID episode.[8]

As already mentioned, as a secondary point, this paper establishes persistence of dealer connections in the bond market and provides evidence of the liquidity crisis for the European market.

The rest of the paper is organized into six sections. Section 2 discusses the data sources used for this study. Section 3 provides background on the bank leverage ratio requirement, and builds the case for the "stickiness" of the dealers at the bond level. Section 4 presents the set of results that measure the impact of the bank leverage ratio requirement on bond liquidity. Section 5 looks into how bank leverage constraints differentially affected the liquidity of bond mutual fund holdings during the COVID-19 pandemic shock. Section 6 concludes.

2. Data description

We employ a range of datasets in this study. We summarized the core datasets used in the analysis below.

Identifying broker-dealers: To identify broker-dealers we use the *Eurosystem Asset Purchase Database,* which is proprietary Eurosystem data on all executed trades under the European Central Bank's (ECB) and the euro area national central banks' Asset Purchase Program (APP). The purchases are conducted with eligible counterparties which we define as broker-dealers. We use two alternative definitions. First, we use broker-dealer banks that engage in the trading of corporate bonds under the Corporate Sector Purchase Program (CSPP), i.e., these are market makers in the corporate bond market. The second definition uses the sample of broker-dealer banks

[8] More generally, a number of recent papers studied dislocations in corporate bond market during the Spring of 2020, see, e.g., Jiang, Li, Sun, and Wang (2022); Haddad, Moreira and Muir (2021), or Kargar, Lester, Lindsay, Liu, Weill, and Zuniga (2021).

that engage in the trading of sovereign bonds under the Public Sector Purchase Program (PSPP). CSPP was active between June 2016 and December 2018. PSPP was active between March 2015 and December 2018. When we look outside of these windows, we assume that being a large bank dealer is a persistent characteristic. This seems like a reasonable assumption; this is in line with Di Maggio, Kermani and Song (2017) who find that the bond dealer market in the U.S. is highly concentrated, with a few core dealers intermediating most of the transactions.

Based on this criterion, we identify 14 broker-dealers using the corporate bond purchase program, and 41 using the sovereign bond purchase program. Overall, the sample contains 116 (dealer and non-dealer) banks. Our methodology likely only picks up the largest broker-dealer banks; however, as we will show later, it captures a substantial share of bond holdings. This is again in line with the "core-periphery" structure of the dealer segment documented in previous literature.

Bond characteristics and pricing: We rely on *DataScope* to collect daily corporate bond bid-ask spreads for the euro area. For information on bond characteristics, we use the *Centralized Securities Database (CSDB)*, a security-by-security level Eurosystem database that contains data on instruments and issuers including maturity and issuance date, bond type (e.g., zero coupon), currency, ratings, and issuer information (location, issuer organization number, name).

Bank holding company leverage ratio: To obtain regulatory leverage ratios for euro area banks, we use the confidential *SSM Supervisory Statistics*, as well as leverage ratios gathered during the 2014 stress tests and asset quality review of euro area banks. These data are used to measure slack under the leverage ratio constraint. We will discuss in the next section how each individual bond is matched to the dealer (and, therefore, to the leverage ratio).

Macro variables: The macroeconomic variables come from *Bloomberg*. Country-specific time-varying variables include: local GDP, local equity indexes, local bank indexes, and 1-, 3-, 5- and 10- year local government bond spreads.

3. Measuring dealers' constraints at the fund level

As highlighted in the introduction, the mechanism that puts pressure on the bond market works through mutual funds exposure to the illiquid bonds (Goldstein, Jiang and Ng, 2017; Ma, Xiao and Zeng, 2020). Specifically, because funds are unable to sell illiquid bonds without moving the price, when facing redemptions they tend to first sell more liquid holdings which, in turn, creates incentive for investors to run. Existing empirical literature has provided support for the mechanism behind the run on mutual funds. Our focus is on the role of the dealer's balance sheet constraints in amplifying fund fragility. Specifically, we evaluate whether dealer's constraints—and, specifically, constraints resulting from post GFC bank regulations—played a role in reinforcing fund illiquidity. To do so, we need to categorize bond funds based on their portfolio's exposure to constrained dealers and then test whether their selling behavior and redemptions they faced were particularly pronounced in 2020.

To construct fund-level exposure to dealer's balance sheet constraints, we follow a three-step procedure. First, we identify constrained dealers. Second, we assign individual dealers to bonds. Third, we aggregate bonds' exposure to illiquidity through the dealer at the fund level.

3.1. Dealer constraints

In the aftermath of the 2008 Global Financial Crisis, the Basel Committee on Banking Supervision (BCBS) initiated a substantial reform program for banking regulation known as Basel III. This reform introduced new international regulatory standards for both capitalization and liquidity risk management. A key regulatory reform was the implementation of the leverage ratio, designed to ensure minimum bank equity capitalization. However, unlike the risk-based capital requirement, the leverage ratio acknowledges limitations in the ability to measure risk (i.e., the "model risk") and therefore is not risk-weighted. Instead, it is a simple ratio of Tier 1 capital to the book value of total assets (including both on-balance sheet exposures and some off-balance sheet items).[9]

The issue arises from the non-risk weighted nature of the leverage ratio, making it more expensive for banks to engage in low-margin activities. Specifically, it has been argued that the leverage ratio could hinder bond intermediation, as the margin on bond dealing—and particularly dealing in safe bonds—is low. Yet, it expands banks' balance sheets and thus attracts a capital charge under the leverage ratio. For these reasons, our study on the regulatory impact on bond liquidity centers around the leverage ratio as the relevant constraint at the bank level.

Figure 2 illustrates the evolution of the leverage ratio of the largest dealer banks in our sample. It's apparent that even within this sample, we observe considerable heterogeneity and the relevance of the constraint.

[FIGURE 2]

To support the conceptual argument that the leverage ratio has significant implications for bond liquidity, we will examine the impact on bond liquidity surrounding the introduction of the leverage ratio in Section 4. As we will discuss later, the European setting offers a potentially quasi-exogenous setting for considering this question around the implementation of this regulation. We will discuss other potential limitations of this approach in Section 4.

3.2. Dealer-bond ties

An important aspect of cross-sectional identification is to establish a source of quasi-exogenous assignment of bonds to broker-dealers. The impact of individual banks' constraints on bond liquidity necessitates some tie between the bond and a specific dealer, making it challenging to switch. If such ties were absent, all bonds would be intermediated by the least constrained dealer.

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[9] In corporate finance, a "leverage ratio" has debt in the denominator (in this context, Debt/Assets) thus, borrowers' constraints on leverage are typically set as a *maximum* leverage ratio. Bank regulatory leverage ratio has equity in the denominator, which is effectively (1-Debt/Assets). So, in the banking context, we talk about a *minimum* leverage ratio.

Previous research offers multiple explanations for how broker-dealers facilitate trade. We build on the importance of dealers in reducing search costs (e.g., Rubinstein and Wolinsky, 1987, Duffie, Garleanu, and Pedersen, 2005) and information asymmetry (e.g., Kyle, 1985; Glosten and Milgrom, 1985; and Biglaiser, 1993) in bilateral trades. It's important to note that the bond market is a quote-based, over-the-counter (OTC) market, meaning it is non-centralized and non-standardized. This heightens market frictions that underscore the economic role of dealers. Based on these observations, we propose two methods of filtering bond-dealer pairings that result from persistent connections and are likely exogenous to the impact of regulatory changes on individual dealers. Both of these explanations hinge solely on the dealer's information extraction from order flow. As far as we know, the long-term persistence of the bond-dealer connections is a novel insight of our paper. [10]

A. Home bias in dealers' activity

In light of the extensive literature building on local and country bias, we examine whether domestic dealers are the most significant for bond intermediation. A home bias in dealer activities could be linked to search costs or the importance of connections to a network of institutional investors. The role of these connections is crucial at the underwriting stage (Benveniste and Spindt, 1989) but is also likely to extend to the secondary market. (It's worth emphasizing that, as we are looking within the euro area, such differences can't be explained by currency denomination.) Table 1 reveals a striking pattern: on average, at the end of 2019, large domestic dealers held about 52.5% of the bond, while the largest foreign country-level holding of dealers was only about 2.0%. This staggering gap between domestic and foreign dealers is both substantial and consistent throughout the sample.

[TABLES 1 & 2]

[10] Dick-Nielson, Feldhutter, and Lando (2012), use stock market evidence from post IPO period in Ellis, Michaely, and O'Hara (2000) and assume (but do not establish) that, in the bond market, underwriters could be relevant in the 3-month following the offering in the bond market.

Thus, in this first approach of isolating stable ties between individual dealers and bonds we look at the bank constraints at the country level. To do so we use within-country weighted averages of dealer distances to the 3% leverage ratio (the regulatory requirement). Distribution of this measure is reported Table 2, Panel A. Lines (i) through (iv) correspond to alternative ways weights are used to construct averages; namely, for dealers participating in the corporate bond purchasing program the averages are: (i) weighted by total assets (our default measure); (ii) weighted by trading volume under the CSPP; (iii) correspond to the top-1 dealer in a country by share of trading volume in the CSPP; (iv) correspond to the top-2 dealers in the country weighted by the trading volume in the CSPP. Overall, the choice among these different methodologies does not affect the central takeaways of this paper.

Using country-level dealers' balance sheet constraints allows us to capture a broad sample of bonds, but it also leaves a possibility that there could be unaddressed country-level factors that might impact liquidity through channels other than balance sheet cost. So, we complement this approach by looking at the persistence of bond underwriter's role as a secondary market dealer. This second approach requires more granular data, and, as a result, constraints the sample of bonds that we can use in the analysis. This is why we find the two approaches complementary to each other.

B. The role of the bond underwriter

Through interviews with several senior market participants, we have learned that bond underwriters continue to play an important role in the secondary market long after the bond issue. This is not a well-documented fact, and, based on the feedback that we received when presenting this paper, there are widely ranging views even among experts in the fixed income market. In the equity context, Ellis, Michaely, and O'Hara (2000) show that the lead underwriters are the dominant market makers in the 3 months following the IPO, which is in line with the price stabilization being part of the underwriter's role which is pivotal when companies become public. It is less clear why this would be true in the bond context and at longer horizons. The mechanism is different from the one Ellis, Michaely, and O'Hara (2000) propose, and might be best understood if one puts themselves in the shoes of a bond investor.

To start, any sizable institutional investor has a representative at each underwriter/dealer. Although some of these relations might be more important than others, investors' access to any dealer in today's market does not appear to be an issue. If an investor wants to buy bonds at issuance which is being underwritten and placed by, say, JPMorgan, it would be natural for them to reach out to JPMorgan directly. Now, imagine instead that the bond was already placed, and the investor is trying to purchase it in the secondary market. The choice of the dealer to call is informed by two factors: the first is the quoted price, and the second is the probability of order fulfillment at that price within a given time window. This is because quotes are not binding and, most likely, only a fraction of the order will be filled at the quoted price. To the degree that the investor values certainty and speed of the execution on the full order, it would want to reach out to the dealer that has the best understanding of "where the bodies are buried," and this is where the underwriter (JPMorgan) comes into focus again. (Note that the identity of the underwriter is on display on the same screen together with quotes throughout the life of the bond.) In other words, the information about the initial demand and placement of the bond in this decentralized OTC market gives the underwriter a private insight that is relevant to the investors in the secondary market. This is likely to diminish over time, but anecdotally this appears to persist for a few years.

We can provide some evidence for this account by examining dealers' activity in the European Central Bank's (ECB) Corporate Sector Purchase Programme (CSPP). The data we use is proprietary and includes trade-by-trade details for all trades executed by the Eurosystem from June 2016 to March 2017 (with the Eurosystem being the buyer). The starting sample contains 637 bonds; after removing those without an issue date, we are left with 569 ISINs. For each bond, we construct a variable that measures the share of the total CSPP bond volume that was intermediated by a given dealer. Bond underwriter information comes from Bloomberg. We identify as underwriters the banks that held the role of "lead manager" or "book runner" during the bond issue.

The results of our analysis are presented in Table 3. In the first two columns, the explanatory variable of interest is an indicator of whether the dealer is also the bond underwriter. The hypothesis is that—even though we are looking at the secondary market—the transaction volume leans towards bonds underwritten by the dealer. Consistent with this hypothesis, we find that, on average, dealer banks have about 25% higher transaction volume in bonds where they were also the underwriter, compared to transaction volumes in bonds underwritten by other banks. In column (3), we include interaction terms indicating whether the bond was outstanding for less than a year, or one to three years since issuance. Although the special role of the underwriter fades over time, even for bonds that have been outstanding for two or three years, the differential effect is substantial and statistically significant. For bonds outstanding up to a year, we see that underwriters intermediate 56% of the CSPP volume (statistically significant at the 1% level). This is also consistent with the underwriter's bond holdings. We observe that the underwriter holds about 75% more inventory than other dealers. This decreases over time, reaching about a 40% higher inventory four quarters after placement.

[TABLE 3]

The fact that the underwriter plays a significant role as a dealer in the secondary market helps us ensure that individual dealer constraints matter. However, a remaining concern is that the choice of dealers might be consequential and could potentially be influenced by the dealer's balance sheet constraints. To overcome this issue, we instead rely on a firm's past choices of bond underwriters and the fact that underwriting relationships tend to be "sticky." This has been documented for other financial segments. For example, Drucker and Puri (2005) show that in 45% of follow-up stock offerings, issuers keep the same underwriter

(57% for deals with previous concurrent lending, which is the focus of their study). However, let's not assume that this will be generalizable to the bond market as there are several reasons why it might not be, and instead, we should look at it directly.

Figure 3 presents the probability that an issuer chooses the same lead bond underwriter as the one used in the past. In any given year (T), we take firms that issue bonds, and we consider firms that also issued a bond one year ago (T-1). Looking at the firms that issued a bond at T and T-1, we create a variable that takes on the value of 1 if the firm used the same lead underwriter, and 0 otherwise. We then average this across all issuers. We repeat this exercise for up to 10 years in the past, that is, from T-1 to T-10. The overall sample covers the period from 2001 to 2017. Figure 3 displays the time-series average, and the 95% confidence bounds for bonds issued between 2008 and 2017. The result indicates that in about 46-50% of cases, firms use the same lead underwriter as they used 1-3 years ago. The relevant benchmark is a random choice from a potential pool of underwriters that could be at least as large as 9 (the number of large broker-dealers in our sample). As Figure 3 shows, the stickiness of the choice of underwriters decays over time, but even 10 years out, it is about 30%, and for issues 5 years out, it is 40%.

[FIGURE 3]

The persistence in bond underwriting relationships could be a result of search costs, although it is unlikely that search costs are high in this context. It could also be a result of proprietary information production. Indeed, certification is one of the fundamental roles performed by underwriters. In connection with this, Drucker and Puri (2005), and Gande, Puri, Saunders, and Walter (2015) emphasize the information production synergies between underwriting and lending. To be clear, it is less important for our analysis what exactly leads to issuer-underwriter stickiness, as long as there is a switching cost. Overall, the idea is that we can rely on *past* underwriting relationships to filter bond-dealer pairings which were unlikely to have been influenced by the bank's capacity under the leverage ratio. Past relationships therefore are a source of quasi-exogenous assignment. Typically, we designate a bond to a dealer bank based on the lead underwriter's role. In instances where there are multiple lead underwriters, we compute the constraint—both weighted and unweighted by dealer size—as an average of the dealers' balance sheet constraints.

Examining the constraints of dealer banks, this part of our analysis focuses on the constraints at the individual bank level, utilizing dealer distances to the regulatory leverage ratio requirement as a measurement. The distribution of this measurement is presented in Table 2, Panel B. The top of the table features dealer banks engaged in the sovereign bond purchase program, while the bottom pertains to those serving as dealers in the corporate purchase program. We provide summary statistics for two key periods: the end of 2019, just before the global outbreak of the COVID-19 pandemic, and prior to the implementation of the leverage ratio at the end of 2013. It's noteworthy that while the latter period includes leverage ratios for the non-dealer banks, the former period excludes this as, for our 2020 analysis of fund runs, we are solely focusing on the constraints of dealer banks. Ultimately, the conclusions drawn in this paper are robust when considering different dealer specification.

3.3. Fund-level dealer exposure

We observe mutual funds' holdings from the *Refinitiv Lipper* database. Specifically, we look at corporate bond mutual funds.[11] We further condition the sample to funds with at least 15% investment in the euro area. In reality, funds appear to have geographically concentrated portfolios. Therefore, imposing a 15% filter leads to the average fund in our sample holding 75% euro area investments. Figure A.1 in the Appendix shows the distribution of euro area holdings for funds in our sample. We cannot simply use the fund’s domicile as most funds are registered in Ireland, Luxembourg, or the Cayman Islands for tax reasons.

When using domestic dealers as the relevant match, we can easily assign a

[11] defines bond mutual funds as funds that invest at least 65% of their assets in corporate bonds.

constraint measure for most of the bonds in the portfolio. For the 2020 analysis, the slack under the leverage ratio is measured as of December 2019 since this information is reported quarterly. We then aggregate this measure of illiquidity based on banks' balance-sheet capacity at the mutual fund level. To do so, for each fund, we use bond portfolio weights from Lipper as of January 31, 2020, that is, the weights before the COVID shock. This enables us to rank mutual funds based on their exposure to the lack of depth in liquidity due to dealers' balance sheet constraints.

Similarly, when using bond underwriter constraints, a bond is matched to the past underwriter. In the case where there is more than one underwriter (constraint) associated with a bond, we take the average. Naturally, it is substantially harder to assign an underwriter to a bond than the country of issuance; data availability is an important issue. On average, we have underwriter constraints for 31% of funds' corporate bond portfolio.

4. Leverage ratio and bond liquidity

The connection between increased bond illiquidity and dealer's constraints is at the center of the economic mechanism studied in this paper. Thus, we start by reviewing the existing evidence on the impact of post-GFC bank regulatory requirements on bond liquidity, and re-examine this evidence in the European context.

As mentioned in the introduction, there is little aggregate evidence on the reduction of overall bond market liquidity leading up to 2020. On the one hand, Dick-Nielsen and Rossi (2019) find that the price of immediacy for corporate bonds in the U.S. has more than doubled after 2008. But on the other hand, Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018) show that while bank-affiliated dealers decreased their "capital commitment" in U.S. corporate bond markets, nonbank dealers (unaffected by regulations) have increased their market commitments. Similarly, Choi, Huh and Shin (2023) point out that after the GFC, customers, rather than dealers, increasingly provided liquidity in bond trades, so dealer's inventory capacity only mattered for those trades in which dealers were providing liquidity. Anderson and Stulz (2017), Trebbi and Xiao (2019), Adrian, Fleming, Shachar, and Vogt (2017) find only limited evidence of a deterioration in market liquidity, with the latter concluding that "the postcrisis stagnation of dealer balance sheets has not markedly impaired bond market liquidity."

To the best of our knowledge, Adrian, Boyarchenko, and Shachar (2017) is the only earlier paper that generalizes to the European context and directly addresses dealers' constraints. (For example, Bao, O'Hara, and Zhou (2018) specifically study the consequences of the Volcker Rule implementation, which is not applicable to European banks.) Therefore, given the lack of a conclusive verdict on the connection between regulatory changes and bond liquidity and its generalizability outside of the Volcker Rule, it suggests that it would be helpful to examine whether we find a similar effect on bond liquidity in our setting. In a contemporaneous paper to ours, Haselmann, Kick, and Vig (2022) also pursue this idea using German data. To look at the connection between bank compliance with the minimum leverage ratio on bond liquidity, we examine bond liquidity two years before (2012:Q1-2013:Q4) and two years after (2014:Q1-2015:Q4) December 31, 2013. This is the date when European banks were required to report their leverage ratio to their supervisor for the first time as a part of the Comprehensive Assessment exercise, the first standardized euro area-wide assessment of the health of bank balance sheets. (Discussions on why this might be a reasonably robust empirical approach are provided in Appendix A.) We estimate the following regression:

$$Bid\text{-}ask\ spread_{i,t} = \alpha_1 Bank\ constraint_i * Post_t + \delta_i + X_{i,t} + \cdots + \epsilon_{i,t} \quad (1)$$

where i identifies the bond and t the date. The $Bid\text{-}ask\ spread_{i,t}$ is the daily bid-ask spread, which is our measure of illiquidity. It is commonly used as a central measure of bond illiquidity (e.g., Falato, Goldstein, and Hortaçsu, 2021.) The $Bank\ constraint_i$ is the dealers' constraint measured as distances to their required leverage ratios as of the end of 2013. We expect smaller slack under the leverage ratio to lead to lower liquidity, which means higher bid-ask spread; i.e., the predicted sign (after the constraint comes into effect) is negative. $Post_t$ is a dummy variable equal to 1 for the period following December 31, 2013 (the first time banks calculated and reported their regulatory leverage ratio to their supervisor), and 0 otherwise. The overall sample period for the first set of tests is 2012:Q1 through 2015:Q4 – a two-year window before and after the leverage ratio becomes binding. The regression also includes bond fixed effects (δ_i), and bond time-varying characteristics ($X_{i,t}$), namely its remaining maturity.

Table 4 shows the regression result of the impact of the leverage ratio regulation on corporate bond market liquidity by focusing on the domestic banks that were dealers in the corporate bond purchasing program. Our main explanatory variable is Bank Constraint. Overall, we have nine countries. The average distance to regulatory requirement ranges from 1.07 to 1.14 percentage points. In columns (1) to (3) we gradually introduce bond-level and time fixed effects. Column (4) controls for bond remaining maturity. As mentioned earlier, one concern with focusing on domestic banks is that changes in bond liquidity might be reflecting country-level factors, albeit such factors would have to be contemporaneous to the leverage ratio implementation schedule. To moderate this concern, in column (5) we introduce a range of country-level time varying measures. Performance of local equity markets, volatility index, and the yield curve are statistically significant. However, the coefficient measuring the shift in bond liquidity is robust to these controls. The estimate of -0.08 indicates that for countries where banks are one percentage point closer to the regulatory requirement (about one standard deviation, according to Table 2, Panel A), the bid-ask spread is 8 basis points higher. This is a sizable margin, considering the average bid-ask spread in our sample is 59 basis points, with the median standing at 37 basis points. In sum, these results underscore the notable impact of leverage ratio regulations on bond market liquidity. This suggests that regulatory requirements can increase the bid-ask spread, thereby implying a decrease in liquidity, particularly in countries where banks are closer to the regulatory thresholds and - as we will show next – also for bonds whose underwriter is relatively more leverage-constrained.

Figure 4 shows point estimates for individual quarters. The solid line in Figure 4 depicts the point estimates, and the dashed lines depict the corresponding 95% confidence band. This figure illustrates a significant and permanent shift in bond liquidity based on how binding the leverage constraint for domestic dealers is.

Figure 5 re-examines the result in Table 4 by credit rating group. This test is aimed at reinforcing that we are measuring the effect of leverage ratio. The idea is that if banks are less likely to engage in low margin activities as a result of compliance with the minimum leverage ratio, it should have a higher impact on less risky bonds.[12] Risk-weighted capital requirements, or demand for liquidity pushes banks to hold safer bonds instead. Consistent with the idea that the leverage ratio is the binding constraint, there is a ranking in the impact on different rating categories, with AAA rated bonds affected the most.

[TABLE 4 & FIGURES 4-5]

The results of the analysis using past underwriting relationships as an alternative connection between bonds and banks are reported in Table 5. We find nearly 90 underwriters in our sample. Because underwriters also act as dealers, we no longer need to rely on the purchase programs data to identify dealer banks. The structure of Table 5 is exactly the same as Table 4; however, a different methodology for mapping bonds and banks leads to a different sample of the bonds.

The estimated coefficient is economically large, robust, and statistically significant. If the bond dealer with existing underwriting ties is one percentage point closer to the regulatory requirement, the bid-ask spread of the bond increases by 4 basis points (about 6.8% of the mean).

[12] Acosta Smith, Grill and Lang (2020) and Choi, Holcomb and Morgan (2020) document that the leverage ratio incentivizes banks to shift their portfolio to riskier assets, but it does not increase overall bank risk.

[TABLE 5]

Overall, these results indicate a plausible relationship between regulatory changes, and in particular the leverage ratio, and bond liquidity. The results by ratings and the timing of the effect suggest that the mechanism operates through the leverage ratio. However, we acknowledge that there may be other factors at play that could be correlated with the slack under the leverage ratio constraint and are consistent with these auxiliary results. That being said, in the following sections, we test a specific theoretical mechanism that impacts bond funds through liquidity. Therefore, any alternative explanation would need to comply not only with the results in this section but also with the results discussed below.

5. Bond liquidity and 2020 mutual fund outflows

The onset of the COVID-19 pandemic represents a clear instance when mutual funds faced the pressure of fund outflows. Importantly, there is plenty of evidence that—at least in the initial stage of the pandemic crisis—this was a liquidity shock to the firms (e.g., Li, Strahan, and Zhang, 2020). In the US market, Falato, Goldstein, and Hortaçsu (2021) analyze large capital outflows from corporate bond mutual funds following the outbreak of the pandemic, arguing that both the illiquidity of fund assets and the vulnerability to fire sales were important factors in explaining redemptions during this episode.

Figure 6 shows that a similar panic took place in Europe. In this figure, daily flows are calculated as:

$$Flows_{i,t} = (TNA_{i,t} - (1 + r_{i,t}) * TNA_{i,t-1}) / TNA_{i,t-1} \quad (2)$$

where $TNA_{i,t}$ is the total net assets of fund i at day t, and $r_{i,t}$ is the fund's daily return. Figure 6 also shows that—similar to the U.S. market—extraordinary central bank interventions in corporate-bond markets mark the reversal of the fund outflows (Breckenfelder and Hoerova, 2021). The earliest vertical dashed line depicts the date of the ECB announcement of the Pandemic Emergency Purchase

Program (PEPP) on March 18, 2020. The program initially established a purchase envelope of EUR 750 billion, which was expanded to EUR 1,850 billion by December 2020. This included purchases of corporate bonds, a practice the ECB has been implementing under its Corporate Bond Purchase Program since 2016. The first purchases under the PEPP program commenced on March 26, 2020, as indicated by the second vertical line in Figure 6.

Given that our focus is on the role of bank balance sheet constraints on mutual fund sell-off pressure, we build on the cross-sectional variation in bond exposure to dealers' constraints. We classify mutual funds with above median exposure values as funds with illiquidity exposure. It's worth reiterating that we are not measuring bond liquidity directly, but instead, we measure the dealers' slack under the leverage ratio for a given bond. In this analysis, the dealers are assigned to the bonds based on the country of the issuer.

The blue line in Figure 6 depicts the average change in market value (Panel A) and change in fund flows (Panel B) for mutual funds that are relatively more exposed to constrained dealers, and the red line represents these values for funds that are relatively less exposed to constrained dealers. Leading up to March 2020, all funds closely tracked each other in terms of valuations and fund flows, but the COVID-19 shock resulted in a decoupling, with funds exposed to banks with lower balance sheet capacity emerging as particularly affected. At the peak of the crisis, the performance differential between the two groups of funds reached 4 percentage points, while the outflow differential amounted to 2 percentage points. This observation is consistent with the notion that fund fragility and fund illiquidity are inherently linked. Promising high liquidity to investors while holding illiquid assets can trigger a run-like dynamic among investors, inciting them to withdraw before others (Chen, Goldstein, and Jiang 2010; Goldstein, Jiang, and Ng, 2017).

[FIGURE 6]

In Table 6, we estimate the following regression:

$$\Delta\, Bond\ holdings_{k,t} = \alpha_1 Illiquidity\ exposure\ _k * COVID\ shock_t + \delta_k\ +\ \epsilon_{k,t} \quad (3)$$

where $\Delta\, Bond\ holdings_{k,t}$ is the monthly (t) change in holdings of bonds by mutual fund k. We look at selling behavior by rating category. In this analysis, we look at the first three month of 2020; *COVID shock* is equal to 1 for March and to 0 otherwise. δ_k are fund fixed effects.

[TABLE 6]

The results in Table 6 align with our hypothesis, showing that funds with more significant exposure to illiquidity due to banks' market-making constraints had to sell their positions more extensively. The effect is primarily observed among bonds with AAA-AA ratings. Column (3) in Table 6 indicates that holdings of the safest bonds by the more exposed funds declined by approximately 5 percentage points more than the other funds, dropping from an average of about 23% of holdings in the most liquid securities to around 18%. This finding is consistent with literature suggesting that the mass selling of the safest securities by funds in March 2020 led to disruptions in rather liquid markets, such as those for Treasury bonds and investment-grade corporate bonds (Vissing-Jorgensen, 2021; Haddad, Moreira, and Muir, 2021).

This notion becomes even more evident when considering the underwriter-bond connection rather than the country-bond connection. In Table 7, we measure bank constraints based on the bond underwriter's constraint. Understandably, it is significantly more challenging to assign an underwriter to a bond than to identify the country of issuance. In total, we have 732 funds holding 1,373 individual bonds, each assigned a leverage ratio slack based on past underwriting relationships. The unit of observation is fund-bond-month, and we examine the log differences of the nominal allocation to individual liquid bonds. The findings align with those in Table 6 and support the hypothesis that bond funds with greater exposure to illiquidity due to banks' market-making constraints sold more of their holdings, especially their safer bonds. Table 7, column (3), indicates that funds reduced their holdings of the safest bonds by 5 percentage points. Interestingly, in addition to finding that the most liquid bonds (AA-AAA rated bonds) were liquidated, we also find that other investment-grade rated bonds (BBB-A) were liquidated as well, albeit to a smaller extent of 3.7 percentage points (column (6)). By contrast, holdings of non-investment grade bonds were not reduced. While the home advantage specification allows us to classify the entire mutual fund portfolio, the underwriter classification does not. However, it does enable us to examine all classified bonds and their average reduction relative to the remainder of the portfolio (the total weights do not add up to 100 as in the home advantage specification). We observe a decline in bonds we could classify of 3.5 percentage points, suggesting that, on an individual bond basis, we tend to classify better-rated bonds more often. This is intuitive as lower-rated bonds do not necessarily have a bond rating to begin with.

[TABLE 7]

In sum, despite significant methodological differences between the home advantage and the underwriter relation setups, we find very similar results: mutual funds more exposed to bank balance sheet constraints liquidate their liquid positions more than those less exposed. The underwriter methodology also reveals that the more liquid (better-rated) the bonds are, the more mutual funds tend to reduce such holdings.

6. Conclusion

Mutual fund runs in the U.S. and Europe in 2020 put unprecedented pressure on the bond market and culminated in sweeping policy interventions designed to stabilize the markets on both sides of the Atlantic. Much of this dynamic is rooted in the expansion of retail investing in the bond market and the illiquidity of the bond asset class. In that sense, some of what we have seen would have unfolded regardless of the bank regulatory changes that followed the Great Financial Crisis. However, for over a decade leading up to the 2020 episode, there has been a concern that bank regulatory adjustments, and the leverage ratio in particular, have impacted bond liquidity by raising the cost of expanding bank balance sheets. Hence, we are interested in understanding how much bank balance sheet constraints for market making have added to mutual fund instability and sell-off pressure.

We shed new light on this question by exploring persistent connections between bonds and individual dealers formed through home bias and previous underwriting relationships. Building on these connections, we are able to show that the introduction of a leverage ratio for European banks had a large impact on exposed bond liquidity. Using the same connections, we show that during the 2020 run episode, mutual funds with larger exposures to bank balance sheet constraints faced bigger redemptions and sell-offs, especially of the safest bonds.

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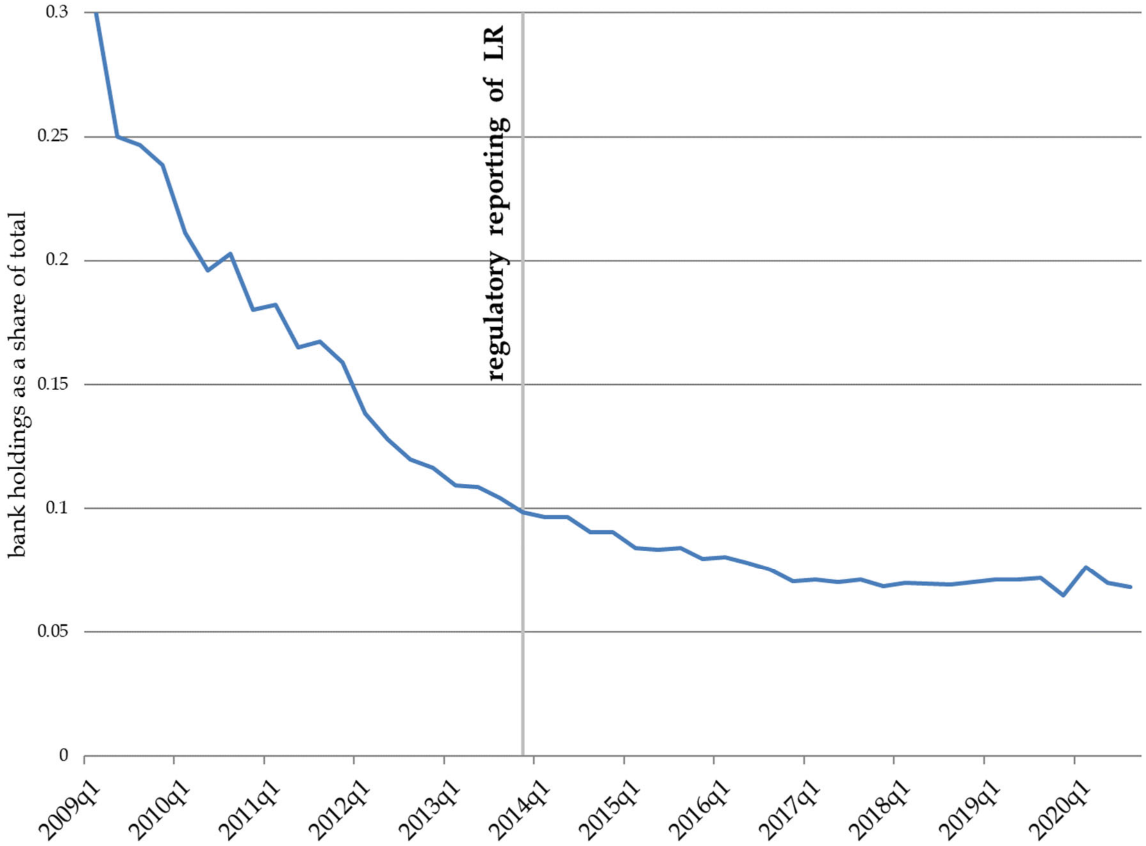
FIGURE 1 – BANK HOLDINGS OF NON-FINANCIAL CORPORATE BONDS

This figure gives average bank holdings of non-financial corporate bonds (share of total, Panel A) as well as holdings of non-financial corporate bonds by all investors, the banking sector and the investment fund sector (EUR bn, Panel B). The figure is compiles using ECB Security Holdings Statistics (SHS).

Panel A: Average bank holdings of corporate bonds (share of total)



Panel B: Total, banking and investment fund sector holdings of corporate bonds (EUR bn)

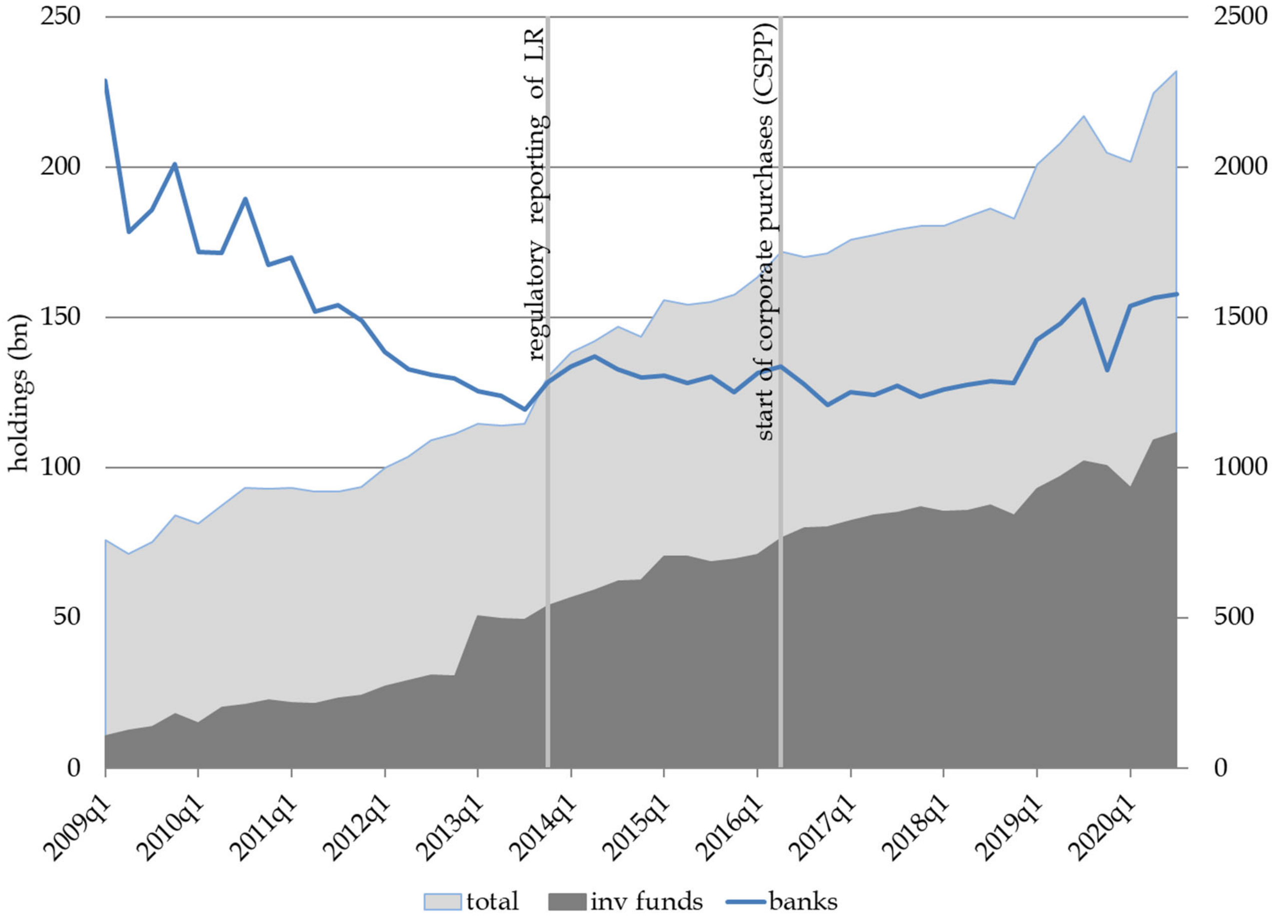


FIGURE 2 – LEVERAGE RATIO OF LARGEST DEALER BANKS OVER TIME

This figure depicts the regulatory leverage ratio of the largest euro area dealer banks from 2013 q4 to 2020 q1. The thick grey line is the regulatory target for large banks in Europe.

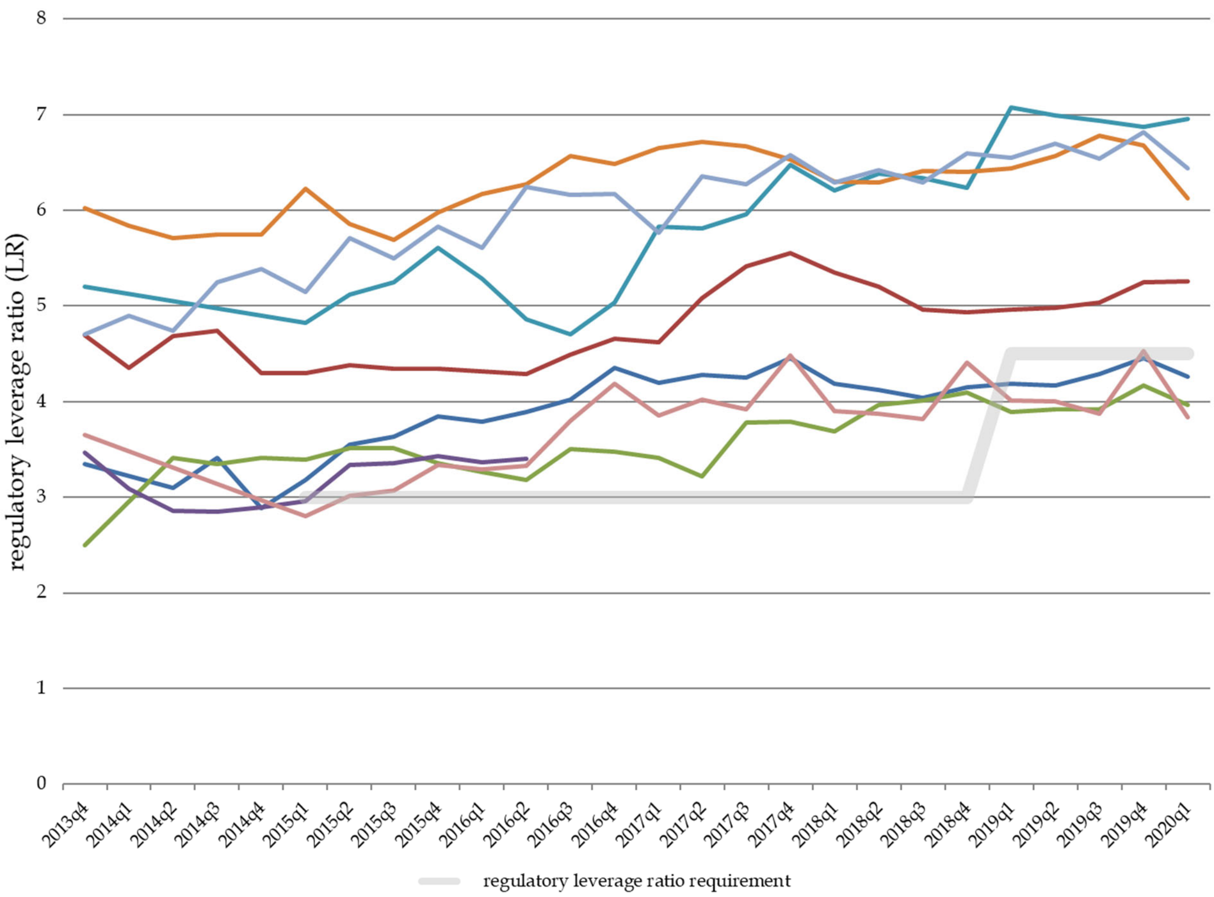


FIGURE 3 – PERSISTENCE OF BOND UNDERWRITING RELATIONSHIPS

This figure presents probability that a company picks the same lead bond underwriter as the one it used in the past. The overall sample corresponds to 2001-2017. As an example, in year 2017, we look at firms that also issued a bond in 2016 (1 year back) and assign a value of 1 if the firm used the same lead underwriter, and 0 otherwise. We then take an average across all issuers for 2017. We repeat this exercise for up to 10 years in the past, which in this example would mean for years 2016 (1 year back) through 2007 (10 years back). At the end we have these series for firms with bond issues between 2008 and 2017. The figure plots the average across the years and the corresponding 95% confidence intervals.

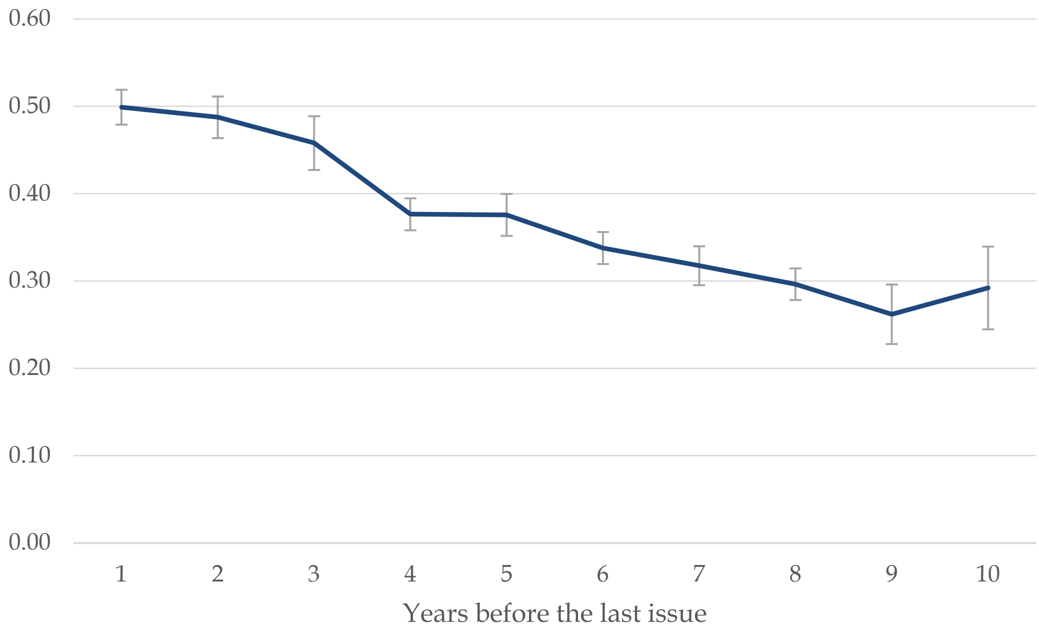


FIGURE 4 – THE LEVERAGE RATIO AND THE BOND MARKET LIQUIDITY

The figure shows the main regression result of the impact of the leverage ratio regulation on corporate bond market liquidity. The graph gives the point estimates for quarterly distances around the first time banks calculated and reported their leverage ratio to their supervisor. The regression specification is as follows:

$$Bid\text{-}ask\ spread_{i,t} = \sum_{t=2012:Q1}^{2015:Q4} \alpha_{1,t}\, BankConstraint_I * Quarter_t + Controls + \epsilon_{i,t},$$

where i is bond and t is days. The $Spread_{i,t}$ is bid-ask spreads; the $Bank\ Constraint_I$ is the dealers' constraints in the issuer's domestic country measured as distances to their required leverage ratios as of the end of 2013. The regression also includes firm fixed effects, country- and security-specific time-varying controls. The y-axis gives the spread change relative to the period prior to the event depending on the distance to the regulatory leverage constraint. The solid line depicts the point estimates and the dashed lines the corresponding 95% confidence band. Standard errors are clustered at bond level.

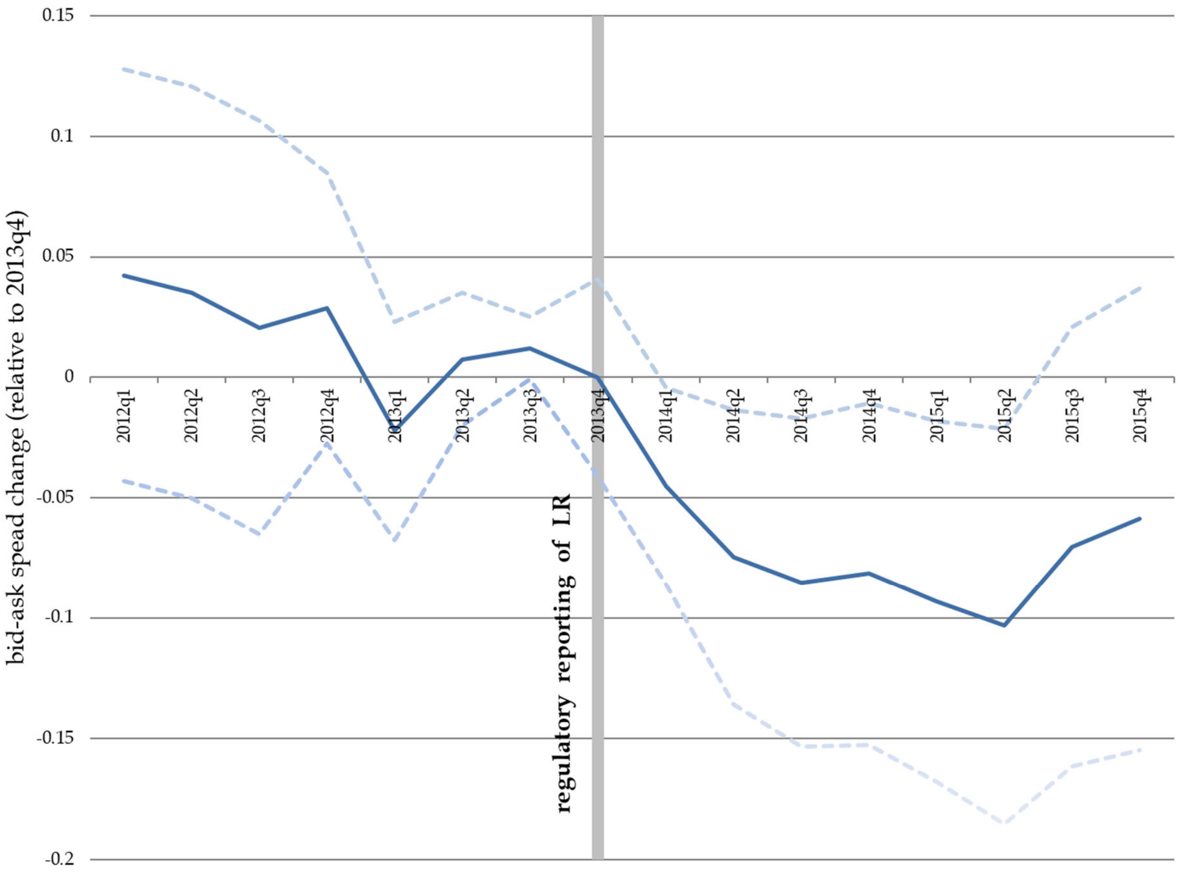


FIGURE 5 – DIFFERENTIAL IMPACT OF BOND RATINGS

The figure shows the regression result of the impact of the leverage ratio regulation on corporate bond market liquidity for different bond ratings. We re-run the same regression as in column (3) but using more granular rating groups. The solid diamonds depict the point estimates and the dashed lines the corresponding 95% confidence band. Standard errors are clustered at bond level.

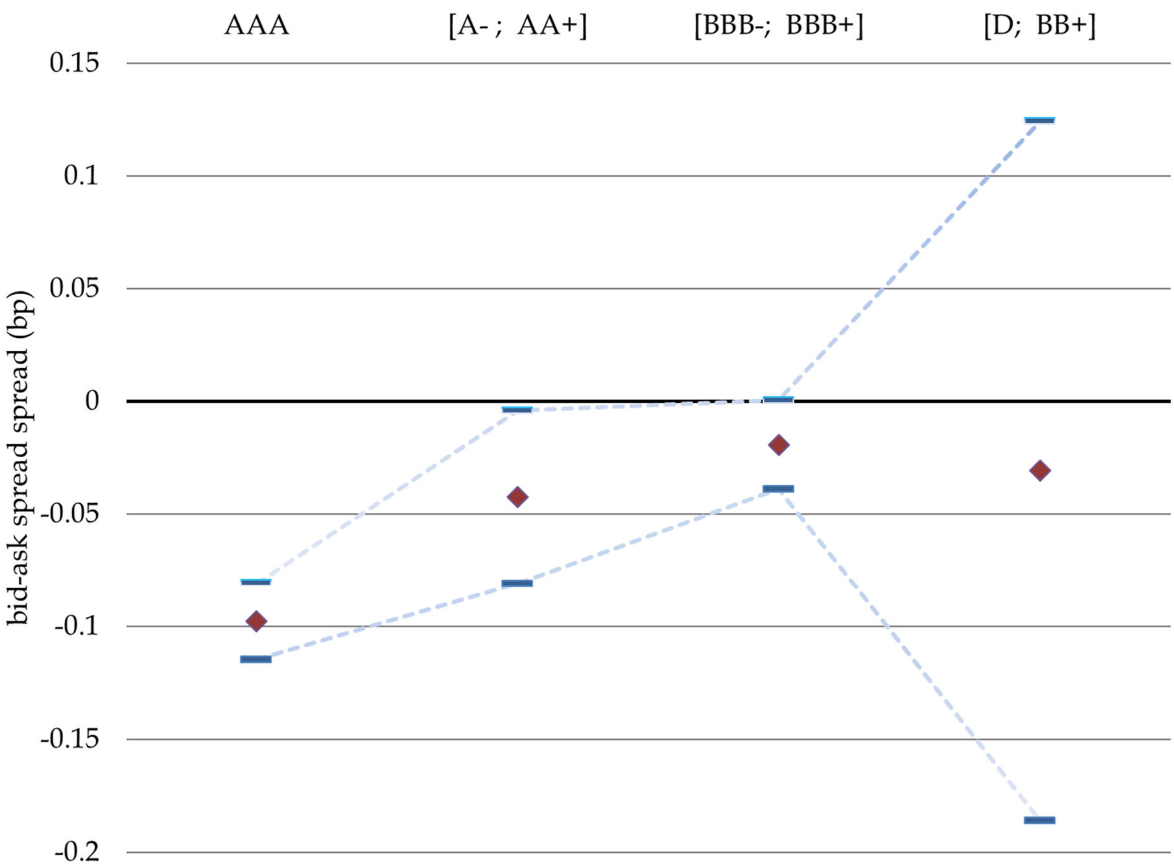


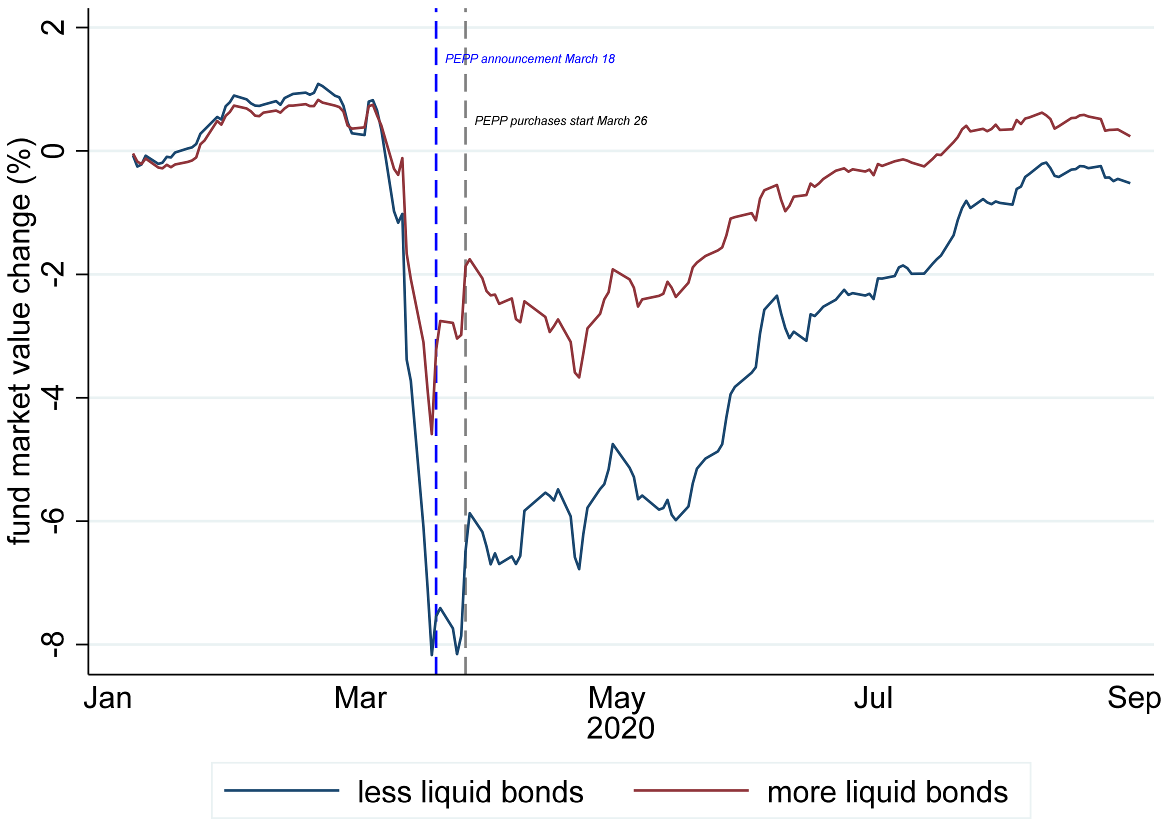
FIGURE 6 – MUTUAL FUND VALUE AND FLOW

This figure gives the evolution of corporate bond mutual funds value (Panel A) and flows (Panel B) before and after the COVID-19 shock. The novel result is the difference in fund value and outflows depending on their holdings of bonds exposed to illiquidity through dealers' balance sheet. The blue line depicts average flows of corporate bond mutual funds that are relatively more exposed to "illiquid" bonds and the red line gives average flows of mutual funds that are relatively less exposed to "illiquid" bonds. Daily flows are calculated as:

$$Flows_{i,t} = (TNA_{i,t} - (1 + r_{i,t}) * TNA_{i,t-1}) / TNA_{i,t-1}$$

where $TNA_{\mathrm{i,t}}$ is total net assets of fund i at day t and $r_{i,t}$ is the fund's daily return. The vertical dashe lines depict the announcement and beginning of the ECB's Pandemic Emergency Purchase Program (PEPP).

Panel A. Changes in corporate bond fund market value



Panel B. Changes in corporate bond fund flows

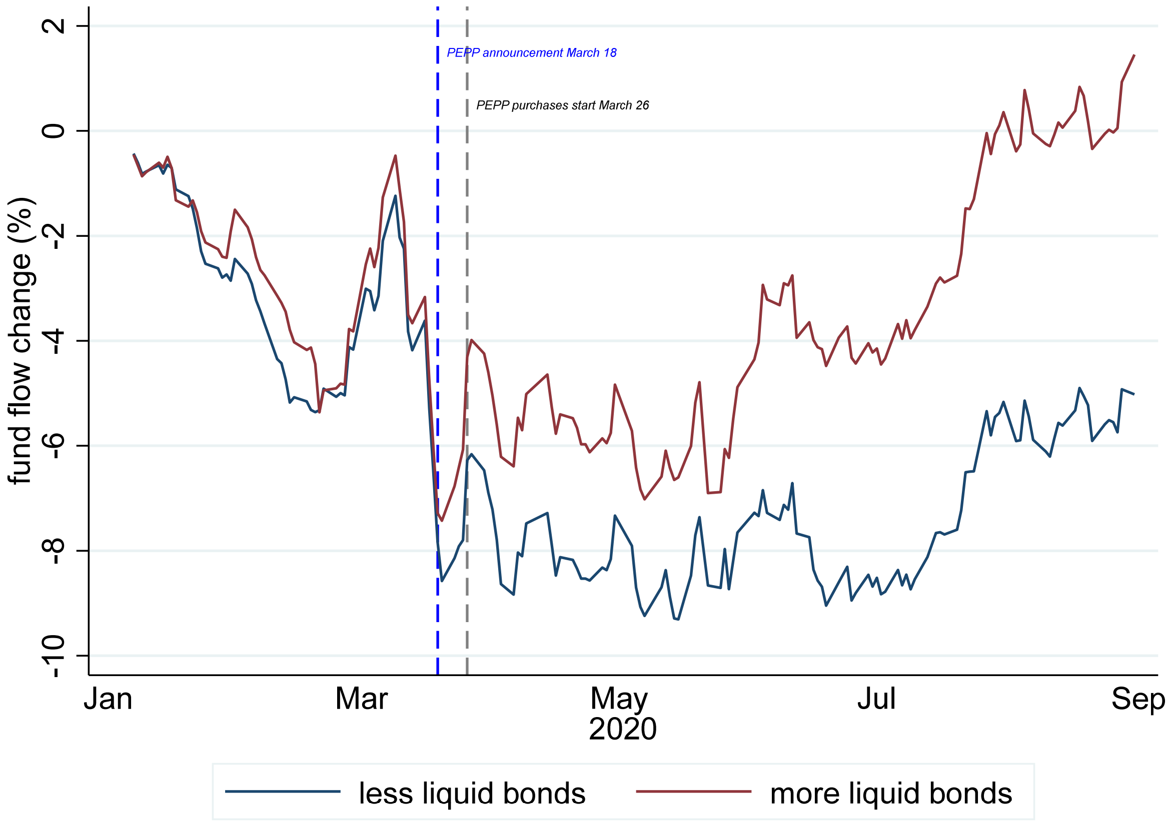


TABLE 1 – DOMESTIC CONCENTRATION OF CORPORATE BOND HOLDINGS

This table shows summary statistics of corporate bond holdings over time. Domestic concentration and largest foreign country concentration (shares of total holdings) are reported as quarterly means and standard deviations. *** indicate significance at the 1% level.

	Home dealers		Foreign dealers (largest)				
Date	Mean	SD	Mean	SD	Diff		Obs.
2009q1	0.612	0.009	0.043	0.003	0.569	***	2,436
2009q2	0.573	0.010	0.044	0.003	0.530	***	2,176
2009q3	0.650	0.009	0.034	0.002	0.616	***	2,498
2009q4	0.642	0.009	0.033	0.002	0.609	***	2,587
2010q1	0.639	0.009	0.031	0.002	0.608	***	2,664
2010q2	0.653	0.008	0.032	0.002	0.621	***	2,852
2010q3	0.647	0.008	0.032	0.002	0.615	***	3,070
2010q4	0.646	0.008	0.029	0.002	0.617	***	3,275
2011q1	0.648	0.008	0.031	0.002	0.617	***	3,237
2011q2	0.616	0.008	0.031	0.002	0.586	***	3,071
2011q3	0.591	0.008	0.034	0.002	0.557	***	2,864
2011q4	0.589	0.009	0.030	0.002	0.559	***	2,810
2012q1	0.586	0.008	0.028	0.002	0.558	***	2,909
2012q2	0.573	0.008	0.028	0.002	0.545	***	2,937
2012q3	0.522	0.009	0.030	0.002	0.492	***	2,771
2012q4	0.510	0.009	0.028	0.002	0.482	***	2,839
2013q1	0.493	0.008	0.018	0.001	0.476	***	2,903
2013q2	0.474	0.008	0.019	0.001	0.455	***	2,897
2013q3	0.486	0.008	0.020	0.001	0.466	***	2,999
2013q4	0.465	0.008	0.021	0.001	0.444	***	3,120
2014q1	0.476	0.008	0.021	0.001	0.455	***	3,434
2014q2	0.463	0.008	0.022	0.001	0.442	***	3,484
2014q3	0.457	0.007	0.022	0.001	0.435	***	3,757
2014q4	0.447	0.008	0.019	0.001	0.428	***	3,156
2015q1	0.460	0.008	0.018	0.001	0.442	***	3,404
2015q2	0.467	0.008	0.018	0.001	0.449	***	3,508
2015q3	0.476	0.008	0.017	0.001	0.459	***	3,600
2015q4	0.464	0.008	0.018	0.001	0.446	***	3,349
2016q1	0.486	0.008	0.017	0.001	0.469	***	3,544
2016q2	0.476	0.008	0.017	0.001	0.459	***	3,560
2016q3	0.471	0.008	0.016	0.001	0.455	***	3,696
2016q4	0.451	0.008	0.016	0.001	0.435	***	3,564
2017q1	0.468	0.007	0.016	0.001	0.453	***	3,851
2017q2	0.468	0.007	0.016	0.001	0.452	***	3,813
2017q3	0.463	0.007	0.016	0.001	0.447	***	3,793
2017q4	0.459	0.007	0.018	0.001	0.442	***	3,642
2018q1	0.485	0.007	0.017	0.001	0.467	***	3,974
2018q2	0.498	0.007	0.017	0.001	0.481	***	4,088
2018q3	0.530	0.007	0.016	0.001	0.513	***	4,461
2018q4	0.517	0.007	0.017	0.001	0,500	***	4,251
2019q1	0.540	0.007	0.017	0.001	0,523	***	4,672
2019q2	0.553	0.007	0.016	0.001	0,526	***	4,909
2019q3	0.549	0.007	0.019	0.001	0,530	***	4,933
2019q4	0.525	0.007	0.020	0.001	0,505	***	4,596

TABLE 2 – BANK CONSTRAINTS

This table reports baseline summary statistics for the regulatory leverage ratio and bank constraints measured as the distance to the regulatory requirement. For country-level bank constraints (Panel A), we consider four alternative ways of aggregating the data: (i), weighted by total assets, (ii), weighted by dealers' trading volume under the CSPP, (iii), largest dealer bank by CSPP trading volume in a country, (iv), two largest dealer banks by CSPP trading volume in a country. Panel B shows statistics for dealer banks and non-dealer banks.

Panel A. Country-level bank constraints (distance to the leverage ratio requirement)

			Dealer banks (2020:Q4)		Dealer banks (2013:Q4)	
		Obs.	Mean	SD	Mean	SD
Dealer banks: Banks acting as dealers in the corporate bond purchase program						
Country-level variable construction:						
(i)	Weighted by assets	9	0.99	1.00	1.08	0.81
(ii)	Weighted by trading volume	9	1.04	1.02	1.14	0.95
(iii)	Top-1 dealer	9	1.05	1.07	1.07	1.14
(iv)	Top-2 dealers	9	1.04	1.01	1.12	0.99
Dealer banks: Banks acting as dealers in the sovereign bond purchase program						
Country-level variable construction:						
(i)	Weighted by assets	15	1.71	1.59	1.96	1.55
(ii)	Weighted by trading volume	15	1.71	1.51	1.93	1.48
(iii)	Top-1 dealer	15	1.68	1.43	1.76	1.59
(iv)	Top-2 dealers	15	1.66	1.42	1.86	1.51

TABLE 2 – BANK CONSTRAINTS (CONT.)

Panel B. Dealer-level constraints

	Obs.	Mean	SD	5th %	95th %
Dealer banks: Banks acting as dealers in the sovereign bonds purchase program					
2019:Q4					
Leverage ratio	36	5.79	1.77	3.93	9.10
Distance to requirement	36	1.29	1.77	-0.57	4.60
2013:Q4					
Leverage ratio	41	4.67	1.72	2.70	7.78
Distance to requirement	41	1.67	1.72	-0.30	4.78
Non-dealer banks	75	3.41	8.95	-0.85	8.62
Dealer banks: Banks acting as dealers in the corporate bonds purchase program					
2019:Q4					
Leverage ratio	14	5.21	0.99	3.93	6.82
Distance to requirement	14	0.71	0.99	-0.57	2.32
2013:Q4					
Leverage ratio	14	3.87	0.97	2.38	6.03
Distance to requirement	14	0.87	0.97	-0.62	3.03
Non-dealer banks	78	1.94	2.68	-1.03	5.34

TABLE 3 – BOND UNDERWRITERS AND SECONDARY MARKET BROKER-DEALER ACTIVITIES

The goal of this table is to illustrate that the bond underwriters (primary dealers) continue to play a special role in the secondary market. The sample consists of trades executed by the Eurosystem from June 2016 to March 2017 as part of the corporate bond purchase program. Unit of observation is bond-dealer. The dependent variable is the fraction of the total transaction volume that was intermediated by a given dealer. In the first two columns, the explanatory variable of interest is an indicator of whether the dealer is also bond underwriter. In column (3), we include interaction terms indicating whether the bond was outstanding for less than one year, or one-to-three years from issuance. Standard errors are clustered at dealer bank level. ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively.

Dependent variable	Share of transaction volume		
	(1)	(2)	(3)
Dealer bank is underwriter	0.248***	0.252***	-0.093
	(0.076)	(0.075)	(0.120)
Underwriter * <1 year from issuance	--	--	0.557***
			(0.203)
Underwriter * 1≤…<3 years from issuance	--	--	0.234*
			(0.119)
Log(amount outstanding)	-0.088**	-0.090**	-0.091**
	(0.043)	(0.043)	(0.044)
Fixed effect: Dealer/Years from issuance	Yes/--	Yes/Yes	Yes/Yes
Obs.	4,137	4,137	4,137
R-squared	0.0379	0.0387	0.0428

TABLE 4 – IMPACT OF THE LEVERAGE RATIO ON BOND MARKET LIQUIDITY

This table shows the main regression result of the impact of the leverage ratio regulation on corporate bond market liquidity. The regression specification is as follows:

$$Bid\text{-}ask\ spread_{i,t} = \alpha_1 Bank\ constraint_I * Post_t + \delta_i + X_{i,t} + \cdots + \epsilon_{i,t}$$

where i is the bond, t is the date, the $Bid\text{-}ask\ spread_{i,t}$ is the measure of bond liquidity, the $Bank\ constraint_I$ is the bank constraint of country I (calculated as the weighted averages of broker dealer distances to their required leverage ratios), $Post_t$ is a dummy variable (1 for indicating the period after the first time banks calculated and reported their regulatory leverage ratio to their supervisor and 0 otherwise). δ_i are bond fixed effects and $X_{i,t}$ is bond remaining maturity, i.e., its time-varying characteristic. Standard errors are clustered at bond level. ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively.

Dependent variable	Bid-ask spread				
	(1)	(2)	(3)	(4)	(5)
Bank constraint x Post	-0.099***	-0.062***	-0.055**	-0.055**	-0.080***
	(0.032)	(0.022)	(0.022)	(0.022)	(0.019)
Post	0.034	-0.073***	--	--	--
	(0.032)	(0.018)			
Bank constraint	0.041	--	--	--	--
	(0.035)				
Residual bond maturity	--	--	--	0.012	-0.004
				(0.021)	(0.023)
Δ Log(Local GDP)	--	--	--	--	0.201
					(0.159)
Δ Log(Local equity index)	--	--	--	--	0.586***
					(0.203)
Δ Log(Local bank index)	--	--	--	--	-0.119*
					(0.064)
Δ Log(Local volatility index)	--	--	--	--	1.472***
					(0.419)
Δ Log(Local government spread, 10Y)	--	--	--	--	-0.201***
					(0.043)
Δ Log(Local government spread, 5Y)	--	--	--	--	0.264***
					(0.085)
Δ Log(Local government spread, 3Y)	--	--	--	--	-0.065
					(0.043)
Δ Log(Local government spread, 1Y)	--	--	--	--	-0.138***
					(0.041)
Fixed effects: Bond	--	Yes	Yes	Yes	Yes
Fixed effects: Day	--	--	Yes	Yes	Yes
Obs.	1,368,161	1,368,161	1,368,161	1,368,161	1,033,192
R-squared	0.0017	0.8003	0.8050	0.8050	0.7486

TABLE 5 – IMPACT OF UNDERWRITERS' LEVERAGE RATIO ON BOND MARKET LIQUIDITY

In this table, instead of looking at the dealers' leverage ratio constraint at the country level, we look at the constraint of the bond underwriter. The regression specification is as follows:

$$Bid\text{-}ask\ spread_{i,t} = \alpha_1 Bank\ constraint_i * Post_t + \delta_i + X_{i,\,t} + \cdots + \epsilon_{i,t}$$

where i is the bond, t is the date, and the $Bid\text{-}ask\ spread_{i,t}$ is the measure of bond liquidity. The main change is the granularity and definition of the $Bank\ constraint_i$. Specifically, we look at the leverage ratio as of 12/31/2013 for the main underwriter/primary dealer bank identified using a two-year window (2010-2011). As before, $Post_t$ is a dummy variable (1 for indicating the period after the first time banks calculated and reported their regulatory leverage ratio to their supervisor and 0 otherwise). δ_i are bond fixed effects and $X_{i,\,t}$ is bond remaining maturity, i.e., its time-varying characteristic. Standard errors are clustered at bond level. ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively.

Dependent variable	Bid-ask spread				
	(1)	(2)	(3)	(4)	(5)
Bank constraint x Post	-0.050	-0.032**	-0.031**	-0.032**	-0.040**
	(0.035)	(0.014)	(0.014)	(0.014)	(0.017)
Post	0.198	0.033	--	--	--
	(0.199)	(0.075)			
Bank constraint	-0.005	--	--	--	--
	(0.019)				
Residual bond maturity	--	--	--	0.010	-0.039
				(0.030)	(0.071)
Δ Log(Local GDP)	--	--	--	--	0.387
					(0.503)
Δ Log(Local equity index)	--	--	--	--	-0.761*
					(0.423)
Δ Log(Local bank index)	--	--	--	--	0.361*
					(0.212)
Δ Log(Local volatility index)	--	--	--	--	1.724
					(1.538)
Δ Log(Local government spread, 10Y)	--	--	--	--	-0.005
					(0.103)
Δ Log(Local government spread, 5Y)	--	--	--	--	0.415*
					(0.215)
Δ Log(Local government spread, 3Y)					-0.300
					(0.184)
Δ Log(Local government spread, 1Y)					-0.128*
					(0.075)
Fixed effects: Bond	--	Yes	Yes	Yes	Yes
Fixed effects: Day	--	--	Yes	Yes	Yes
Obs.	141,417	141,417	141,417	138,037	138,037
R-squared	0.0058	0.8375	0.8423	0.8434	0.8460

TABLE 6 – IMPACT OF DEALER BANKS' LEVERAGE RATIO CONSTRAINTS ON FUND SELLS, DOMESTIC DEALERS

This table shows regression results examining how leverage-ratio constrained dealer banks impact fund sell-offs during the start of the COVID-19 crisis. Analysis considers euro area corporate bond mutual funds. The unit of observation is fund*month. The core sorting variable is *Illiquidity exposure* which sorts funds into those above the median (equal to 1) and below the median (equal to 0) exposure to constrained dealers. The dependent variable is change in holdings of "liquid" bonds:

$$\Delta Bond\ holdings_{k,t} = \alpha_1 Illiquidity\ exposure_k * COVID\ Shock_t + \delta_k + \epsilon_{k,t}$$

where $\Delta\ Bond\ holdings_{k,t}$ is the monthly (t) change in holdings of mutual fund k. In columns (1)-(6) we look at sales of "liquid" bonds, that is bonds matched to dealers The variable δ_k are fund fixed effects. Standard errors are clustered at the fund level. ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively.

Dependent variable	Change in bond holdings								
	[AA - AAA]			[BBB - A]			[below BBB]		
Sample (funds)	Exposed	Less exposed	All	Exposed	Less exposed	All	Exposed	Less exposed	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Illiquidity exposure * COVID Shock	--	--	-0.051**	--	--	0.014			0.009
			(0.025)			(0.010)			(0.016)
COVID Shock (March 2020)	-0.061***	-0.006	-0.007	0.008	-0.008	-0.008	0.024**	0.012	0.012
	(0.016)	(0.020)	(0.020)	(0.006)	(0.008)	(0.008)	(0.009)	(0.013)	(0.012)
Fund cash position	0.001	-0.009**	-0.005*	-0.012***	-0.004***	-0.008***	-0.007***	0.001	-0.003*
	(0.005)	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Fixed effect: Fund	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2,109	1,377	3,486	2,109	1,377	3,486	2,109	1,377	3,486
R-squared	0.6227	0.5798	0.6084	0.5362	0.6119	0.5649	0.6117	0.5918	0.6006

TABLE 7 – IMPACT OF DEALER BANKS' LEVERAGE RATIO CONSTRAINTS ON FUND SELLS, UNDERWRITERS

Similar to Table 6, this table shows regression results examining how leverage-ratio constrained dealer banks impact fund sell-offs during the start of the COVID-19 crisis. The difference is that here we use underwriter level constraints. Analysis considers euro area corporate bond mutual funds. The unit of observation is fund*month*security. Standard errors are clustered at the fund portfolio level. Otherwise, the specifications are the same as in Table 6. ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively.

Dependent variable	Change in bond holdings									
	[AA - AAA]			[BBB - A]			[below BBB]			
Sample (funds)	Exposed	Less exposed	All	Exposed	Less exposed	All	Exposed	Less exposed	All	Full sample
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Illiquidity exposure * COVID Shock	--	--	-0.050**	--	--	-0.037**	--	--	-0.026	-0.035***
			(0.022)			(0.019)			(0.029)	(0.012)
COVID Shock (March 2020)	-0.044**	0.001	0.003	-0.080*	-0.043	-0.043	-0.045	-0.016	-0.017	-0.034
	(0.022)	(0.021)	(0.020)	(0.041)	(0.042)	(0.042)	(0.057)	(0.038)	(0.039)	(0.035)
Fund cash position	0.012	-7.665	-4.952	-0.030	-0.289	-0.056	0.050	-0.350	0.024	-0.038
	(0.403)	(7.935)	(4.448)	(0.033)	(0.303)	(0.045)	(0.118)	(0.298)	(0.117)	(0.039)
Fixed effect: Fund/Bond/Rating	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/Yes/-	Yes/ - /Yes
Obs.	598	248	858	14,835	5,194	20,078	4,672	3,064	7,767	28,776
R-squared	0.3738	0.4047	0.3315	0.1753	0.4030	0.2487	0.1880	0.0965	0.1663	0.2005

APPENDIX

A. Bond Liquidity Before and After Leverage Ration Introduction

Ideally, the introduction of the leverage regulation would be isolated and unexpected. Alas, that is not the case, as the Basel Committee first indicated that it planned to introduce a leverage ratio in a consultation document in 2009 and proposed a 3 percent target in 2010 (BCBS, 2009 and 2010). Figure A.1 below gives an overview of the implementation of different policy and regulatory measures, including the timeline of the regulatory leverage ratio across the European Union, the United Kingdom, and the U.S. Overall, our results are unlikely to be impacted by the ECB purchasing programs; as Figure A.1 illustrates, these programs took place at a later stage: the sovereign bonds purchase program (PSPP) starts in March 2015, over one year and three months after the leverage ratio becomes binding, and the corporate bonds purchase program (CSPP) starts in mid-2016 and is outside of the analysis window. However, we cannot rule out that regulatory measures other than the leverage ratio were at play. The EU introduced a package of capital requirements directives, in July 2013.[13] This was the third set of amendments to the original banking directive which transposed Basel III recommendations into EU law, which set out the rules for calculating capital requirements and reporting and general obligations for liquidity requirements.

There are also reasons to believe that over the period of our analysis, the leverage was the binding constraint. Following the Comprehensive Assessment, several banks with low leverage ratio were asked to develop a plan to improve their slack. The capital plans provided by banks fed into the Supervisory Review and Evaluation Process for purposes of calculating their capital requirements.[14] Ultimately, the numbers were disclosed to the public, with the message that the

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[13] This package known as CRD IV included Directive 2013/36/EU and Regulation (EU) N° 575/2013.

[14] For more details on the ECB's Comprehensive Assessment see Breckenfelder, J. and B. Schwaab, 2019, "Bank to sovereign risk spillovers across borders: Evidence from the ECB's Comprehensive Assessment," Journal of Empirical Finance 49, 247-262.

steps toward compliance are on the way but still faced substantial public scrutiny. In contrast, the phasing-in of the liquidity coverage ratio (LCR) was gradual: banks started reporting the ratio to supervisors in 2014, but this number was not made public. LCR became 60% binding as of October 2015 and phased in to 100% by 2018.

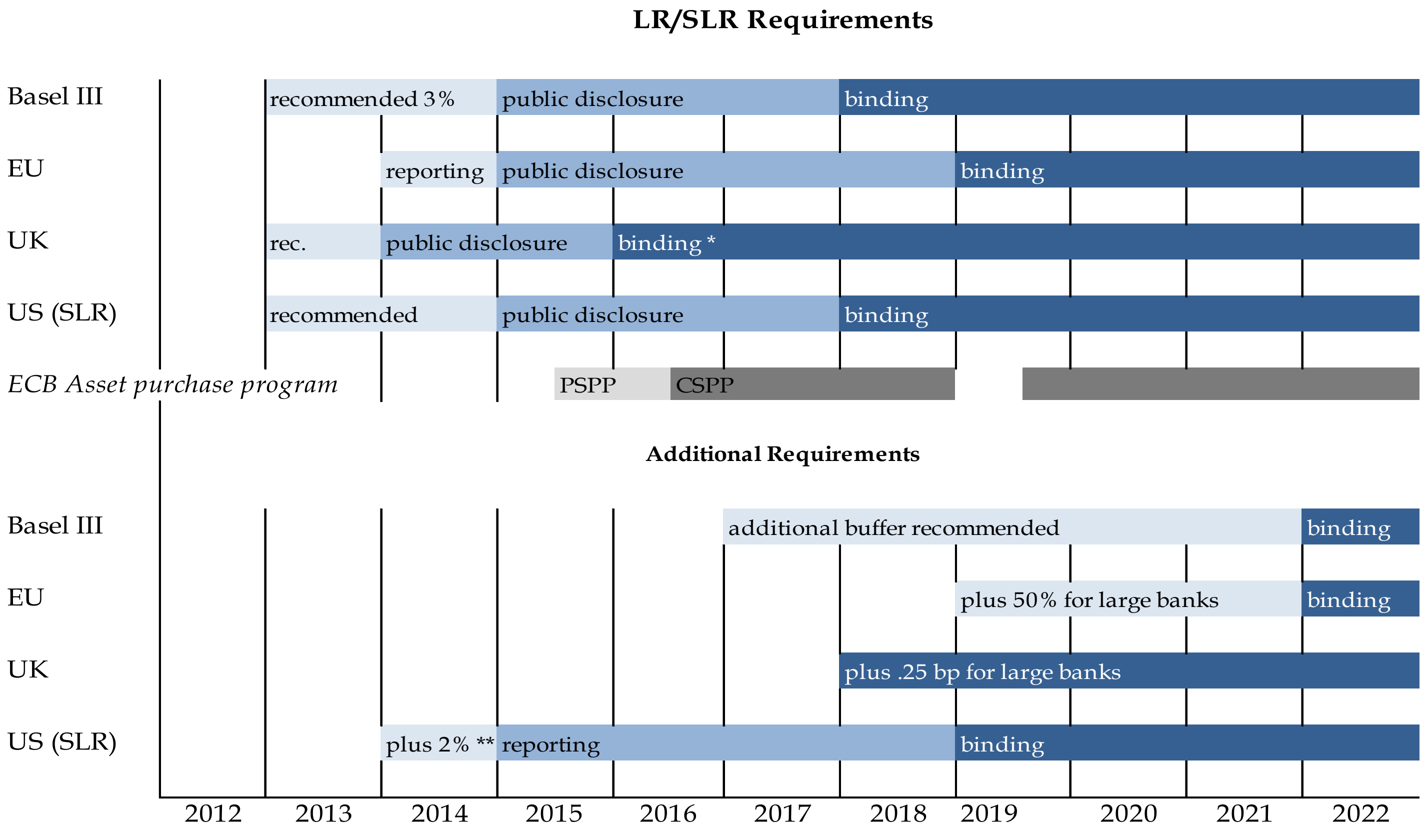
It is also relevant to recall that at the end of 2013, European banks were under substantial stress.[15] In fact, the Comprehensive Assessment for which the regulatory leverage ratio had to be submitted was a one-off exercise of unprecedented scope and granularity, aimed at achieving the goals of establishing transparency on the condition of bank balance sheets and restoring confidence in the European banking sector.[16] Thus, banks did not have much capacity to prepare for regulatory compliance.

[15] Mario Draghi's famous "whatever it takes" speech which sets the recovery phase for the euro area dates back to July 26, 2012, and bond purchase programs were not implemented until 2015.

[16] The results of the Comprehensive Assessment and the capital plans provided by banks fed into the Supervisory Review and Evaluation Process (SREP) for purposes of calculating capital requirement.

FIGURE A.1 – LEVERAGE RATIO IMPLEMENTATION TIMELINE

This figure gives an overview of the implementation timeline for the regulatory Leverage Ratio (LR) across the European Union, the United Kingdom, and the United States. The figure shows both the baseline requirement of 3 percent and additional LR requirements across regulatory jurisdictions. The grey bars depict the Eurosystem Asset Purchase Programs, the Public Sector Purchase Program (PSPP) and additionally the Corporate Sector Purchase Program (CSPP). (*) The UK leverage ratio requirements (quarterly reporting) were reported as monthly averages, but as of January 2018 as daily averages. (**) Fed's rule is for US top-tier bank holding company (SLR 5%) with more than 700 billion dollars in consolidated assets or more than 10 trillion in assets under custody and for IDI subsidiaries (SLR 6%) of covered BHCs.



B. Additional Tables and Figures

FIGURE B.1 –EURO AREA FUND HOLDINGS

This figure gives the distribution of the share invested in the euro area by bond funds in the sample.

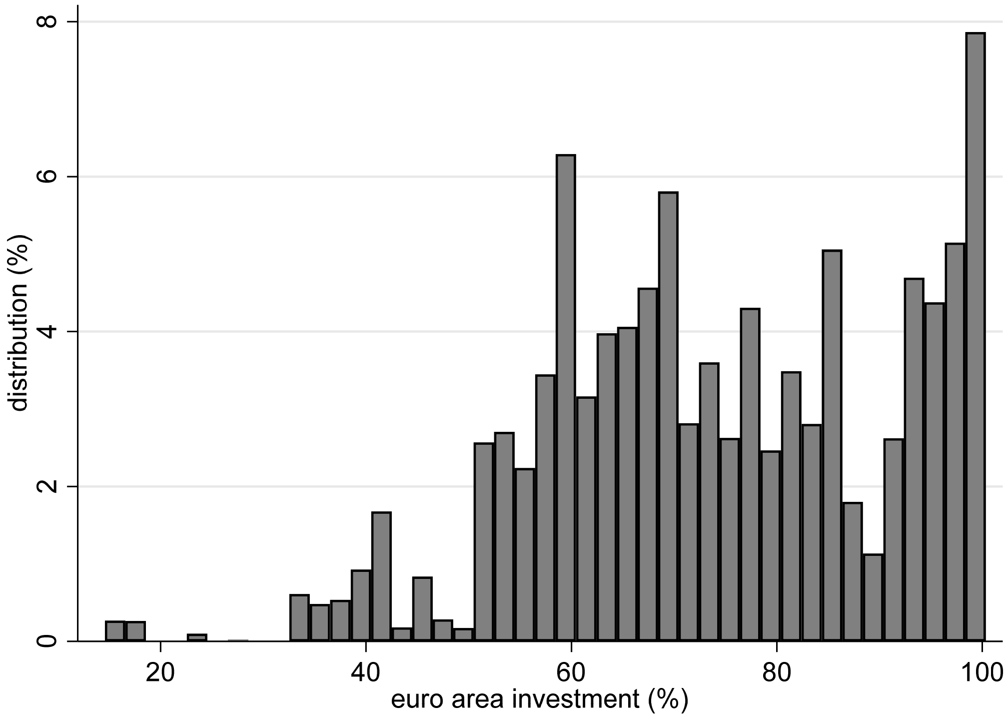


TABLE B.1 – IMPACT OF THE LEVERAGE RATIO ON BOND MARKET LIQUIDITY, SURVIVING BONDS

This table re-examines results in Table 4, specifications (3) and (5) for a subset of bonds that are outstanding for a minimum of (i) two years before and two years after the event (December 31, 2013), i.e., full sample; (ii) one year before and one year after the event; and (iii) six months before and six months after the event.

Sample (bonds)	Minimum bond survival around event					
	2 years		1 year		6 months	
	(1)	(2)	(3)	(4)	(5)	(6)
Bank constraint x Post	-0.065**	-0.076***	-0.091***	-0.094***	-0.060***	-0.084***
	(0.027)	(0.023)	(0.022)	(0.019)	(0.021)	(0.019)
Residual bond maturity	--	0.025	--	0.010	--	0.002
		(0.036)		(0.032)		(0.027)
Macro controls (Table 4, column (5))	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects: Bond /Day	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes
Obs.	460,391	382,005	809,886	614,309	982,446	751,676
R-squared	0.7309	0.6995	0.8605	0.7059	0.8489	0.7232

TABLE B.2 – IMPACT OF UNDERWRITERS' LEVERAGE RATIO ON BOND MARKET LIQUIDITY

This table shows robustness of results in Table 5 to the use of an alternative window for detecting core underwriting ties. In Table 5, we use a two-year window (2010-2011) to look at other bond issues. Here, we look at a three-year window (2010-2012) instead. Everything else is the same. Standard errors are clustered at bond level. ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively.

Dependent variable	Bid-ask spread				
	(1)	(2)	(3)	(4)	(5)
Bank constraint x Post	-0.056**	-0.054**	-0.054**	-0.054**	-0.053**
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Post	0.099	0.091	--	--	--
	(0.108)	(0.108)			
Bank constraint	0.044	--	--	--	--
	(0.036)				
Residual bond maturity	--	--	--	0.013	0.022
				(0.032)	(0.035)
Δ Log(Local GDP)	--	--	--	--	0.415
					(0.255)
Δ Log(Local equity index)	--	--	--	--	0.195
					(0.268)
Δ Log(Local bank index)	--	--	--	--	-0.135
					(0.135)
Δ Log(Local volatility index)	--	--	--	--	0.355
					(0.454)
Δ Log(Local government spread, 10Y)	--	--	--	--	-0.119*
					(0.065)
Δ Log(Local government spread, 5Y)	--	--	--	--	0.157
					(0.253)
Δ Log(Local government spread, 3Y)	--	--	--	--	-0.108
					(0.238)
Δ Log(Local government spread, 1Y)	--	--	--	--	-0.025
					(0.047)
Fixed effects: Bond	--	Yes	Yes	Yes	Yes
Fixed effects: Day	--	--	Yes	Yes	Yes
Obs.	181,921	181,921	181,921	180,877	145,718
R-squared	0.0193	0.6684	0.6865	0.6880	0.7086