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Mike Anderson
René M. Stulz

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ABSTRACT

Price-based liquidity metrics are better in 2013-2014 for small trades and large high-yield bond trades, but not for large investment grade bond trades, relative to before the crisis, and are better for all bond types and trade sizes relative to 2010-2012. This evidence contrasts with the widely-held view among practitioners that liquidity has worsened. However, turnover falls sharply after the crisis compared to before the crisis, which is consistent with investors having more difficulty completing trades on acceptable terms and supports the practitioner view. A frequent concern is that post-crisis liquidity could be low when markets are stressed. We consider three stress events: extreme VIX increases, extreme bond yield increases, and downgrades to high yield. We find evidence that liquidity is lower after the crisis for extreme VIX increases. However, we find no evidence that liquidity is worse for idiosyncratic stress events after the crisis than before the crisis. Our results emphasize the importance of considering how liquidity reacts to shocks which can affect financial stability and of taking into account the information from non-price liquidity metrics.

Mike Anderson
4400 University Drive
Enterprise Hall 237
Fairfax , VA 22030
mander19@gmu.edu

René M. Stulz
The Ohio State University
Fisher College of Business
806A Fisher Hall
Columbus, OH 43210-1144
and NBER
stulz@cob.osu.edu

The global financial crisis was followed by many important changes in laws and regulations affecting the financial system. The Basel capital requirements were changed for market risk through Basel 2.5 and then through Basel 3. The Basel framework added liquidity requirements. U.S. banks were also affected by Dodd-Frank. These changes impacted the return of market-making activities and, in the case of the Volcker rule, potentially limited such activities. Further, investment banks also became subject to Basel capital requirements through acquisitions or conversion to bank holding company status. As a result, it has become more costly for them to hold risky securities. With such changes, we would expect the provision of market-making services to have fallen and for banks to be especially reluctant to hold riskier bonds on their books. A decrease in the provision of market-making services should lead to an increase in the cost of trading and a decrease in liquidity.

Though lower participation in market-making activities by dealers should reduce liquidity, markets have evolved since the crisis to make matching buyers and sellers more efficient and new sources of liquidity have appeared and grown. Electronic trading for corporate bonds has become more important. For instance, the percentage of trading volume of investment grade corporate bonds on electronic platforms doubled between 2013 and 2016 and, in early 2016, more than 1,700 corporate bonds had two-way quotes on electronic platforms almost every day.[1] Pre-trade transparency has increased sharply. Buy-side firms have become more active as liquidity providers. All-to-all platforms, which enable the buy-side to offer liquidity, have become more important. Hence, it could be that, while traditional large dealers are not providing as much liquidity as they used to, changes in the structure of markets and technological progress have offset the change in their behavior to some extent.

In this paper, we investigate whether liquidity in the corporate bond market has fallen and whether it has fallen more for bonds for which regulatory changes have made the provision of market-making services especially more costly. We first consider traditional metrics of bond market liquidity, namely a price pressure measure (the Amihud illiquidity measure), the effective bid-ask spread, the cost of a roundtrip

[1]See "Remarks at the North American Electronic Bond Trading Forum," by Jonathan S. Sokobin, FINRA.

transaction, turnover, the number of trades per day, and the percentage of days without trades. If regulatory changes decreased liquidity, we would expect our metrics to worsen as these changes took effect, but much more so for the riskier bonds. The opposite seems to have taken place for price-based metrics. We find that, while our metrics provide evidence that liquidity is worse using these metrics over the period 2010-2012 relative to before the crisis, these metrics are marginally better than before the crisis for the period 2013-2014. In other words, liquidity measured using price-based metrics improved as the regulatory changes were implemented. Further, the regulatory changes that were implemented since the crisis should have had a more adverse impact on riskier bonds, as these changes, at least early on, increased capital requirements more for riskier bonds. Yet, the evidence surprisingly shows that liquidity metrics have improved for such bonds, but some metrics have worsened for investment grade bonds.[2]

A fundamental difficulty with measuring liquidity is that price-based measures only capture liquidity for completed trades. When a bond's liquidity is poor, an investor on average must offer a higher premium to buy the bond or accept a larger discount to sell the bond. As a result, some investors will not trade in order to avoid the higher trading cost resulting from lower liquidity. These trades that do not take place do not show up in price-based liquidity metrics and hence do not worsen these metrics. However, when trades are no longer executed because of a decrease in liquidity, turnover is lower, which we observe in the data. Turnover is sharply lower after the crisis compared to its pre-crisis level and is lower in 2013-2014 than in 2010-2012. This evidence is surprising in light of the increase in the number of trades per day and the decrease in the number of days without trading we document. We call this the turnover puzzle, in that more trades and somewhat better price-based liquidity metrics would predict higher turnover, not lower. To reconcile the increase in the number of trades with the decrease in turnover, trade size must have fallen.

[2] Such a result could be understood if the marginal capital requirement for banks is the leverage ratio, as this ratio makes it relatively more expensive to hold safe assets. A 3% supplementary leverage ratio was put in place in 2013 for the institutions with more than $250 billion in assets or more than $10 billion in on-balance sheet foreign exposure. In 2014, an enhanced supplementary leverage ratio was finalized for the 8 US G-SIBs. The implementation of this supplementary leverage ratio starts after the end of our sample period and does not become fully effective until January 1, 2018. See "Why are big banks offering less liquidity to bond markets?" by Darrell Duffie, Forbes, March 11, 2016, for the impact of the supplementary leverage ratio on dealers.

Hence, the drop in turnover is not due to investors trading less often, but rather is due to investors trading smaller quantities. Such an outcome makes sense in an inventory model of dealer activities where holding inventory has become more expensive (Stoll (1979)). Hence, investors find it more difficult to successfully complete trades on acceptable terms. Other explanations unrelated to changes in liquidity can potentially help explain this evidence, but the findings cannot be explained by a common decrease in turnover for equity and bond markets because, contrary to bonds, the same turnover measure increases for the equity market. Further, the findings on turnover cannot be explained by a general decrease in turnover for bonds in that turnover measured using small trades decreases only by a small amount. The evidence on turnover helps resolve the paradox that practitioners generally find that liquidity has deteriorated while price-based metrics failing to show a systematic worsening of liquidity as the regulations are implemented.

A concern that is often expressed by practitioners is that liquidity may be abundant under normal market conditions but could quickly evaporate during stress days. For instance, a Deutsche Bank analyst is quoted as saying that "Even if liquidity is decent a lot of the time, the problem is it is effectively non-existent during periods of market stress."[3] Stress days could be days when dealers must bear a substantial amount of risk to provide liquidity. Under the new regulations, they may no longer be able or willing to bear such risk, either because the cost is prohibitive or due to outright restrictions. We focus on three different types of stress events. Our approach is to compare liquidity at the bond level for stress events after the crisis to stress events before the crisis. Our first stress event is a systemic event in that we look at days with extreme increases in VIX. The two other stress events are bond-specific. The first bond-specific stress event is an extreme yield increase. The second bond-specific stress event is a selloff associated with the downgrade of a bond from investment grade to high yield.

First, we consider extreme shocks to the VIX index. VIX is often discussed as a crisis indicator or fear index. Large values of VIX indicate high uncertainty. Recent papers find that liquidity is low when VIX is high. Nagel (2012) shows that equity market liquidity moves with VIX. Bao, Pan, and Wang (2011) find

[3] "Everyone is worried about the thing markets need most, but they're not asking the right questions," by Matt Turner, Business Insider, March 20, 2016.

that bond liquidity moves negatively with VIX. Adrian and Shin (2010) argue that the risk-bearing capacity of intermediaries is lower when VIX is high. We define a VIX shock day to be a day with a change in the VIX that exceeds the 95th percentile of changes. We find that large bond trades have a higher impact and the cost of trading is higher on VIX shock days after the crisis than before the crisis. This result suggests that liquidity is less resilient on days of increased systemic risk than it was before the crisis.

We then turn to extreme increases in yield. Our stress event days are all days with yield changes in the top 95th percentile of the distribution of yield changes. We would expect the demand for liquidity to be high on such days, as the yield shock leads investors to reassess their positions, as well as days following the yield shock. We find that the price-based liquidity measures improve after the crisis on the days following a yield shock.

It is well-known that some institutional investors have mandates that require them to sell bonds downgraded from investment grade and that this forced selling can cause bond prices to be temporarily abnormally low (Ambrose, Cai, Helwege, 2012; Ellul, Jotikasthira, Lundblad, 2012). We investigate the impact on liquidity of forced selloffs following downgrades. We use two approaches to identify forced selloffs. The first approach uses bonds which have a large increase in volume on the day of the downgrade and immediately after. The second approach uses, as forced-sale bonds, those bonds where we can identify sales by insurance companies. For these companies, holding such bonds is costly and sometimes prohibited. We find that, immediately after a downgrade, trades in bonds with a high trading volume have a higher price impact. However, there is no evidence that this price impact is higher after the crisis than before. Specifically, the price impact is significantly lower in 2010-2012 than before the crisis and insignificantly lower in 2013-2014. When we use bonds sold by insurance companies as bonds with forced sales, we find that the price pressure measure for these bonds from the day of the downgrade to 10 days later increases after the crisis, so that trades of these bonds have a higher price impact after the crisis than before compared to other downgraded bonds. However, the price impact of downgrades in general falls after the crisis, so that even the bonds sold by insurance companies have a lower price impact after the crisis than before despite the fact that their price impact increases relative to the price impact of other downgraded bonds. As a result, irrespective of our approach, downgraded bonds do not have a higher price impact after the crisis than before.

There is a rapidly growing literature on the evolution of liquidity in the corporate bond market since the crisis. This literature uses a number of different approaches and reaches different conclusions. The literature examining price-based liquidity metrics generally reaches the conclusion that liquidity is poor during the crisis but eventually reverts to similar or better levels than before the crisis. None of these papers addresses explicitly the turnover puzzle that turnover falls sharply while price-based liquidity metrics, the number of trades, and the fraction of days with trade all improve. Adrian, Fleming, Shachar, and Vogt (2016) document a decrease in dealer balance sheets but they conclude that their price impact measure falls to a level well below the level before the crisis and that there is "ample liquidity" in the bond market. Trebbi and Xiao (2015) using time-series methods fail to find breaks in an extensive set of liquidity metrics for corporate bonds associated with the implementation of the regulatory reforms. They conclude that "If anything, we detect evidence of liquidity improvement during periods of regulatory interventions, possibly due to the entry of non-banking participants." Bessembinder, Jacobsen, Maxwell, and Venkataraman (2016) provide evidence on transaction costs and volume from 2002 to early 2015. They show that transactions costs increase sharply with the crisis but then improve and keep improving after the implementation of Dodd-Frank. However, they also conclude that the market quality has worsened in that dealers commit less capital to trades and that this phenomenon is heightened on days when customer trading volume is high. Choi and Huh (2016) show that non-dealers provide more liquidity, which could mistakenly lead to the conclusion that transaction costs have fallen. The corporate bond market is closely tied to the CDS market. It is therefore interesting to note that Loon and Zhong (2014) conclude that Dodd-Frank reduces transaction costs and improved liquidity on the index CDS market.

In contrast to these studies that fail to find evidence of a deterioration in liquidity despite in some cases documenting important changes in dealer activities, two studies find evidence of a deterioration. These studies focus on specific events rather than on estimating liquidity metrics in normal times. Dick-Nielsen and Rossi (2016) consider index exclusions, which is a time when institutional investors who track indices would require immediacy as they would have to sell the excluded bonds. They find that the price of immediacy in these events has doubled for short-term investment grade-bonds and tripled for speculative-grade bonds. Their post-crisis sample period is 2010-2013. Bao, O'Hara, and Zhou (2016) focus on downgrades to non-investment grade as stress events, which is one of our stress events. They show that the price impact associated with such downgrades increases after the crisis relative to their pre-crisis period, but especially so when the Volcker rule comes into effect. They conclude that price impact during such events has increased considerably because of the Volcker rule in that, with that rule, it is as high as during the crisis. They also document that market-making by dealers subject to the Volcker rule has changed in comparison to market-making by dealers not subject to the rule. It is important to note, however, that dealers affected by the Volcker rule are also affected by the contemporaneous implementation of Basel III.[4]

Our paper adds to the studies investigating liquidity metrics by showing price-based metrics improve over time after the crisis and that the improvement is stronger for high yield bonds, but that turnover worsens and does so compared to equity markets. We then investigate how liquidity has changed from before the crisis to after for three types of stress events. We consider two stress events that have not been studied in the literature and one of these allows us to assess liquidity in the presence of systemic stress. Of the two other studies that investigate stress events, our study is closest to the contemporaneous study of Bao, O'Hara, and Zhou (2016). They are heavily focused on the part of their sample which they call the post-Volcker period and define from April 1, 2014, to March 31, 2016. Our sample ends at the end of 2014, so that it overlaps with their post-Volcker period only for eight months, because full data about trades after 2014 is not yet publicly available.

Although the Volcker rule specifically exempts market-making activities, Duffie (2012) rightfully expresses concerns that implementation of the Volcker rule could dissuade dealers from some market-making activities because there is no clear line that makes it possible to distinguish between market-making

[4] See U.S. Basel III Final Rule: Visual Memorandum, July 8, 2013, Davis Polk, for the timetable of the implementation of Basel III.

activities and proprietary trading activities.[5] However, holdings acquired as a result of excess selling following a downgrade would seem justifiable as part of the Volker rule market-making exemption. It is noteworthy that during part of the sample period studied by Bao, O'Hara, and Zhou (2016), one high-yield bond trader at Goldman Sachs had more than $100 million in trading profits providing liquidity on bonds downgraded from investment grade.[6]

Our investigation differs substantially from Bao, O'Hara, and Zhang (2016) in that we focus on downgrades that are accompanied by likely forced sales and compare those to downgrades without likely forced sales. The motivation to focus on downgrades to non-investment grade is that some institutional investors have to sell bonds that experience such a downgrade. However, if a bond is not held by such investors or if these investors sell ahead of the downgrade, there may not be forced selling at the time of a downgrade. Further, the information content of downgrades can plausibly differ depending on the economic environment. Our matching approach also helps control for changes in the information content of downgrades. It is plausible that the information content of downgrades might be different during a credit boom such as the boom before the crisis compared to the post-crisis period. Finally, we use a three-year period before the crisis excluding all of 2007 while Bao, O'Hara, and Zhou (2016) use one and a half years ending in the middle of 2007, thereby focusing on the peak of the credit bubble and excluding the Ford and GM downgrades of 2005. We find that the price impact of downgrades associated with forced sales does not increase in absolute value after the crisis compared to before the crisis. When we use an approach similar to the one used by Bao, O'Hara, and Zhou (2016), we find that the results are sensitive to the choice of the pre-crisis period and that downgrades during their pre-crisis period do not appear to have an impact on liquidity metrics. We compare our approach with Bao, O'Hara, and Zhou (2016) further when we discuss our experiment.

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[5] See Final Volcker Rule, Flowcharts: Prop Trading, Davis Polk, for the complexity of demonstrating that the market-making exemption applies (slide 6).
[6] "How one Goldman Sachs trader made more than $100 million," by Justin Baer, Wall Street Journal, October 19, 2016.

The paper proceeds as follows. In Section 1, we present how we construct our dataset. In Section 2, we show how liquidity metrics evolve after the crisis and compare these metrics to what they were before the crisis. In Section 3, we investigate liquidity on days of large VIX moves. In Section 4, we consider liquidity on days of large yield changes. In Section 5, we show our results for downgrades from investment grade. We conclude in Section 6.

1. Data and liquidity metrics

In this section, we first explain how we construct our dataset and then describe the liquidity measures we use in the analysis.

1.1. Data

Our analysis focuses on two distinct periods. We have a pre-crisis period from 2004 to 2006 and a post-crisis period from 2010 to 2014. Later, we split the post-crisis period into two subperiods, 2010-2012 and 2013-2014.

It is common in the literature to use transaction data from TRACE. However, not all bonds trade and hence not all bonds have transactions in TRACE. To evaluate whether fewer bonds ever trade, we start with the set of corporate bonds available in Mergent's Fixed Income Securities Database (FISD), which we also use to obtain bond characteristics. Over the sample period, we exclude bonds issued by US or foreign governments/agencies (including taxable municipal bonds), pass-through securities, bank notes, preferred securities, and mortgage or asset backed securities issued by US corporations. Additionally, puttable, convertible and insured debt is excluded along with bonds that have warrants, sinking fund provisions, floating rate coupons, and foreign currency denomination. We also drop utilities, 144a issues, bonds in default, and bonds issued as part of unit deals. These filters reduce the sample from 16,562,589 (54,396,776) transactions to 13,389,445 (41,667,535) transactions over the pre-crisis (post-crisis) period.

We obtain bond transaction prices and volume from the Enhanced Trade Reporting and Compliance Engine (ETRACE). These data are cleaned following Dick-Nielsen (2014). ETRACE offers two important advantages over standard TRACE. First, it reports transactions without truncating volume like TRACE which is essential to judge the evolution of volume-based liquidity measures. Second, the buy/sell and agency tags provide enough information to derive an effective bid-ask spread. However, the additional transparency comes with an 18 month lag, which restricts our investigation to a period ending on December 31, 2014.

To contrast liquidity before and after the 2009 crisis, we define pre- and post-crisis periods from Jan. 1, 2004 to Dec. 31, 2006, and Jan. 1, 2010 to Dec. 31, 2014, respectively. There is some arbitrariness in the definition of these periods. While dealers had to report trades to TRACE from the start, public dissemination of trade information took place in phases. By excluding the initial years of TRACE (July 1 2002-Dec. 31, 2003), we avoid changes in liquidity that likely relate to the first two phases of the implementation of public dissemination of trades on TRACE (see Bessembinder Maxwell, and Venkataraman, 2006; Edwards, Harris, and Piwowar, 2007; and Goldstein, Hotchkiss, and Sirri, 2006). The last phase of TRACE added 9,558 bonds to public dissemination on October 1, 2004, and an additional 3,016 bonds on February 2005.[7] The bonds added in the last phase tend to be high-yield or infrequently traded bonds. The bonds added in February 2005 are bonds that trade infrequently and which have delayed disclosure for trades in excess of $1 million if their rating is BB or below. We want a pre-crisis period which is unaffected by tremors of the crisis. Our post-crisis period starts after credit spreads have fallen back to pre-crisis levels.

Using the FISD and remaining ETRACE data, we define three samples. The "FISD" sample represents our benchmark bond universe. On each day of the sample period, we apply the bond filters described above to active bonds in the FISD database. Bonds are active after the issue date but before maturity or before their amount outstanding goes to zero, whichever comes first. This sample provides insight into the question of whether bonds are less likely to trade in the post-crisis period. For the majority of the analysis, we focus on the "TRACE" subsample which includes all bond transactions that appear in ETRACE after filtering. For this sample, we consolidate trades taking place at the same time and remove other transactions that

[7] See Asquith, Covert, and Pathak (2013).

appear to be due to recording errors. These trading filters further reduce the sample by 1,818,645 and 7,202,616 transactions over the pre-crisis and post-crisis periods respectively.[8] The TRACE sample has 11,570,800 transactions in the pre-crisis period and 34,464,919 transactions in the post-crisis period.

Finally, the "Filtered" sample employs two additional filters that have become popular in the literature (see, for instance, Bao, Pan, and Wang, 2011, and Schestag, Schuster, and Uhrig-Homburg, 2016): i) bonds must be active in ETRACE for more than one year, ii) bonds must trade on at least 50% of the days they are active in ETRACE.

Table 1 provides bond/firm counts and descriptive statistics for each sample and sample period. There are many more bonds after the crisis than before the crisis. The number of bonds in the 2010-2014 sample exceeds the number of bonds in the 2004-2006 sample by 79.88%. The offering amount and the amount outstanding are higher in the TRACE sample than in the FISD sample and higher in the Filtered sample than in the TRACE sample. They also increase from before the crisis to after the crisis.

1.2. Liquidity measures

Our analysis investigates how liquidity metrics differ from before the crisis to after the crisis both for the whole sample and for stress events. We focus on daily liquidity measures that are typically used in the literature (for instance, in Dick-Nielsen, Felhütter, and Lando, 2012). The six bond-level liquidity metrics we use are the Amihud illiquidity measure (Amihud), the imputed roundtrip cost (IRC), the effective spread (EFFSPD), the number of trades (NTrades), turnover, and the percent of zero trading days (ZDays). We call the first three measures price-based measures.

Amihud follows from Amihud (2002) and is the average absolute return between transactions normalized by trade size for each bond on each day:

[8] We consolidate trades at the same day, time, price, and volume – this accounts for 54% (76%) of pre-crisis (post-crisis) transactions dropped. A recursive filter is used to eliminate recording errors. We drop transactions after maturity or if FISD records zero amount outstanding, transactions with prices over 10 times principal value or less than \$10, and fractional trades (volume less then principal). We also drop bonds with less than \$1,000 amount outstanding, less than \$100 principal value, and bonds with coupon frequency of 99, 12 or -1.

$$1/(n-1)\sum_{t=2}^{n}|(P_t - P_{t-1})/P_{t-1}|/Q_t \quad (1)$$

where P_t and P_{t-1} are the prices of sequential intraday trades, Q_t is volume, in millions, of trade t, and n is the number of intraday trades. The computation of this measure requires at least two intraday trades per bond-day. Note that, with this measure, liquidity improves when the value of the measure falls, as it means that trades have a lower price impact.

Feldhütter (2012) introduces a measure of transaction costs based on roundtrip trades. We use his approach to estimate the imputed round trip costs (IRC) as implemented by Dick-Nielsen, Feldhütter, and Lando (2012). IRC is the average percentage change in price over all imputed roundtrip trades within a day:

$$1/n\sum_{i=1}^{n}\left(P_{max,i} - P_{min,i}\right)/P_{max,i} \quad (2)$$

where $P_{max,i}$ and $P_{min,i}$ are the maximum and minimum transaction prices, respectively, for imputed roundtrip trade (IRT) i, and n is the number of ITRs in a day. An imputed roundtrip trade is any series of 2 or 3 trades for a given bond on the same day at the same volume. At least one imputed roundtrip trade is required on each bond-day to calculate IRC. Liquidity is better if the IRC is lower.

EFFSP is the daily trade-weighted average customer buy price minus the daily trade-weighted customer sell price, $\overline{P_{buy}} - \overline{P_{sell}}$, where $\bar{P}$ is the daily trade-weighted price as a percent of principal. Customer-initiated buy/sell transactions are identified using the RPT_SIDE_CD and CNTRA_MP_ID tags in ETRACE (see Dick-Nielsen, 2014; Adrian, Fleming, Shachar, and Vogt, 2016). A lower EFFSP means that liquidity is better in that trading costs due to the bid-ask spread are lower.

To capture trading intensity, we construct NTrades, Turnover, and ZDays. NTrades is simply the total number of trades for a given bond over each day. Turnover is the total volume traded in a given bond on a given day divided by the total principal amount outstanding for that bond on the same day. Amount outstanding is obtained from FISD. Note that, for the FISD sample, NTrades and turnover equal zero on days when the bond does not trade.

Finally, ZDays is an indicator variable that is equal to zero if the bond trades and one if no trade is recorded on that day. Averaged across active bonds on a day, ZDays is the fraction of bonds that do not trade on that day. The time-series average of the daily average of ZDays over a period is the percentage of days bonds do not trade over that period.

2. The evolution of liquidity metrics after the crisis

In this section, we examine how the liquidity metrics change from the pre-crisis period, 2004-2006, to the post-crisis period, 2010-2014. Though many papers discard trades of less than $100,000, we do not follow that approach in this section since differences in the evolution of liquidity metrics for small and large trades can be instructive about the evolution of liquidity. As explained in Section 1, we have three samples: the FISD sample, the TRACE sample, and the Filtered sample. For the FISD sample, the liquidity metrics that require trade volume or trade prices are the same as for the TRACE sample as these measures can only be computed on days with trades.

An obvious concern is that bonds could simply trade less often. One way to address this concern is to compare the number of bond-days for which we can compute our various liquidity measures to the number of bond-days available in the FISD sample shown in Table 1. For small trades, we ignore the Amihud measure as it is not informative. Figure 1 shows the results for the pre-crisis period and the post-crisis period. Whether we use small trades or large trades, we can compute the measures proportionately more often after the crisis than before the crisis. The Amihud measure is our price-pressure measure. Pre-crisis, we can compute that measure for large trades for 7.46% of the bond-days available on FISD. After the crisis, the measure is available for 11.14% of the FISD bond-days. This means that the Amihud measure is available for 50% more bond-days after the crisis than before for large trades.

Table 2 reports the liquidity metrics for our three samples for the pre-crisis and the post-crisis periods.[9] To compute the measures in Table 2, we compute the measures for each bond each day that the data is

[9] We exclude unrated bonds from the analysis.

available for a specific sample. We then compute daily averages of the measures for each day to obtain a time-series of daily averages. Finally, we estimate averages from regressions with indicator variables for each period and use robust t-statistics. The table reports the results for our time-series measures. The first panel is for the sample of all trades. The second panel is for small trades and the third is for large trades. The Amihud measure is not meaningful for small trades and we do not report it.

Looking at the first panel, we see that all price-based liquidity metrics improve after the crisis compared to before the crisis. Focusing on our price pressure measure, we see that it falls by 36.51% for the TRACE sample, which corresponds to a decrease in the price pressure of trades. However, the message from quantity-based liquidity metrics is mixed. Though the fraction of days without trades falls for the TRACE sample from 73.55% to 70.94% and the number of trades per day increases from 4.78 to 6.54, turnover falls from 0.0087 to 0.0070, or by 19.54%. The decrease in turnover that we find in our sample has been documented both in academic research and in industry reports. We compute the same turnover measure for stocks trading on exchanges in the U.S. Instead of a decrease in turnover, we find an increase of 9.21%.[10] Consequently, the fall in turnover for bonds cannot be explained by a general decrease in turnover. Hence, factors unique to the bond market must be driving the decrease in turnover in bonds.

The next two panels show that the improvement in price-based liquidity metrics for the whole sample is driven by a rather large improvement in trading conditions for small trades.[11] Not surprisingly, as is well-known (Schultz, 2001), small trades are more expensive than large trades. In Panel B, the improvement is particularly notable in the IRC, which falls by 31.03% for the TRACE sample. The change in turnover computed using small trades is not economically meaningful. When we look at Panel C instead, which is the panel for large trades, we see that IRC does not change. In that panel, we compute the Amihud measure,

[10] To estimate turnover on the stock market, we use all listed stocks on exchanges in the US. Each day, we average turnover across all stocks. We then average daily average turnover for the pre-crisis period and the post-crisis period.

[11] In their Table 4, Bessembinder, Jacobsen, Maxwell, and Venkateraman (2016) show their measure of transaction costs for subsets of bonds and trades. They do not report tests of significance of differences. They report a decrease in their transaction cost measure for small trades from their baseline period of 2006-2007 to 2012-2014 but no changes for large trades.

and we see that it worsens from 0.0076 to 0.0083, or by 9.21%. The effective spread increases more noticeably, as it increases by 17.15%. However, the number of trades increases for large trades and the fraction of days without large trades falls. Panel C shows that the decrease in turnover is driven by large trades, as turnover using large trades drops by 33.11%. The sharp difference in the evolution of turnover for small and large trades is inconsistent with common factors driving correlated changes in turnover across investors and is inconsistent with the view that investors generally wanted to trade less in corporate bonds.

It follows from Table 2 that the price-based liquidity metrics improve from the pre-crisis period to the post-crisis period for the whole sample and the sample of small transactions, but they worsen for the Amihud measure and for the effective spread for large transactions. The result for the quantitative metrics is mixed, as there are more trades and fewer days without trades, but turnover falls. We repeat the analysis without using 2004 since in that year dissemination by TRACE of bonds increased. Our inferences are unaffected when we do not use 2004.

We now investigate in greater detail the evolution of the liquidity metrics for large transactions. In Table 3, we split the post-crisis period into two subperiods, 2010-2012 and 2013-2014. We construct the measures in the same way as for Table 2. Panel A shows the results for the sample of large trades. Panel B focuses on the results for large trades in investment grade bonds and Panel C displays the results for large trades in high yield bonds.

Other papers have shown that liquidity metrics improve from early after the crisis to later after the crisis (for instance, Adrian, Fleming, Shachar, and Vogt, 2017, and Bessembinder, Jacobsen, Maxwell, and Venkataraman, 2016). The existing evidence is less clear about how liquidity metrics change from before the crisis to after the crisis and, especially, for high-yield bonds relative to investment-grade bonds. In this comparison, we use a three-year pre-crisis period that does not correspond to the peak of the credit boom. We believe that such a comparison period is more meaningful because it reflects liquidity under more normal conditions rather than over a period that is generally considered overheated. Starting with Panel A, we show that, whereas IRC, Amihud, and EFFSPD are all higher during the first post-crisis subperiod than the pre-crisis period, the opposite is the case when we compare the second subperiod to the pre-crisis period (except for EFFSPD for the filtered sample). The improvement in the price-based liquidity metrics from the first post-crisis subperiod to the second is economically important. For instance, using the TRACE sample, the Amihud measure falls by 23.91% from the first subperiod to the second. Amihud in the second subperiod is also 9.09% lower than in the pre-crisis period. EFFSPD falls from the first to the second subperiod by 26.01%. However, while EFFSPD is lower in the second-subperiod than before the crisis for the TRACE sample by 3.13%, it is insignificantly higher for the filtered sample. When we turn to the quantity metrics, we see that the number of trades keeps increasing across subperiods and is higher in the second subperiod than before the crisis. Similarly, the fraction of days without trades keeps falling. However, whereas all other liquidity metrics improve from the first subperiod to the second and are better than in the pre-crisis period for the second subperiod, turnover keeps falling so that it is significantly lower than before the crisis in both the first and second subperiods.

We now look separately at investment grade bonds and high yield bonds. With investment grade bonds, we see the same fairly dramatic evolution in the liquidity metrics between the first post-crisis subperiod and the second one. However, both IRC and EFFSPD, but not Amihud, are significantly higher in the post-crisis second subperiod than they are in the pre-crisis period. Amihud is insignificantly different in the second post-crisis subperiod from the pre-crisis period. The difference in IRC is just one basis point, but the difference in EFFSPD is more consequential as it is higher by 19.53% using the TRACE sample. The evolution of the liquidity metrics for high-yield trades is different from the evolution for investment grade trades. We see in Panel C that the price-based metrics improve for high yield trades in both post-crisis subperiods compared to the pre-crisis period. This result is surprising because risk-weighted capital requirements increased immediately after the crisis for riskier bonds, so that we would expect investment grade bonds to be less affected. The IRC improves by 30.56% for the TRACE sample when we compare the second subperiod to the pre-crisis period and Amihud improves by 11.11%. Again, however, turnover falls while the other quantity metrics improve. The fall from before the crisis is rather dramatic as it corresponds to 52.02%.

Figure 2 shows the evolution of our equally weighted price-based liquidity metrics from the start of 2004 to the end of 2014 for large and small trades and shows turnover for large trades. Not surprisingly, there is a large degradation in all price-based measures during the crisis. We see that, since the crisis, these measures have steadily improved so that most recently they are roughly at the level that they were at before the crisis. This evolution is hard to reconcile with an adverse impact from regulatory changes. The regulatory changes take effect starting in 2009 throughout our post-crisis period. Everything else equal, we expect the price-based metrics to worsen as these regulations are implemented. The figure for turnover shows that turnover is much lower at the end of the sample than before the crisis. Paradoxically, turnover is worse at times during 2013-2014 than at the worst times during the crisis.

Looking at the evidence presented so far in this section, there is a mixed message in that all liquidity metrics except turnover are better in the second post-crisis subperiod for high yield bonds than before the crisis, and two price-based metrics and turnover are worse for investment grade bonds. The behavior of turnover raises important questions. First, how can turnover worsen when the other quantity metrics improve? Second, why is turnover falling? For turnover to fall while the number of trades increases, it has to be that the size of trades falls. We find that it is so.[12] The average size of large trades before the crisis is $2.16 million. In the first subperiod after the crisis, the average size of large trades drops to $1.68 million. The average trade size keeps dropping from the first post-crisis subperiod to the second post-crisis subperiod as in that subperiod average trade size is $1.55 million. In contrast, average trade size for small trades increases slightly, from $26.96 thousands before the crisis to $29.81 thousands in the second subperiod after the crisis. The evolution of trade size is shown in the last two panels of Figure 2. The trade size for large trades falls after 2007 and keeps doing so.

[12] We focus on large trades as our explanation is based on changes in turnover and trade size for large trades. Bessembinder, Jacobsen, Maxwell, and Venkataraman (2016) report in their Table 4 a decrease in average trade size across all trades from their benchmark period of January 2006 to July 2007 to their Dodd Frank period and an increase from what they call their TRACE phase-in period. In their regression analysis, they do not include the TRACE phase-in period but find that turnover is lower during the Dodd Frank period than in their benchmark period.

The decrease in turnover for large trades contrasts with the lack of a comparable decrease for the stock market when we use an equivalent measure of turnover. The decrease in turnover for large trades is also surprising considering the lack of a similar decline in turnover for small trades. The evidence suggests that there is something unique about large trades that leads to lower turnover after the crisis. The most plausible explanation is that investors had to cut the size of their trades for the trades to complete on acceptable conditions. For instance, instead of making one large trade with a dealer, investors would make two smaller, but still "large", trades with separate dealers.

The literature has two classes of models that address trade size. One class of models focuses on inventory costs, building on Stoll (1979). The other class of models builds on Easley and O'Hara (1987). This class of models focuses on the information of traders and the adverse selection problem this information creates for dealers. With the inventory cost models, dealers charge for being forced away from their preferred inventory position. The regulatory reforms increase the cost of taking more risk, so that we would expect dealers to charge more for trades that lead them to bear more risk and hence the equilibrium size of trades to fall. Thus, the fall in trade size is consistent with regulatory reforms that increase inventory costs for dealers. However, it is important to note that the growing role of electronic platforms could also have the effect of reducing trade size, as investors have more trading options and hence might naturally choose to trade with more counterparties but in smaller quantities. We are not aware of reasons why there would have been a systematic change in the composition of order flow worsening since the crisis that would provide an information-based explanation for the decrease in trade size.

A drawback of conventional price-based liquidity metrics is they only convey information from completed trades. If an investor does not try to make a trade because of low liquidity, this has no impact on these measures. The problem with price-based liquidity metrics is that they only show the liquidity associated with the trades that take place. The fact that trades have fallen in size and that turnover has fallen is consistent with the view that investors find fewer trades with acceptable conditions. This drop in turnover helps explain why practitioners are concerned about liquidity though price-based liquidity metrics are better than before the crisis for some types of bonds.

3. Is liquidity worse for tail VIX shocks?

The motivation for changes in regulations was to reduce systemic risk. During the crisis, systemic shocks affected liquidity adversely and worsening liquidity decreased asset values, which made the financial system more fragile. It is important, therefore, to assess whether the changes in regulations make liquidity less sensitive to systemic shocks. We cannot assess what liquidity would be if October 2008 were to repeat. Nevertheless, we can conduct an experiment that is instructive about systemic shocks. The VIX index is typically viewed as a crisis indicator or an indicator of systemic shocks. Therefore, we analyze the impact of VIX shocks on the liquidity metrics.

To create our sample of VIX shocks, we use all days from our pre-crisis and post-crisis samples. We then rank all VIX changes and select those that exceed the 95^{th} percentile of the distribution of VIX changes. Table 4 shows the distribution of bond days affected by VIX shocks. The years most affected by VIX shocks are 2010 and 2011. Not surprisingly, there are fewer affected bond-days before the crisis.

To assess whether liquidity metrics change from before the crisis to after the crisis on days of VIX shocks, we estimate the following regression:

$$LIQ = \alpha + \beta_1 D_{Post} + \beta_2 D_{95} + \beta_3 D_{Post} D_{95} + Controls + \varepsilon \qquad (3)$$

where D_{Post} is an indicator variable for the post-crisis period, D_{95} is an indicator variable for a VIX change above the 95^{th} percentile of VIX changes. The dependent variable is a liquidity metric on the day of a VIX shock. The controls are whether the bond is callable, the amount of principal outstanding, the coupon, the bond's rating on the decimal scale, the market return, the risk-free rate, the slope of the yield curve (10-year minus 3-month yields), and Moody's spread between Baa and AAA bonds. We cluster the standard errors by firm and by day.

Table 5 shows the regression estimates. We find that VIX exceedances are not associated with changes in liquidity metrics before the crisis. After the crisis, we find that Amihud, IRC, and EFFSPD are significantly higher on days with VIX shocks. The increase is 11% of the average value of Amihud, 3% of average IRC, and 10% of average EFFSPD. Note that the average change in VIX on shock days is 3.3 points. The highest single-day increase in the VIX in 2008 after the Lehman bankruptcy is 16.54 points. With our estimate, such an increase would correspond to an increase in the Amihud measure of 0.015, which represents an increase corresponding to 186% of the post-crisis Amihud average. It follows that the magnitude of the increased impact of VIX shocks is such that in a crisis the incremental effect of VIX shocks could be large. We looked at the results separately for investment grade bonds and for high-yield bonds. We do not report these results in a table, but we find that the result for the whole sample is driven by high-yield bonds.

There are two important caveats to our results. First, though we do not report the results, we also split the sample into a 2010-2012 subperiod and a 2013-2014 subperiod. This split is less instructive for VIX shocks because these shocks are more frequent during the first subperiod than during the second. During the subperiod 2010-2012, there are two days where the VIX increases by more than 10 points. In contrast, for the 2013-2014 period, the VIX never exceeds 21 and the highest single-day change in the VIX is 5.21 points. Not surprisingly, the effect of VIX shocks on liquidity metrics is stronger in 2010-2012. For 2013-2014, the coefficients on the price-based metrics are positive but not significant. In contrast, they are positive and significant for the period 2010-2012. Second, the VIX gained considerable attention during the crisis. It may well be that the market reaction to VIX shocks changed with the crisis, so that VIX shocks had more of an impact after the crisis. However, these caveats do not change our results that large VIX shocks after the crisis are associated with liquidity decreases.

In summary, the evidence concerning VIX shocks indicates that these shocks have an adverse impact on price-based liquidity metrics after the crisis but not before. This impact is of the order of an increase in the Amihud measure and in the effective spread of more than 10%.

4. Is liquidity worse for tail bond yield changes?

We would expect that investors are likely to change their views and trade when a bond experiences an extremely large yield increase. Such high yield changes imply an increase in return volatility on a bond, which also would correspond to an increase in the VaR contribution of holding such bonds. Hence, days following such increases would be days with a heightened demand for market-making services but also with possibly a reduced supply of liquidity that would depend on the cost to a market-maker of VaR increases, costs that likely would be higher after the crisis than before.

We collect the yield changes that are in the 95th percentile of all yield changes over the pre-crisis period and the post-crisis period. Panel A of Table 6 shows the distribution of the extreme yield-change days for the sample of all bonds, the sample of investment grade bonds, and the sample of high-yield bonds. We see that there are relatively more extreme yield changes earlier in the sample period, namely in the pre-crisis period and in the years immediately after the crisis.

To assess whether liquidity metrics change from before the crisis to after the crisis for bonds experiencing extreme yield changes, we estimate the following regression:

$$LIQ = \alpha + \beta_1 D_{Post} + \beta_2 D_{[95,99]} + \beta_3 D_{99} + \beta_4 D_{Post} D_{[95,99]} + \beta_5 D_{Post} D_{99} + Controls + \varepsilon \qquad (4)$$

where D_{Post} is an indicator variable for the post-crisis period. $D_{[95,99]}$ is an indicator variable that equals one over the five days following a yield change [+1,+5] that exceeds the 95th percentile but does not exceed the 99th percentile. This specification omits the yield spike from the window over which we investigate the impact of the spike on the liquidity metrics. The reason for this is that yield changes correspond to price changes, so that the price changes might affect mechanically the liquidity metrics. To avoid the influence of outliers on changes in liquidity we dummy out the most extreme changes in yields above the 99th percentile. D_{99} equals one on the day of and for the 5 days following a 99th percentile yield change exceedance. The control variables are the same as in Table 5. We cluster the standard errors by firm and day as we can have multiple bonds with a yield change above the 95th percentile on a given day.

Panel A of Table 7 shows the results for yield exceedances when we discard the small trades. Extreme yield changes are followed by higher Amihud, higher IRC, and higher EFFSPD. As expected, higher extreme yield changes have higher Amihud, IRC, and EFFSPD than lower extreme yield changes. With extreme yield changes, turnover and the number of trades are higher. However, extreme yield changes have a lower impact on price-based liquidity metrics after the crisis as well as on the number of trades. Specifically, NTrades, Amihud, IRC, and EFFSPD are all lower. In Panels B and C, we repeat the analysis for subperiods. The results are similar in each subperiod.

5. Is liquidity worse for downgrade selloffs?

Some investment mandates force institutional investors to sell bonds when they are downgraded from investment grade. Consequently, downgrades from investment grade can be accompanied by forced sales and hence a high demand for liquidity from bond sellers. The existing evidence is that in some cases downgrades from investment grade are accompanied by temporary drops in bond prices as forced sellers have to accept a discount for immediacy. However, there is controversy in the literature concerning fire-sale discounts as it is difficult to separate price drops that are due to a demand for liquidity from price drops that are due to new information from the downgrade. Ellul, Jotikasthira, and Lundblad (2011) show that downgraded bonds held by insurance companies under greater pressure to sell experience greater price pressure. Ambrose, Cai, and Helwege (2012) do not control for the circumstances of the seller and conclude that price pressure is negligible when information effects are absent. Both papers take the view that forced selling occurs when bonds are downgraded from investment grade, but the extent of forced selling depends on who owns the bonds when the downgrade happens. While some downgrades are informative, others are not. If investors expect a downgrade, they will most likely reduce their positions before the event, so that sales would be spread out over time. It follows from these considerations that we would not expect all downgrades from investment grade to have the same price pressure effect.

It is important to note that downgrades often occur with a delay, so that the information that leads to the downgrade is already public when the downgrade occurs. When the information is already public, Ambrose, Cai and Helwege (2012) point out that trading in the bond as a result of the downgrade is not informed trading. Thus, it is possible for the liquidity measures to be better around downgrades than on other days where there may be more informed trading.

In this section, we first create a sample of downgraded bonds. We consider a bond to be downgraded from investment grade if all its ratings are investment grade before the downgrade and it loses one or more investment grade rating. Table 8 shows our sample of downgrades for the FISD sample, the TRACE sample, and the Filtered sample. We show the number of bonds for which we have data for the day of the downgrade, day 0, and for the period from the day of the downgrade to the tenth trading day after the downgrade, days [0,+10]. The number of firms downgraded is larger for the pre-crisis period than the post-crisis period. Using FISD, we see that there are 201 firms with downgrades in the pre-crisis period and 151 in the post-crisis period. The number of bonds downgraded is larger than the number of firms with a downgrade as firms often have multiple rated bonds. When we require trading data, the number of bonds available drops, but less so in the post-crisis period. We conduct our analysis using the TRACE sample.

In this analysis, downgrades to high yield are used as an exogenous shock to the demand for market-making services caused by the fact that some institutional investors have to trade out of downgraded bonds. Not all bonds are held by rating-restricted investors who must sell in response to a downgrade. Moreover, some downgrades are expected, so investors may rebalance their positions prior to event. It is therefore important to distinguish downgrades that likely result in forced sales from those that do not. Otherwise, changes in liquidity might correspond to information effects rather than increased demand for market-making services. Such an approach is especially important given the evidence on the price effect of downgrades since, as discussed, the literature finds that not all downgrades are associated with temporary lower bond prices.

To examine the impact of downgrades before and after the crisis, we create two samples where we expect a high demand for market-making services as a result of a downgrade. To create the first sample, we select bonds with an unusually high transaction volume during the 10 days starting with the downgrade day. Volume for these bonds over the event window exceeds the 95th percentile of trading volume calculated over days -100 to -30 before the downgrade and days +30 to +100 after the downgrade. We would expect the volume on such days directly following the downgrade to be driven by investors wanting to exit the downgraded bonds. Since the downgraded bonds have unusually high volume, we would also expect the downgrade to be largely unanticipated. Therefore, we expect high transaction volume downgrades to be associated with likely forced sales. If the transaction volume around a downgrade is not noticeably different from the transaction volume on other days, we would expect that either the downgrade is anticipated or, if it is not, the investors holding the bond are not investors who find it difficult or costly to hold downgraded bonds. To create the second sample, we use the bonds that are sold by insurance companies during the period from the day of the downgrade to 10 days later. We assume that sales by insurance companies are likely to be forced sales.

The period before the crisis is unusual in that it corresponds to a credit boom that ends with historically low high-yield spreads. It is therefore plausible that information asymmetries around downgrades before the crisis differ from the post-crisis period. Another important change from before the crisis to after the crisis is the increase in corporate bond funds. In 2003, the total net assets of corporate bond funds were less than $400 billion. In 2014, total net assets of corporate bond funds have increased to more than $1,800 billion (Goldstein, Jiang, and Ng, 2017). Lastly, corporate bonds outstanding increase sharply after the crisis. It follows that changes in liquidity around downgrades could result from changes in the composition of investors, increases in bonds outstanding, or changes in the information content of downgrades as a result of changes in the economic environment. To reduce this possibility and to explicitly consider bonds with likely forced sales, we compare liquidity metrics of downgraded bonds with likely forced sales to liquidity metrics of downgraded bonds without likely forced sales. The presumption is that changes in the information content of downgrades or changes due to the composition of the market in general would affect the liquidity metrics around all downgrades but would keep relative changes in liquidity metrics around downgrades stable.

With the sample of likely forced sales identified based on volume, 10.49% of the downgraded bonds before the crisis are identified as treated bonds and 25.97% of downgraded bonds are identified as treated bonds after the crisis. We match downgraded bonds with likely forced sales (the treated downgraded bonds) with other downgraded bonds (the control downgraded bonds) based on age, time to maturity, average trades, and Mergent industry code. We use the nearest neighbor propensity score match with replacement.

We find no significant differences between the matching characteristics for treated and control downgraded bonds for the pre-crisis and the post-crisis periods for either one of our forced sales samples. When we consider separately a first post-crisis subperiod and a second post-crisis subperiod, the matching characteristics are not significantly different between the treated downgraded bonds and the control downgraded bonds.

To assess whether price pressure associated with likely forced selling around downgrades has increased from before the crisis, we estimate triple differences-in-differences regressions over days -100 to +100 around a downgrade where the dependent variable is a daily liquidity metric:

$$\begin{aligned} LIQ = \alpha + \beta_1 D_{SellOff} + \beta_2 D_{[0,10]} + \beta_3 D_{PostCrisis} + \beta_4 D_{SellOff} D_{[0,10]} + \beta_5 D_{[0,10]} D_{PostCrisis} \\ + \beta_6 D_{SellOff} D_{PostCrisis} + \beta_7 D_{SellOff} D_{[0,10]} D_{PostCrisis} + \text{Controls} + \varepsilon \end{aligned} \tag{5}$$

where $D_{SellOff}$ takes value 1 if the bond is a forced sale bond, $D_{[0,10]}$ is an indicator variable for the event days from the day of downgrade to day +10, and $D_{PostCrisis}$ is an indicator variable for the post-crisis period. We simplify the notation, so that we suppress the time, bond, and liquidity measure subscripts. We estimate the regression for each liquidity measure. The controls are whether the bond is callable, the amount of principal outstanding, the coupon, the market return, the risk-free rate, the slope of the yield curve (10-year minus 3-month yields), and Moody's spread between Baa and AAA bonds. We cluster observations by firm.

In Table 9, we show regression estimates using the sample of likely forced sales bonds determined using trading volume. Panel A of Table 9 shows estimates of our regressions in which we match downgraded and sold off bonds with downgraded bonds over the pre-crisis period and again for the whole post-crisis period. We include only trades that exceed $100,000 in volume and do not report the coefficients on the control variables. On days when bonds do not trade, Turnover and NTrades are set to zero and ZDays is set equal to 1. For the price-based metrics, we use the TRACE sample, so that days without trades are missing observations. The results for the Amihud measure are striking. The coefficient in column (1) for the interaction of the forced-sale indicator variable and the event window ($D_{SellOff} \times D_{[0,10]}$) is 0.01 and significant at the 10% level. This means that a downgraded bond with likely forced sales experiences an increase in the Amihud measure relative to the base case of no forced selling that is more than 100% of the sample mean of the Amihud measure for large trades (0.0076 before the crisis and 0.0081 after the crisis for the TRACE sample). However, the coefficient on the triple interaction that adds the post-crisis indicator variable is not significant, which means that the change in the Amihud measure for the treated sample compared to the control sample during the event window is not different after the crisis from before. When we turn to the other price-based liquidity metrics, we also find no evidence of a decrease in liquidity for forced-sale bonds after the crisis. For the volume-based metrics, we see that the number of trades and turnover are larger after the crisis during the event window for forced-sale bonds. Finally, the event window Amihud measure falls after the crisis for the sample of downgraded bonds. Specifically, during the event window, the Amihud measure falls by 0.01 for both control bonds and treated bonds. This drop is statistically significant at the 10% level for control bonds and at the 1% level for treated bonds.

We saw earlier that there is an improvement in liquidity metrics from 2010-2012 to 2013-2014. We examine now whether the evidence reported in Panel A changes if we consider these subperiods. Panel B shows the results for large trades from 2010-2012. We find that the Amihud measure falls for treated bonds during the event window after the crisis, so that liquidity is better than before the crisis. We also see that the effective spread is lower for these bonds after the crisis. There is evidence of an improvement in Amihud during the event window after the crisis irrespective of whether a bond has forced sales or not. There is also similar evidence for EFFSPD. There is no evidence of a change for IRC. The last panel of Table 9 is for the period 2013-2014. None of the price-based liquidity measures are significantly different for forced-sale bonds during the event period after the crisis from before the crisis. However, it is noticeable that the coefficients on the triple interaction for the 2013-2014 subperiod are similar to the coefficients for the 2010-2012 period, so that one cannot conclude that the price-based liquidity measures worsened. We also estimated the regressions using a (-3,+3) event window. With that event window, the conclusions are similar.

We repeat our analysis using the bonds sold by insurance companies as bonds subject to forced sales instead of using our volume criterion. Before the crisis, 8.91% of downgraded bonds are treated bonds. After the crisis, 22.33% of the bonds are treated bonds. We show the results in Table 10. In our discussion, we focus on the Amihud measure because no other change is significant. In contrast to the results of Table 9, we find that the Amihud measure increases after the crisis for forced sales during the event window. Specifically, we find that the coefficient on the triple interaction (i.e., sales by insurance companies during the event window after the crisis) is significantly positive and equal to 0.01. Such an increase is economically large. The post-crisis estimate of the increase in the Amihud measure during the event window for bonds sold by insurance companies is the same for the 2010-2012 and the 2013-2014 subperiods, but the increase is only significant for the latter subperiod. However, we also find that the Amihud measure falls sharply for the downgraded bonds after the crisis as the coefficient on the interaction of the event window with the post-crisis period is -0.02. As a result, despite the increase in the Amihud measure for the forced sales bonds during the event window compared to other downgraded bonds, the total change in the Amihud measure during the event window is a drop of -0.01.

Our approach differs from the approach in the contemporaneous study of Bao, O'Hara, and Zang (2016) in a several ways. First, we focus explicitly on bonds where forced sales are likely since the maintained hypothesis is that downgrades lead to unusual demand for liquidity and that such a demand occurs because of forced selling. Second, we compare the change in liquidity metrics for bonds with likely forced sales to downgraded bonds without likely forced sales. Instead, they compare price pressure for downgraded bonds to price pressure for BB-rated bonds, which does not control for changes in the information content of downgrades over time. Third, we have a shorter window than they do. They include observations for one month after the downgrade, while we focus on the period immediately after the downgrade, which we believe provides stronger identification. The advantage of the shorter window is that it is less likely to be affected by the disclosure of new information about the creditworthiness of the downgraded firm, but a longer window may generate more precise estimates. Fourth, we exclude utilities bonds while they do not.

Fifth, they use different subperiods, including one that we cannot match because the data is not publicly available.

Our results are not directly comparable to the results of Bao, O'Hara, and Zhou (2016) because we compare likely forced sales downgraded bonds to other downgraded bonds while they compare downgraded bonds, whether they had likely forced sales or not, to BB-rated bonds. In the spirit of the Bao, O'Hara, and Zhou (2016), we also estimate a regression for all downgraded bonds ignoring our forced-sales requirement. We regress the daily liquidity measures on indicator variables and control variables. The estimated regression is the same as in Table 9 but assuming that all bonds are forced-sale bonds. The estimates are shown in Table 11. The results are striking in that, for all priced-based liquidity metrics, the liquidity metrics are significantly lower after the crisis than before the crisis for the event window. In other words, when we consider all downgraded bonds, we find that liquidity improved in the [0,+10] day downgrade window after the crisis relative to the same window over the pre-crisis period. With our approach, we compare the liquidity of a bond around the downgrade to the liquidity of the same bond before and after the downgrade. We find that the change in liquidity around a downgrade is smaller than before the crisis.

These results are more comparable to the results from Bao, O'Hara, and Zhang (2016) in that they use all downgraded bonds and do not attempt to control for changes in the information content of downgrades, but we compare a bond's liquidity change to its own liquidity rather than to BB-rated bonds in general. Yet, these results are quite different from theirs. They find that the price impact of downgrades is significant for all subperiods compared to the pre-crisis subperiod. We find that the difference is partly related to differences in estimated price impact in the pre-crisis period. That is, their price impact measure for BB-rated bonds is 0.004 for their pre-crisis period, which is all of 2006 and the first half of 2007. They use only large trades. Our pre-crisis period is three years instead of a year and a half. Our Amihud measure for investment grade bonds for that period is 0.0063 while our measure for high yield bonds is 0.0101. Therefore, the price-impact measures in our pre-crisis period are substantially higher than the price-impact measures for their pre-crisis period. It is also important to note that the most visible downgrades before the crisis, the Ford Motor Company and GM downgrades in May 2005, are in our pre-crisis sample but not in theirs.[13] When we estimate the regressions of Table 11 for the same pre-crisis sample period as Bao, O'Hara, and Zhang (2016), we find that the post-crisis price impact of downgrades is not lower than before the crisis – but it is also not higher. We also find that the information content of downgrades during the pre-crisis sample period is quite different from the information content of downgrades during our pre-crisis sample period in that, during their pre-crisis subperiod, there is no price pressure effect from downgrades.

5. Conclusion

In this paper, we investigate whether liquidity metrics are worse after the crisis than before and whether liquidity worsened further as implementation of financial system reforms increased. We find that, on average, price-based liquidity metrics improve after the crisis and are better in 2013-2014, when more reforms are implemented, than before the crisis. The improvement from 2010-2012 to 2013-2014 occurs across both investment grade and high yield bonds. The improvement from before the crisis to 2013-2014 is more concentrated among high yield bonds. The fact that price-based liquidity improves for high yield bonds is hard to square with an impact of the regulatory reforms as these measures increased the costs of holding risky bonds on bank balance sheets more than safer bonds if the risk-weighted capital requirement is the binding regulatory capital constraint for banks.[14] In contrast to the improvement in price-based measures, there is a striking worsening of turnover. Turnover keeps falling after the crisis, so that average daily turnover for bonds is worse at times in 2013-2014 than at the height of the crisis.

The apparent contradiction between the evolution of turnover and of the price-based liquidity metrics reveals a limitation of the price-based liquidity measures in assessing the overall liquidity of markets. These measures use data from completed trades. As such, they do not account for trades that do not take place because of poor liquidity. If investors have to offer too high a premium to buy a bond or too high a discount to sell it because of poor liquidity, they may choose not to trade, which manifests itself in lower turnover.

[13] See Acharya, Schaefer, and Zhang, 2015.

[14] If the leverage ratio is the binding constraint, the increase in capital requirements would disadvantage holdings of low risk bonds more than holdings of riskier bonds. However, the supplementary leverage ratio becomes more of an issue late in our sample period and afterwards as discussed in footnote 2.

Hence, the lower turnover is consistent with a material worsening in liquidity that is not apparent from the price-based measures. At the same time, however, other factors affect turnover. Bonds in our sample are mostly securities issued by public firms with traded equity. Hence, one would expect commonality in turnover between the bond market and the equity market. However, the drop in turnover we observe is specific to bonds as there is a slight increase in turnover of common stocks when it is computed in the same way as our measure of bond turnover. The drop we observe is also a drop for large trades as opposed to small trades. Turnover for small trades hardly changes, which is inconsistent with investors in general wanting to trade bonds less as an explanation for the decrease in turnover.

We consider three types of stress events. First, we investigate the effect of extreme VIX increases. Second, we consider extreme yield increases. Finally, we look at downgrades from investment grade. We find no consistent evidence that liquidity metrics worsen after the crisis for bond-specific stress events. Specifically, liquidity metrics appear to be unchanged for downgrades to non-investment grade ratings when we choose our likely forced sales sample using a volume criterion and worsen for the price pressure measure when we use our insurance company sales criterion. With the latter criterion, the worsening of the price pressure measure is such that the measure is not higher than before the crisis for downgraded bonds sold by insurance companies because of the improvement in the price pressure measure for downgraded bonds generally after the crisis. When we do not focus on bonds with likely forced sales, we find a systematic improvement in liquidity immediately after downgrades for the post-crisis period relative to the pre-crisis period. In contrast, however, we find that liquidity metrics are worse for systemic stress events after the crisis than before. This result should be interpreted with caution in that extreme changes in VIX might convey different information to the markets after the crisis than before. However, irrespective of whether this is the case or not, the result shows that large changes in VIX after the crisis are bad for price liquidity metrics.

It is important to note that these stress events all involve adverse developments where investors are likely to want to sell bonds. We do not have events where investors are likely to want to buy bonds. Investors wanting to sell bonds is the situation that is relevant for consideration of systemic risk. It is also the situation where dealers have to take on risk to absorb the increased supply. Situations where investors want to buy bonds are situations where investors reduce the inventory of dealers. This inventory fell with the crisis and has been low since. Absent dealer inventory, a dealer has to find the bonds that investors want to buy. If a dealer cannot find bonds without offering a substantial premium, the trade may not take place and we would not observe it with our data.

Our results show that it is important to distinguish between bond idiosyncratic shocks and systemic shocks in assessing changes in bond market liquidity. While the results we find for idiosyncratic stress events suggest that liquidity has not worsened and has somewhat improved, the results for systemic events imply that liquidity has worsened for such events. This last result is concerning in that, from the perspective of the safety of the financial system, the most important liquidity issue is not how liquidity metrics react to bond-specific events but how they react to systemic stress events. Adverse reaction of liquidity to systemic stress events can magnify the liquidity spirals emphasized by Brunnermeier and Pedersen (2009) that were so destructive during the financial crisis.

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Figure 1. Data availability to construct liquidity metrics before and after the crisis.

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. Small trades are for less than $100,000 and large trades are trades in excess of that amount. The Amihud measure is omitted for small trades as it is not informative. The figure shows the fraction of bond-days available in FISD for which the liquidity measures can be calculated using enhanced TRACE with our filtering criteria.

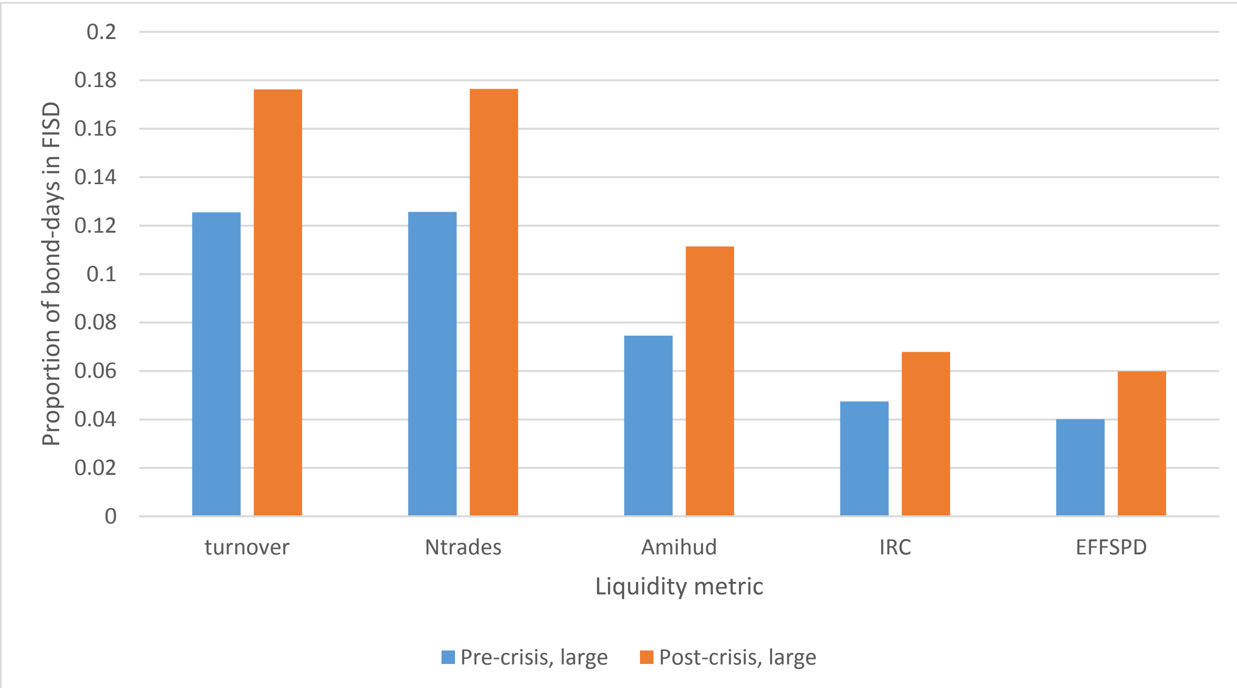

Figure 2. Evolution of liquidity metrics.

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The sample includes all bonds that satisfy our sampling criteria with trades in Enhanced TRACE. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. Small trades are for less than $100,000 and large trades are trades in excess of that amount. The Amihud measure is omitted for small trades as it is not informative. The turnover measure includes only large trades.

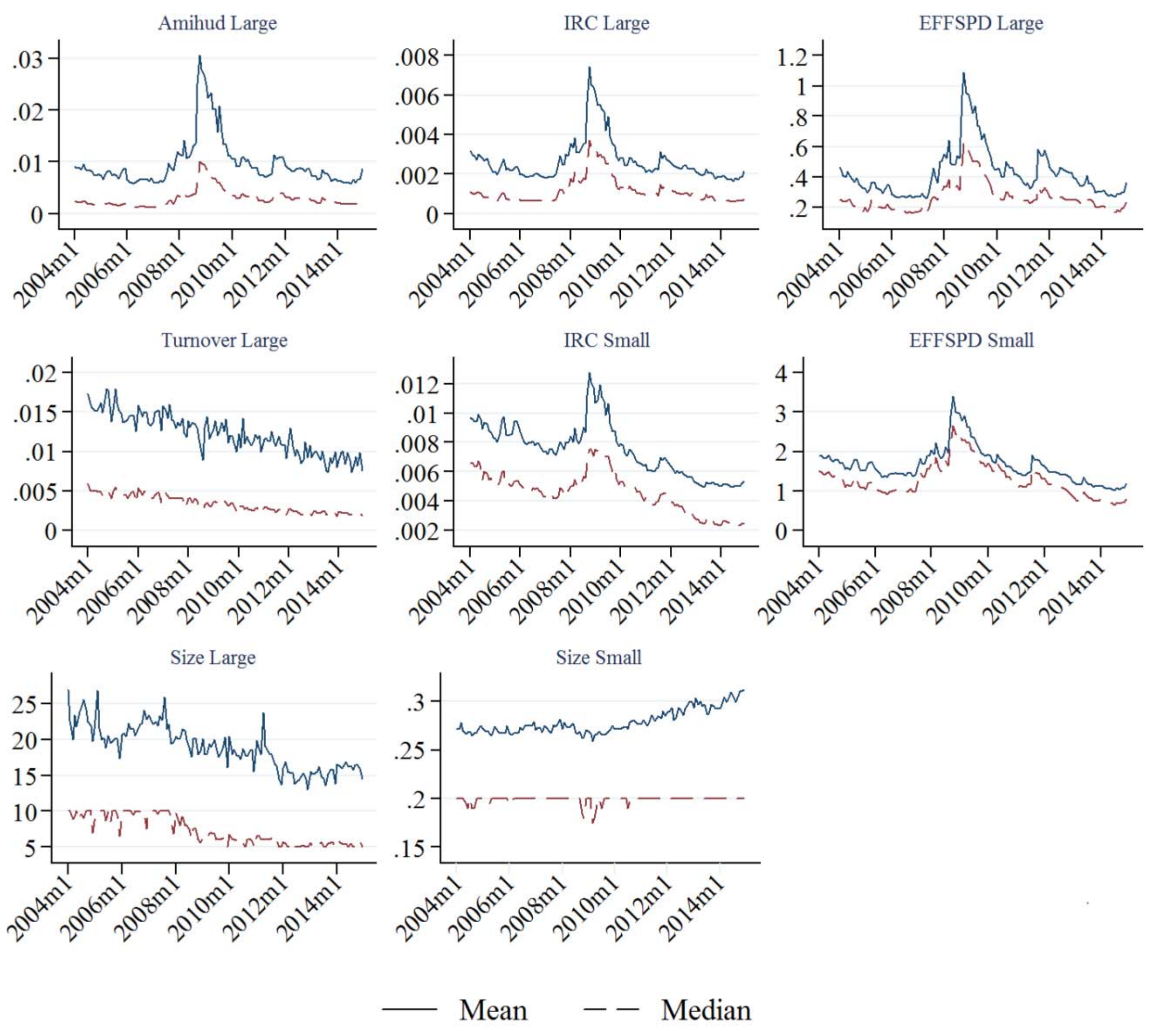

Table 1. Sample descriptive statistics

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The FISD sample includes all active bonds (between the issue and maturity date with non-zero amount outstanding) listed in Mergent FISD. TRACE includes all bonds that appear in Enhanced TRACE over the sample period. The Filtered sample removes, from the TRACE sample, bonds that are active in TRACE less than one year and bonds that trade on less than 50% of the days that they are active in Enhanced TRACE. The bond characteristics are obtained from the Mergent FISD database. Age and time to maturity (TTM) are reported in years. IG denotes investment grade and HY denotes high yield grade. S&P (Moody's) ratings are quantified using the numerical scale. Coupon is the annualized coupon rate and Interest Frequency is the number of coupon payments per year.

Panel A: Bond and firm counts

	Pre-Crisis			Post-Crisis		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered
# Bonds	17,946	16,510	3,248	27,884	26,478	5,750
# Firms	2,757	2,599	847	2,656	2,528	1,338
# Bond-Day	9,069,334	2,387,810	1,337,638	16,314,374	5,213,048	3,640,616

Panel B: Pre-crisis (2004-2006) bond descriptive statistics

	FISD			TRACE			FILTERED		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Age	4.14	2.88	3.86	3.29	1.94	3.73	3.60	2.62	3.61
Time to Maturity	7.35	4.74	8.71	8.02	5.42	8.53	7.74	5.75	7.10
Moody's	7.75	7.00	4.72	7.71	7.00	4.73	8.37	7.00	4.89
Moody's IG	5.26	6.00	2.43	5.25	6.00	2.43	5.37	6.00	2.43
Moody's HY	13.66	13.00	3.40	13.69	13.00	3.46	13.74	13.00	3.35
S&P	8.04	7.00	4.47	7.96	7.00	4.38	8.57	7.00	4.51
S&P IG	6.09	6.00	2.98	6.09	6.00	2.95	6.21	6.00	2.89
S&P HY	12.66	12.00	3.99	12.50	12.00	3.95	12.77	12.00	3.77
Coupon (%)	6.02	6.00	2.19	6.01	6.00	2.12	6.38	6.50	1.82
Interest Frequency	2.12	2.00	0.68	2.13	2.00	0.67	2.01	2.00	0.35
Offering Amnt (Mills)	196.21	50.00	354.88	201.00	50.00	360.90	597.15	475.00	562.01
Amnt Outstd (Mills)	190.77	34.43	369.01	196.49	39.66	375.27	605.26	450.00	604.33

Panel C: Post-crisis (2010-2014) bond descriptive statistics									
	FISD			TRACE			FILTERED		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Age	4.35	2.90	4.48	3.76	2.30	4.40	3.56	2.39	3.90
Time to Maturity	6.58	3.86	8.57	7.27	4.72	8.41	8.10	5.86	7.56
Moody's	11.30	9.00	6.76	11.07	9.00	6.58	9.32	9.00	4.73
Moody's IG	6.12	6.00	2.34	6.19	6.00	2.32	6.39	6.00	2.24
Moody's HY	17.40	19.00	4.93	17.08	18.00	4.95	13.98	13.00	3.81
S&P	11.55	9.00	7.19	11.20	9.00	6.98	8.99	8.00	4.41
S&P IG	7.55	6.00	4.99	7.42	6.00	4.76	6.94	7.00	3.07
S&P HY	16.28	16.00	6.49	15.85	15.00	6.45	12.25	12.00	4.26
Coupon (%)	4.26	5.00	2.97	4.43	5.00	2.89	5.58	5.65	2.18
Interest Frequency	1.57	2.00	0.94	1.63	2.00	0.89	2.00	2.00	0.17
Offering Amnt (Mills)	298.99	29.09	518.76	323.44	75.00	533.16	828.21	620.00	683.96
Amnt Outstd (Mills)	289.20	24.88	528.33	313.80	44.49	545.34	828.03	600.00	722.30

Table 2. Liquidity metrics before and after the crisis

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The FISD sample includes all active bonds (between the issue and maturity date with non-zero amount outstanding) listed in Mergent FISD. TRACE includes all bonds that appear in Enhanced TRACE over the sample period. The Filtered sample removes, from the TRACE sample, bonds that are active in TRACE less than one year and bonds that trade on less than 50% of the days that they are active in Enhanced TRACE. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). The table reports means of the liquidity metrics. Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. ZDays is the fraction of days without trades. For IRC, Amihud, and EFFSPD, missing values are recorded on days when the bond does not trade or if there is not enough information to calculate a value. Therefore, averages for these variables will be the same for FISD and TRACE samples. For Ntrades and Turnover in the FISD sample, a zero is recorded on days with no trades. In contrast, missing values are recorded in the TRACE and Filtered samples on these days. Bold face indicates a significant difference between pre-crisis and post-crisis values at the 1% level.

Panel A: All transactions

	Pre- Crisis			Post- Crisis		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered
IRC	0.0070	0.0070	0.0065	**0.0051**	**0.0051**	**0.0048**
Amihud	0.7688	0.7688	0.7080	**0.4881**	**0.4881**	**0.4289**
EFFSPD	1.0890	1.0890	1.0218	**0.9784**	**0.9784**	**0.9150**
NTrades	0.9256	4.7858	6.7465	**1.3978**	**6.5513**	**7.9455**
Turnover	0.0017	0.0087	0.0068	**0.0015**	**0.0070**	**0.0050**
ZDays	0.8090	0.7355	0.2539	**0.7882**	**0.7094**	**0.2122**

Panel B: Small Trades (<= 100,000)

	Pre- Crisis			Post-Crisis		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered
IRC	0.0087	0.0087	0.0082	**0.0060**	**0.0060**	**0.0057**
EFFSPD	1.6211	1.6211	1.5425	**1.4133**	**1.4133**	**1.3438**
NTrades	0.6475	3.3577	4.7449	**1.0134**	**4.7619**	**5.7467**
Turnover	0.0003	0.0020	0.0004	**0.0003**	**0.0019**	**0.0004**
ZDays	0.8484	0.7900	0.3757	**0.8259**	**0.7611**	**0.3395**

Panel C: Large Trades (> 100,000)

	Pre-Crisis			Post-Crisis		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered
IRC	0.0023	0.0023	0.0022	**0.0023**	**0.0023**	0.0022
Amihud	0.0076	0.0076	0.0078	**0.0083**	**0.0083**	**0.0082**
EFFSPD	0.3323	0.3323	0.3196	**0.3893**	**0.3893**	**0.3907**
NTrades	0.2779	1.4281	2.0009	**0.3841**	**1.7872**	**2.1960**
Turnover	0.0014	0.0148	0.0110	**0.0012**	**0.0099**	**0.0073**
ZDays	0.9088	0.8737	0.5652	**0.8829**	**0.8396**	**0.4949**

Table 3. Evolution of liquidity metrics for sub-samples

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The FISD sample includes all active bonds (between the issue and maturity date with non-zero amount outstanding) listed in Mergent FISD. TRACE includes all bonds that appear in Enhanced TRACE over the sample period. The Filtered sample removes, from the TRACE sample, bonds that are active in TRACE less than one year and bonds that trade on less than 50% of the days that they are active in Enhanced TRACE. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). The table reports means of the liquidity metrics. Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. ZDays is the fraction of days without trades. For IRC, Amihud, and EFFSPD, missing values are recorded on days when the bond does not trade or if there is not enough information to calculate a value. Therefore, averages for these variables are the same for FISD and TRACE samples. For NTrades and Turnover in the FISD sample, a zero is recorded on days with no trades. In contrast, missing values are recorded in the TRACE and Filtered samples on these days. Financials are Mergent industry category 2 and non-financials are Mergent industry category 1 companies, respectively. Bold face indicates a significant difference at the 1% level between the average metric calculated over the respective subperiod and that calculated over the 2004-2006 subperiod. Italics indicates a significant difference at the 1% level between the 2013-2014 subperiod and the 2010-2012 subperiod.

Panel A: All Large Trades

	2004-2006			2010-20102			2013-1014		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered	FISD	TRACE	Filtered
IRC	0.0023	0.0023	0.0022	**0.0025**	**0.0025**	**0.0024**	***0.0019***	***0.0019***	***0.0019***
Amihud	0.0076	0.0076	0.0078	**0.0092**	**0.0092**	**0.0091**	***0.0070***	***0.0070***	***0.0070***
EFFSPD	0.3323	0.3323	0.3196	**0.4341**	**0.4341**	**0.4358**	***0.3222***	***0.3222***	*0.3232*
NTrades	0.2779	1.4281	2.0009	**0.3661**	**1.7504**	**2.2739**	***0.4111***	***1.8422***	***2.0794***
Turnover	0.0014	0.0148	0.0110	**0.0012**	**0.0108**	**0.0079**	**0.0012**	***0.0087***	***0.0063***
ZDays	0.9088	0.8737	0.5652	**0.8911**	**0.8485**	**0.4978**	***0.8707***	***0.8264***	**0.4904**

Panel B: Investment Grade

	2004-2006			2010-2012			2013-2014		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered	FISD	TRACE	Filtered
IRC	0.0016	0.0016	0.0015	**0.0023**	**0.0023**	**0.0022**	***0.0017***	***0.0017***	***0.0016***
Amihud	0.0063	0.0063	0.0062	**0.0088**	**0.0088**	**0.0086**	*0.0062*	*0.0062*	*0.0061*
EFFSPD	0.2489	0.2489	0.2396	**0.4403**	**0.4403**	**0.4335**	***0.2975***	***0.2975***	***0.2928***
NTrades	0.2211	1.2141	1.7550	**0.5170**	**1.7017**	**2.2486**	***0.6955***	**1.7282**	***1.9606***
Turnover	0.0011	0.0133	0.0092	**0.0016**	**0.0100**	**0.0070**	***0.0019***	***0.0084***	***0.0056***
ZDays	0.9213	0.8908	0.5578	**0.8456**	**0.8186**	**0.4658**	***0.7743***	***0.7414***	**0.4582**

Panel C: High Yield

	2004-2006			2010-2012			2013-2014		
	FISD	TRACE	Filtered	FISD	TRACE	Filtered	FISD	TRACE	Filtered
IRC	0.0036	0.0036	0.0036	**0.0029**	**0.0029**	**0.0029**	***0.0024***	***0.0024***	***0.0025***
Amihud	0.0099	0.0099	0.0109	0.0101	0.0101	**0.0103**	***0.0088***	***0.0088***	***0.0091***
EFFSPD	0.4347	0.4347	0.4487	**0.4246**	**0.4246**	0.4445	***0.3738***	***0.3738***	***0.3888***
NTrades	0.6943	1.9751	2.6222	**0.7493**	**1.8853**	**2.3415**	***1.2011***	***2.1858***	***2.4212***
Turnover	0.0036	0.0173	0.0148	**0.0028**	**0.0127**	**0.0106**	*0.0034*	***0.0096***	***0.0083***
ZDays	0.7980	0.7751	0.5410	**0.7803**	**0.7518**	**0.5253**	***0.6493***	***0.6025***	***0.4198***

Table 4. VIX shock counts

The bonds are the bonds that have trades on TRACE. The VIX change is calculated for each day over the pre-crisis and post-crisis period. A VIX shock is defined to be a change in VIX that exceeds the 95th percentile. The table shows the number of bond-days affected by VIX shocks for each year and the percentage of bond-days for investment grade bonds and high yield bonds.

	All Bonds		IG Bonds		HY Bonds	
	#	%	#	%	#	%
2004	12,362	1.58%	9,574	1.59%	2,641	1.56%
2005	6,445	0.80%	4,356	0.80%	2,048	0.80%
2006	22,139	2.77%	14,607	2.80%	7,414	2.71%
2010	90,357	9.12%	65,135	9.14%	23,721	9.07%
2011	113,403	11.38%	82,470	11.39%	28,385	11.31%
2012	56,153	5.48%	40,859	5.53%	13,855	5.44%
2013	31,369	2.86%	22,791	2.86%	7,644	2.87%
2014	52,424	4.74%	38,466	4.73%	12,077	4.68%

Table 5. Evolution of liquidity metrics on VIX shock days

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The bonds are the bonds that have trades on TRACE. A VIX change is calculated for each day over the pre-crisis and the post-crisis periods. D_{95} denotes a VIX shock, which is a change in VIX that exceeds the 95th percentile. D_{Post} indicates the post-crisis period. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. Age is age of the bond in years. TTM denotes time to maturity. Moody's is the Moody's rating using the quantitative scale. MKT is the return on the market portfolio. RF is the risk-free rate. Slope is the slope of the term structure of Treasuries measures as the 10-year yield minus the three-month yield. DEF is the default spread measured as the difference between the Baa yield and the AAA yield. The standard errors are clustered by firm and day. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: VIX shocks and liquidity, 2004-2006 vs. 2010-2014

	Turnover	NTrades	Amihud	IRC	EFFSPD
Constant	0.0135***	1.0767***	-0.0019***	-0.0005***	-0.0617***
	(20.97)	(7.76)	(-4.30)	(-5.23)	(-3.83)
D_{post}	-0.0049***	-0.7806***	-0.0010***	-0.0006***	0.0020
	(-13.24)	(-9.11)	(-3.98)	(-11.42)	(0.29)
D_{95}	0.0004	0.0216	0.0000	-0.0001	-0.0155
	(0.73)	(0.23)	(0.07)	(-1.25)	(-1.00)
$D_{post} \times D_{95}$	-0.0003	0.0094	0.0009*	0.0003***	0.0385**
	(-0.52)	(0.10)	(1.88)	(3.03)	(2.36)
Age	-0.0004***	-0.0720***	0.0005***	0.0001***	0.0143***
	(-14.57)	(-13.43)	(18.12)	(13.30)	(14.52)
Callable	-0.0038***	-0.2007***	-0.0015***	-0.0003***	-0.0292***
	(-16.58)	(-4.23)	(-8.89)	(-9.05)	(-5.18)
TTM	0.0001***	0.0149***	0.0003***	0.0001***	0.0117***
	(13.45)	(4.54)	(23.30)	(27.14)	(29.78)
Moodys	0.0006***	0.1574***	0.0003***	0.0001***	0.0062***
	(23.72)	(22.88)	(13.10)	(26.65)	(8.51)
Amnt Outstd ($M)	-0.0040***	1.6729***	-0.0010***	-0.0002***	-0.0320***
	(-19.43)	(23.03)	(-12.03)	(-8.10)	(-11.65)
Coupon	-0.0006***	-0.0837***	-0.0003***	-0.00004***	0.0071***
	(-13.73)	(-8.61)	(-4.80)	(-4.01)	(5.69)
MKT	0.0000	0.0293***	0.0000	0.0000	-0.0003
	(-0.37)	(3.45)	(-0.08)	(-0.19)	(-0.13)
RF	0.1597***	-27.3167***	0.0041	-0.0104**	-5.7463***
	(4.27)	(-4.78)	(0.22)	(-2.45)	(-8.40)
Slope	0.1176***	1.8858	0.0834***	0.0245***	-0.1610
	(12.43)	(0.79)	(10.39)	(13.76)	(-0.54)
DEF	0.2359***	53.3327***	0.5650***	0.1392***	22.2045***
	(8.97)	(7.86)	(24.97)	(27.36)	(27.55)
R2-adj	0.0157	0.1245	0.0388	0.0490	0.0600
N	3,764,911	3,764,717	2,333,141	1,437,472	1,253,193

Panel B: VIX shocks and liquidity, 2004-2006 vs. 2010-2012					
	Turnover	NTrades	Amihud	IRC	EFFSPD
Constant	0.0192***	1.39***	0.0012**	0.0002	0.0599***
	(20.70)	(7.85)	(2.26)	(1.25)	(3.02)
D_{post}	-0.0037***	-0.69***	-0.0004	-0.0004***	0.0255***
	(-9.44)	(-7.76)	(-1.49)	(-7.51)	(3.43)
D_{95}	0.0005	0.03	0.0002	-0.0001	-0.0086
	(0.92)	(0.35)	(0.36)	(-0.88)	(-0.57)
$D_{post} \times D_{95}$	-0.0005	-0.02	0.0009**	0.0003***	0.0449***
	(-0.78)	(-0.15)	(2.01)	(3.01)	(2.75)
Age	-0.0004***	-0.07***	0.0006***	0.0001***	0.0149***
	(-11.83)	(-11.73)	(17.18)	(12.99)	(13.28)
Callable	-0.0036***	-0.28***	-0.0018***	-0.0004***	-0.0391***
	(-13.67)	(-5.15)	(-8.60)	(-9.40)	(-5.58)
TTM	0.0001***	0.01***	0.0003***	0.0001***	0.0117***
	(11.38)	(3.09)	(19.43)	(23.91)	(24.26)
Moodys	0.0007***	0.17***	0.0003***	0.0002***	0.0066***
	(22.02)	(18.65)	(11.79)	(25.78)	(7.63)
Amnt Outstd ($M)	-0.0043***	1.73***	-0.0009***	-0.0001***	-0.0290***
	(-17.13)	(17.87)	(-9.01)	(-5.80)	(-8.17)
Coupon	-0.0009***	-0.10***	-0.0004***	-0.0001***	0.0055***
	(-14.27)	(-7.99)	(-5.65)	(-4.92)	(3.59)
MKT	0.0000	0.03***	0.0000	0.0000	0.0021
	(-0.27)	(3.27)	(0.62)	(0.35)	(0.78)
RF	0.0755*	-31.96***	-0.0347*	-0.0213***	-7.8433***
	(1.87)	(-5.08)	(-1.75)	(-4.55)	(-10.35)
Slope	0.0660***	-1.18	0.0575***	0.0172***	-1.5303***
	(5.31)	(-0.43)	(6.35)	(8.20)	(-4.39)
DEF	-0.1230**	30.81***	0.3616***	0.0801***	13.7511***
	(-2.51)	(3.46)	(12.76)	(11.46)	(12.93)
R2	0.0151	0.1168	0.0348	0.0462	0.0513
N	2,563,069	2,562,882	1,585,607	994,093	837,628

Panel C: VIX shocks and liquidity, 2004-2006 vs. 2013-2014					
	Turnover	NTrades	Amihud	IRC	EFFSPD
Constant	0.0214***	1.57***	0.0010*	0.0000	-0.0513***
	(19.94)	(7.68)	(1.78)	(-0.31)	(-2.77)
D_{post}	-0.0072***	-1.10***	-0.0023***	-0.0010***	-0.0137
	(-14.07)	(-9.22)	(-6.59)	(-12.98)	(-1.63)
D_{95}	0.0007	0.02	0.0000	-0.0001	-0.0217
	(1.22)	(0.17)	(0.03)	(-1.32)	(-1.40)
$D_{post} \times D_{95}$	-0.0012*	-0.04	0.0003	0.0002	0.0140
	(-1.94)	(-0.37)	(0.68)	(1.56)	(0.78)
Age	-0.0003***	-0.07***	0.0005***	0.0001***	0.0131***
	(-10.19)	(-10.87)	(11.85)	(9.97)	(11.17)
Callable	-0.0029***	-0.14***	-0.0009***	-0.0002***	-0.0097*
	(-11.04)	(-2.59)	(-4.43)	(-4.17)	(-1.76)
TTM	0.0001***	0.02***	0.0003***	0.0001***	0.0103***
	(13.03)	(4.57)	(17.47)	(21.90)	(24.73)
Moodys	0.0006***	0.17***	0.0004***	0.0002***	0.0105***
	(17.91)	(19.39)	(12.23)	(24.38)	(14.57)
Amnt Outstd ($M)	-0.0043***	1.82***	-0.0010***	-0.0002***	-0.0319***
	(-15.68)	(18.39)	(-10.19)	(-7.08)	(-11.47)
Coupon	-0.0005***	-0.08***	-0.0004***	-0.0001***	0.0042***
	(-8.63)	(-7.13)	(-4.63)	(-4.79)	(2.96)
MKT	0.0000	0.00	-0.0001*	0.0000	-0.0034**
	(0.08)	(0.36)	(-1.66)	(-1.42)	(-2.11)
RF	-0.1416**	-62.93***	-0.1140***	-0.0364***	-6.1176***
	(-2.51)	(-7.31)	(-5.32)	(-6.69)	(-8.25)
Slope	-0.0473**	-15.73***	0.0283***	0.0126***	-0.3748
	(-2.49)	(-4.05)	(2.92)	(4.90)	(-1.08)
DEF	-0.2173***	35.45***	0.4670***	0.1188***	19.2805***
+	(-3.90)	(2.93)	(14.57)	(15.54)	(17.65)
R2-adj	0.0180	0.1260	0.0323	0.0513	0.0485
N	2,275,295	2,275,252	1,383,963	848,386	754,975

Table 6. Yield shock counts

The bonds are the bonds that have trades on TRACE. The median daily yield for each bond-day represents the daily yield. Daily yield changes are changes that cannot be more than four days apart. Shocks are defined as daily yield changes that exceed the 95th percentile calculated over the pre-crisis period and the post-crisis period. The table shows the number of bond-days and the percentage of bond-days for bond-days where the yield change exceeds the 95th percentile.

	All Bonds		IG Bonds		HY Bonds	
	#	%	#	%	#	%
2004	47,279	7.71%	32,716	6.93%	14,127	10.45%
2005	48,895	7.73%	23,384	5.53%	25,162	12.22%
2006	34,964	5.60%	13,826	3.43%	20,908	9.53%
2010	47,531	6.09%	26,752	4.65%	20,279	10.17%
2011	41,585	5.32%	23,256	3.98%	17,584	9.29%
2012	34,222	4.21%	17,320	2.87%	16,618	8.29%
2013	26,843	2.97%	10,910	1.63%	15,710	7.04%
2014	21,588	2.37%	8,371	1.24%	13,035	5.83%

Table 7. Evolution of liquidity metrics on days of shocks to yield spreads

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The bonds are the bonds that have trades on TRACE. The median daily yield for each bond-day represents the daily yield. Daily yield changes are changes in daily yields that cannot be more than four days apart. $D_{[95,99]}$ takes a value of one for the five days following a shock defined as a daily yield change between the 95th percentile and the 99th percentile, where the percentiles are calculated over the pre-crisis period and the post-crisis period. D_{99} takes a value of one for the day of a yield change in excess of the 99th percentile and the five following days. D_{Post} denotes the post-crisis period. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. Age is age of the bond in years. TTM denotes time to maturity. Moody's is the Moody's rating using the quantitative scale. MKT is the return on the market portfolio. RF is the risk-free rate. Slope is the slope of the term structure of Treasuries measured as the 10-year yield minus the three-month yield. DEF is the default spread measured as the difference between the Baa yield and the AAA yield. The standard errors are clustered by firm and day. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Yield change shocks and liquidity, 2004-2006 vs. 2010-2014					
	Turnover	NTrades	Amihud	IRC	EFFSPD
Constant	0.0071***	0.9841***	-0.0026***	-0.0007***	-0.0862***
	(14.07)	(6.58)	(-5.68)	(-6.74)	(-5.01)
D_{post}	-0.0050***	-0.8583***	-0.0006**	-0.0005***	0.0205***
	(-14.26)	(-8.78)	(-2.46)	(-8.27)	(2.82)
$D_{[95,99]}$	0.0008***	0.4779***	0.0038***	0.0010***	0.0691***
	(3.11)	(7.88)	(10.46)	(14.65)	(8.91)
$D_{post} \times D_{[95,99]}$	0.0001	-0.3490***	-0.0031***	-0.0009***	-0.0970***
	(0.40)	(-4.75)	(-8.06)	(-12.39)	(-10.45)
D_{99}	0.0027***	0.3512***	0.0037***	0.0011***	0.0340**
	(3.68)	(3.13)	(4.52)	(5.88)	(2.18)
$D_{post} \times D_{99}$	0.0004	-0.2811**	-0.0038***	-0.0012***	-0.1283***
	(0.52)	(-2.05)	(-4.29)	(-5.91)	(-6.96)
Age	-0.0003***	-0.0810***	0.0005***	0.0001***	0.0150***
	(-13.54)	(-13.73)	(15.76)	(11.02)	(12.70)
Callable	-0.0013***	-0.1736***	-0.0014***	-0.0003***	-0.0288***
	(-8.33)	(-3.41)	(-7.82)	(-7.47)	(-5.07)
TTM	0.0001***	0.0157***	0.0003***	0.0001***	0.0117***
	(13.85)	(4.14)	(22.11)	(24.95)	(28.18)
Moody’s	0.0006***	0.1612***	0.0003***	0.0001***	0.0065***
	(28.08)	(21.70)	(12.32)	(26.14)	(8.48)
Amnt Outstd ($M)	-0.0019***	1.6712***	-0.0010***	-0.0001***	-0.0333***
	(-15.03)	(22.01)	(-11.32)	(-6.61)	(-11.62)
Coupon	-0.0003***	-0.0703***	-0.0002***	-0.00004***	0.0079***
	(-8.83)	(-6.50)	(-4.06)	(-3.49)	(5.69)
MKT	0.0001**	0.0280***	-0.0001**	-0.00002	-0.0030
	(2.10)	(3.49)	(-2.18)	(-1.61)	(-1.49)
RF	0.1742***	-28.5291***	0.0167	-0.0063	-5.4489***
	(4.50)	(-4.47)	(0.86)	(-1.43)	(-7.44)
Slope	0.1128***	2.5871	0.0859***	0.0242***	-0.1955
	(14.98)	(0.97)	(9.96)	(12.86)	(-0.60)
DEF	0.1724***	58.6002***	0.5805***	0.1391***	23.0428***
	(8.81)	(7.96)	(23.82)	(25.78)	(26.55)
R2	0.0347	0.1279	0.0418	0.0501	0.0666
N	3,276,132	3,275,941	2,094,953	1,282,118	1,127,331

Panel B: Yield change shocks and liquidity, 2004-2006 vs. 2010-2012					
	Turnover	NTrades	Amihud	IRC	EFFSPD
Constant	0.0097***	1.2103***	0.0005	0.0001	0.0459**
	(15.52)	(6.28)	(0.92)	(0.46)	(2.16)
D_{post}	-0.0040***	-0.7389***	0.0000	-0.0003***	0.0469***
	(-11.29)	(-7.25)	(0.08)	(-4.29)	(5.89)
$D_{[95,99]}$	0.0007***	0.4675***	0.0039***	0.0009***	0.0707***
	(2.96)	(7.83)	(10.63)	(14.42)	(9.20)
$D_{post} \times D_{[95,99]}$	0.0000	-0.3957***	-0.0032***	-0.0009***	-0.0991***
	(-0.01)	(-5.06)	(-7.77)	(-11.75)	(-9.52)
D_{99}	0.0028***	0.3364***	0.0038***	0.0011***	0.0351**
	(3.76)	(3.03)	(4.62)	(5.87)	(2.24)
$D_{post} \times D_{99}$	0.0003	-0.2929*	-0.0045***	-0.0014***	-0.1434***
	(0.39)	(-1.93)	(-4.92)	(-6.71)	(-6.99)
Age	-0.0003***	-0.0821***	0.0006***	0.0001***	0.0159***
	(-12.01)	(-12.85)	(14.96)	(10.93)	(11.83)
Callable	-0.0013***	-0.2569***	-0.0017***	-0.0003***	-0.0391***
	(-7.15)	(-4.47)	(-7.65)	(-8.00)	(-5.48)
TTM	0.0001***	0.0145***	0.0003***	0.0001***	0.0118***
	(12.00)	(2.75)	(18.65)	(22.27)	(23.17)
Moodys	0.0007***	0.1724***	0.0003***	0.0001***	0.0070***
	(26.19)	(17.70)	(11.04)	(25.98)	(7.74)
Amnt Outstd ($M)	-0.0020***	1.7364***	-0.0009***	-0.0001***	-0.0297***
	(-12.21)	(17.04)	(-8.36)	(-4.41)	(-8.09)
Coupon	-0.0004***	-0.0795***	-0.0004***	-0.0001***	0.0058***
	(-9.52)	(-5.72)	(-5.06)	(-4.95)	(3.44)
MKT	0.0001**	0.0341***	-0.0001	0.0000	-0.0021
	(2.29)	(3.83)	(-1.50)	(-1.09)	(-0.88)
RF	0.1562***	-28.2409***	-0.0228	-0.0175***	-7.7980***
	(3.85)	(-4.06)	(-1.08)	(-3.58)	(-9.59)
Slope	0.0954***	1.5583	0.0594***	0.0165***	-1.7152***
	(10.32)	(0.51)	(6.11)	(7.46)	(-4.57)
DEF	-0.0742**	30.8807***	0.3706***	0.0759***	13.8501***
	(-2.27)	(3.19)	(12.53)	(10.55)	(12.21)
R2	0.0323	0.1251	0.0385	0.0485	0.0584
N	2,201,270	2,201,077	1,408,700	877,303	745,034

Panel C: Yield change shocks and liquidity, 2004-2006 vs. 2013-2014

	Turnover	NTrades	Amihud	IRC	EFFSPD
Constant	0.0144***	1.5362***	0.0007	0.0000	-0.0524***
	(15.58)	(6.79)	(1.20)	(-0.22)	(-2.71)
D_{post}	-0.0070***	-1.2265***	-0.0021***	-0.0008***	-0.0014
	(-13.85)	(-9.25)	(-5.76)	(-11.06)	(-0.15)
$D_{[95,99]}$	0.0008***	0.5217***	0.0038***	0.0009***	0.0601***
	(3.14)	(8.76)	(10.45)	(13.57)	(8.07)
$D_{post} \times D_{[95,99]}$	0.0003	-0.2510***	-0.0030***	-0.0009***	-0.0976***
	(0.82)	(-2.86)	(-7.27)	(-11.09)	(-9.87)
D_{99}	0.0028***	0.3996***	0.0037***	0.0010***	0.0272*
	(3.78)	(3.64)	(4.53)	(5.63)	(1.78)
$D_{post} \times D_{99}$	0.0006	-0.2285	-0.0025**	-0.0008***	-0.1153***
	(0.64)	(-1.49)	(-2.54)	(-3.58)	(-5.59)
Age	-0.0003***	-0.0720***	0.0005***	0.0001***	0.0136***
	(-9.61)	(-9.89)	(11.02)	(8.65)	(9.82)
Callable	-0.0008***	-0.0981*	-0.0008***	-0.0001***	-0.0090
	(-3.87)	(-1.69)	(-3.61)	(-3.00)	(-1.57)
TTM	0.0001***	0.0245***	0.0003***	0.0001***	0.0103***
	(13.24)	(4.32)	(16.66)	(20.44)	(23.45)
Moodys	0.0006***	0.1711***	0.0004***	0.0002***	0.0104***
	(20.00)	(18.18)	(11.34)	(25.19)	(13.43)
Amnt Outstd ($M)	-0.0024***	1.8225***	-0.0010***	-0.0002***	-0.0325***
	(-11.77)	(17.70)	(-9.56)	(-5.90)	(-11.12)
Coupon	-0.0003***	-0.0760***	-0.0004***	-0.0001***	0.0045***
	(-5.57)	(-5.87)	(-4.32)	(-4.57)	(2.85)
MKT	0.0001	0.0041	-0.0001**	0.0000	-0.0025
	(1.39)	(0.31)	(-2.28)	(-1.52)	(-1.49)
RF	-0.0990*	-68.7033***	-0.1109***	-0.0381***	-6.1114***
	(-1.67)	(-7.19)	(-4.97)	(-6.84)	(-7.96)
Slope	-0.0325*	-17.0397***	0.0256**	0.0093***	-0.5994*
	(-1.86)	(-3.95)	(2.57)	(3.64)	(-1.68)
DEF	-0.1352***	43.0795***	0.4641***	0.1153***	18.9370***
	(-3.01)	(3.27)	(14.19)	(14.96)	(16.33)
R2	0.0349	0.1321	0.0369	0.0534	0.0562
N	1,987,521	1,987,467	1,251,182	761,960	683,762

Table 8. Downgrade counts.

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The FISD sample includes all active bonds (between the issue and maturity date with non-zero amount outstanding) listed in Mergent FISD. TRACE includes all bonds that appear in Enhanced TRACE over the sample period. The Filtered sample removes, from the TRACE sample, bonds that are active in TRACE less than one year and bonds that trade on less than 50% of the days that they are active in ETRACE. The downgrades are obtained from Mergent. The table reports the number of bonds downgraded as well as the number of firms with downgraded bonds. MR denotes a Moody's rating, SPR a Standard &Poor's rating, and FR a Fitch rating. Note that a bond can be downgraded on the same day by multiple agencies, so that the total number of bonds downgraded is less than the number of downgrades.

Panel A: Number of Downgrades in FISD

	Pre-Crisis				*Post-Crisis*			
	#Firms		*#Bonds*		*#Firms*		*#Bonds*	
	[0]	[0,10]	[0]	[0,10]	[0]	[0,10]	[0]	[0,10]
MR	89	89	244	244	81	81	255	255
SPR	159	159	2,021	2,021	98	98	357	357
FR	49	49	214	214	33	33	85	85
Total	201	201	2,376	2,376	151	151	647	647

Panel B: Number of Downgrades in TRACE

	Pre-Crisis				*Post-Crisis*			
	#Firms		*#Bonds*		*#Firms*		*#Bonds*	
	[0]	[0,10]	[0]	[0,10]	[0]	[0,10]	[0]	[0,10]
MR	25	43	61	108	42	46	100	126
SPR	45	60	595	1,182	41	48	99	124
FR	18	21	85	138	13	18	40	50
Total	78	110	686	1,354	87	99	217	271

Panel C: Number of Downgrades in Filtered TRACE

	Pre-Crisis				*Post-Crisis*			
	#Firms		*#Bonds*		*#Firms*		*#Bonds*	
	[0]	[0,10]	[0]	[0,10]	[0]	[0,10]	[0]	[0,10]
MR	14	14	33	36	30	33	74	80
SPR	25	25	250	292	30	30	79	80
FR	13	15	59	68	12	13	31	33
Total	43	44	302	353	65	69	166	175

Table 9. Evolution of liquidity metrics around downgrade from investment grade

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The sample includes the bonds downgraded from investment grade in our TRACE sample. A downgraded bond is a bond that goes from having no high-yield rating to having at least one. We selected as likely forced-sales bonds the bonds with daily volume during the (0,+10) window around the downgrade in the 95th percentile of their daily volume distribution for days (-100,-30) and (+30,+100). We match each forced sales bond with a bond that is downgraded without likely forced sales. The sample includes the forced sales bonds and the matching bonds for the 200 days around the downgrade. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. ZDays is the fraction of days without trades. $D_{SellOff}$ is an indicator variable for whether a bond has forced sales, $D_{[0,+10]}$ is an indicator variable that takes value one for days during the (0,+10) event period. $D_{PostCrisis}$ takes value one during the post-crisis period The control variables (coefficients not tabulated) are the age of the bond in years, time to maturity, the Moody's rating using the quantitative scale, the return on the market portfolio, the risk-free rate, the slope of the term structure of Treasuries measured as the 10-year yield minus the three-month yield, the default spread measured as the difference between the Baa yield and the AAA yield, industry Mergent categories for financial and non-financial companies. Standard errors are clustered by firm. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Liquidity changes for downgrades, 2004-2006 vs. 2010-2014

	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.02***	0.0050***	0.75***	0.97***	0.01	-0.08
	(3.75)	(2.95)	(3.32)	(7.72)	(0.54)	(-0.08)
$D_{SellOff}$	0.00	0.00	0.04	-0.02	0.00	-0.32***
	(-0.06)	(-0.59)	(0.41)	(-1.12)	(0.32)	(-2.85)
$D_{[0,10]}$	0.00	0.0013*	0.07	-0.02	0.00	0.68***
	(0.83)	(1.89)	(1.00)	(-1.54)	(0.75)	(5.56)
$D_{PostReg}$	-0.01	0.00	-0.02	-0.03	-0.01	-2.19***
	(-1.17)	(-1.20)	(-0.09)	(-0.35)	(-0.98)	(-2.98)
$D_{SellOff} \times D_{[0,10]}$	0.01*	0.00	0.10	-0.10***	0.01**	0.98
	(1.68)	(0.84)	(0.78)	(-5.23)	(2.33)	(1.11)
$D_{SellOff} \times D_{PostCrisis}$	0.00	0.0002	-0.05	-0.14***	0.01	1.09**
	(-0.31)	(0.17)	(-0.37)	(-2.98)	(1.26)	(2.02)
$D_{[0,10]} \times D_{PostCrisis}$	-0.01*	-0.0009	-0.17*	-0.11	0.01	0.68
	(-1.95)	(-1.11)	(-1.84)	(-1.64)	(1.25)	(0.79)
$D_{SellOff} \times D_{[0,10]} \times D_{PostCrisis}$	0.00	-0.0003	-0.05	-0.05	0.03**	5.86***
	(-0.48)	(-0.26)	(-0.37)	(-0.65)	(2.05)	(3.53)
R-sqrd	0.0347	0.0233	0.0547	0.3655	0.0019	0.2943
N	13,469	9,854	6,718	83,751	83,751	83,751

Panel B: Liquidity changes for downgrades, 2004-2006 vs. 2010-2012						
	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.03***	0.0034*	0.41*	1.1093***	-0.01**	-0.18
	(3.15)	(1.78)	(1.81)	(9.11)	(-2.32)	(-0.15)
$D_{SellOff}$	0.00	0.00	0.04	-0.02	0.00	-0.34***
	(-0.06)	(-0.66)	(0.37)	(-1.09)	(0.28)	(-3.32)
$D_{[0,10]}$	0.00	0.0012*	0.06	-0.02	0.00	0.69***
	(0.82)	(1.87)	(0.89)	(-1.39)	(0.27)	(5.54)
$D_{PostReg}$	-0.01**	-0.0028**	-0.17	-0.11	0.00	-2.08**
	(-1.99)	(-2.19)	(-1.10)	(-1.16)	(0.00)	(-2.57)
$D_{SellOff} \times D_{[0,10]}$	0.01*	0.00	0.10	-0.09***	0.01**	0.98
	(1.76)	(0.87)	(0.80)	(-5.38)	(2.33)	(1.11)
$D_{SellOff} \times D_{PostCrisis}$	0.00	0.00	0.02	0.03	0.00	0.86
	(0.44)	(0.88)	(0.17)	(0.51)	(-0.15)	(0.93)
$D_{[0,10]} \times D_{PostCrisis}$	0.00	-0.0013	0.00	-0.07*	0.00	-0.25
	(-0.48)	(-1.62)	(0.04)	(-1.92)	(0.70)	(-1.26)
$D_{SellOff} \times D_{[0,10]} \times D_{PostCrisis}$	-0.01**	0.00	-0.26*	-0.04	0.03**	5.71***
	(-2.11)	(-0.15)	(-1.82)	(-0.92)	(2.47)	(3.08)
R-sqrd	0.0385	0.0263	0.0532	0.4036	0.0217	0.3473
N	9,804	7,278	4,892	70,060	70,060	70,060

Panel C: Liquidity changes for downgrades, 2004-2006 vs. 2013-2014						
	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.02**	0.0053**	0.63**	1.62***	-0.0088	-0.24
	(1.96)	(2.12)	(1.97)	(14.92)	(-0.73)	(-0.21)
$D_{SellOff}$	0.00	-0.0005	0.03	-0.01	0.0001	-0.33***
	(-0.08)	(-0.60)	(0.35)	(-0.69)	(0.09)	(-3.19)
$D_{[0,10]}$	0.00	0.0013**	0.06	-0.01	0.0002	0.68***
	(0.88)	(2.00)	(1.00)	(-0.71)	(0.30)	(5.16)
$D_{PostReg}$	-0.01**	-0.0033**	-0.35**	-0.33***	-0.0055	-2.04***
	(-2.24)	(-2.50)	(-2.31)	(-5.20)	(-0.59)	(-3.45)
$D_{SellOff} \times D_{[0,10]}$	0.01*	0.0008	0.09	-0.10***	0.0117**	0.99
	(1.66)	(0.81)	(0.73)	(-5.67)	(2.36)	(1.11)
$D_{SellOff} \times D_{PostCrisis}$	0.00	0.0009	0.14	0.00	0.0107	1.00*
	(0.33)	(0.88)	(0.84)	(0.01)	(1.02)	(1.86)
$D_{[0,10]} \times D_{PostCrisis}$	0.00	-0.0010	-0.09	-0.05	0.0045	1.10
	(-0.13)	(-1.32)	(-0.95)	(-0.88)	(1.21)	(1.40)
$D_{SellOff} \times D_{[0,10]} \times D_{PostCrisis}$	-0.01	-0.0001	-0.11	-0.13*	0.03*	6.29***
	(-1.42)	(-0.05)	(-0.73)	(-1.86)	(1.72)	(3.24)
R-sqrd	0.0553	0.0482	0.0879	0.4124	0.0017	0.3266
N	11,389	8,202	5,649	72,823	72,823	72,823

Table 10. Evolution of liquidity metrics for downgrades from investment grade with insurance company sales as forced sales indicator

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The sample includes the bonds downgraded from investment grade in our TRACE sample. A downgraded bond is a bond that goes from having no high-yield rating to having at least one. We select as likely forced-sales bonds the bonds sold by insurance companies using the NIAC data. We match each forced sales bond with a bond that is downgraded without likely forced sales. The sample includes the forced sales bonds and the matching bonds. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. ZDays is the fraction of days without trades. $D_{SellOff}$ is an indicator variable for whether a bond has forced sales, $D_{[0,+10]}$ is an indicator variable that takes value one for days during the (0,+10) event period. $D_{PostCrisis}$ takes value one during the post-crisis period. The control variables (coefficients not tabulated) are the age of the bond in years, time to maturity, the Moody's rating using the quantitative scale, the return on the market portfolio, the risk-free rate, the slope of the term structure of Treasuries measured as the 10-year yield minus the three-month yield, the default spread measured as the difference between the Baa yield and the AAA yield, industry Mergent categories for financial and industrial companies. Standard errors are clustered by firm. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.04***	0.0058***	1.49***	0.70***	0.01	1.17
	(4.67)	(4.49)	(3.70)	(3.30)	(0.69)	(0.83)
$D_{SellOff}$	-0.02***	-0.0024***	-0.55**	-0.09*	0.01***	0.37*
	(-2.63)	(-3.79)	(-2.12)	(-1.67)	(3.05)	(1.67)
$D_{[0,10]}$	0.01***	0.0018	0.13	-0.04**	0.00	0.49
	(2.91)	(1.55)	(0.60)	(-2.39)	(1.53)	(1.59)
$D_{PostCrisis}$	-0.01**	-0.0027***	-0.56*	0.16*	0.00	-1.81***
	(-2.18)	(-3.52)	(-1.71)	(1.67)	(-1.14)	(-2.73)
$D_{SellOff} \times D_{[0,10]}$	-0.01**	0.00	-0.03	-0.08***	0.01**	2.65***
	(-2.19)	(-0.25)	(-0.14)	(-3.70)	(2.23)	(3.92)
$D_{SellOff} \times D_{PostCrisis}$	0.01**	0.0021***	0.45*	-0.09	0.00	-0.01
	(2.05)	(2.94)	(1.66)	(-1.23)	(-0.56)	(-0.02)
$D_{[0,10]} \times D_{PostCrisis}$	-0.02***	-0.0021*	-0.28	0.02	0.00	-0.09
	(-3.20)	(-1.70)	(-1.23)	(0.97)	(-0.11)	(-0.20)
$D_{SellOff} \times D_{[0,10]} \times D_{PostCrisis}$	0.01**	0.0009	0.10	-0.04	0.01	0.34
	(2.39)	(0.76)	(0.46)	(-1.27)	(1.63)	(0.39)
R-sqrd	0.0977	0.0662	0.1062	0.1598	0.0014	0.2039
N	51,744	38,294	24,973	176,215	176,215	176,215

Table 11. Evolution of liquidity metrics around downgrade from investment grade without matching

The pre-crisis period is from 1/1/2004 to 12/31/2006 and the post-crisis period is from 1/1/2010 to 12/31/2014. The sample includes the bonds downgraded from investment grade in our TRACE sample. A downgraded bond is a bond that goes from having no high-yield grade rating to having at least one. IRC is the imputed roundtrip cost (Dick-Nielsen, Feldhutter, and Lando, 2012). Amihud is the illiquidity measure of Amihud (2002). EFFSPD is the effective spread. NTrades is the number of trades per day. ZDays is the fraction of days without trades. $D_{[0,+10]}$ is an indicator variable that takes value one for days during the (0,+10) event period. $D_{PostCrisis}$ takes value one during the post-crisis period. The control variables (coefficients not tabulated) are the age of the bond in years, time to maturity, the Moody's rating using the quantitative scale, the return on the market portfolio, the risk-free rate, the slope of the term structure of Treasuries measured as the 10-year yield minus the three-month yield, the default spread measured as the difference between the Baa yield and the AAA yield, industry Mergent categories for financial and non-financial companies. The standard errors are clustered by firm. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Liquidity changes for downgrades, 2004-2006 vs. 2010-2014

	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.01***	0.0015***	0.49***	0.82***	0.01***	-0.03
	(7.45)	(3.77)	(6.29)	(96.06)	(3.78)	(-0.26)
$D_{[0,10]}$	0.0037***	0.0013***	0.08***	-0.03***	0.0024***	0.69***
	(5.17)	(7.77)	(2.71)	(-11.74)	(3.17)	(20.03)
$D_{PostCrisis}$	-0.0059***	-0.0015***	-0.14***	-0.16***	0.00	-0.81***
	(-8.82)	(-8.98)	(-4.54)	(-44.83)	(-0.56)	(-17.80)
$D_{[0,10]} \times D_{PostCrisis}$	-0.0040***	-0.0011***	-0.15***	-0.08***	0.01***	2.09***
	(-3.89)	(-4.38)	(-3.39)	(-12.12)	(5.78)	(25.17)
R-sqrd	0.0737	0.0664	0.0764	0.4042	0.0031	0.4103
N	46,083	34,056	22,466	303,073	303,073	303,073

Panel B: Liquidity changes for downgrades, 2004-2006 vs. 2010-2012

	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.02***	0.0024***	0.63***	0.90***	-0.0017*	-0.45***
	(8.29)	(4.50)	(5.96)	(90.31)	(-1.71)	(-3.67)
$D_{[0,10]}$	0.0038***	0.0013***	0.08**	-0.03***	0.0023***	0.68***
	(5.07)	(7.47)	(2.54)	(-11.50)	(8.78)	(21.10)
$D_{PostCrisis}$	-0.0054***	-0.0014***	-0.13***	-0.07***	-0.0009**	-0.91***
	(-6.18)	(-6.79)	(-2.93)	(-16.28)	(-2.13)	(-17.93)
$D_{[0,10]} \times D_{PostCrisis}$	-0.0039***	-0.0010***	-0.13**	-0.07***	0.01***	1.58***
	(-2.79)	(-3.08)	(-2.15)	(-8.35)	(9.89)	(15.67)
R-sqrd	0.0673	0.0587	0.0606	0.3868	0.0251	0.4268
N	34,928	25,758	16,934	278,764	278,764	278,764

Panel C: Liquidity changes for downgrades, 2004-2006 vs. 2013-2014

	Amihud	IRC	EFFSPD	ZDays	Turnover	NTrades
Constant	0.02***	0.0026***	0.79***	1.12***	0.01***	-0.95***
	(6.23)	(4.18)	(6.42)	(97.78)	(2.80)	(-6.53)
$D_{[0,+10]}$	0.0038***	0.0013***	0.09***	-0.02***	0.0024***	0.68***
	(5.15)	(7.75)	(2.88)	(-9.36)	(2.98)	(20.39)
$D_{PostCrisis}$	-0.0080***	-0.0020***	-0.25***	-0.23***	0.00	-0.61***
	(-8.96)	(-9.23)	(-5.89)	(-54.30)	(-1.48)	(-11.54)
$D_{[0,+10]} \times D_{PostCrisis}$	-0.0043***	-0.0012***	-0.18***	-0.09***	0.01***	2.69***
	(-3.23)	(-3.88)	(-3.17)	(-10.38)	(5.06)	(24.28)
R-sqrd	0.0788	0.069	0.0673	0.4098	0.0031	0.4173
N	35,892	26,526	17,682	275,048	275,048	275,048