Nondefault Bond Spread and Market Trading Liquidity*

Song Han† and Hao Zhou‡
Division of Research & Statistics
Federal Reserve Board
Washington DC

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Abstract

We examine the relationship between the nondefault component of corporate bond spread and liquidity measures constructed from intraday transactions data, with the default component controlled by the term structure of credit default swap (CDS). We explicitly control for the unobservable firm heterogeneity and conventional bond characteristics, in order to identify the stochastic liquidity effects over time across bonds issued by the same firm. We find a clear positive significant relationship between the illiquidity of intraday trading and nondefault bond spread. These trading liquidity effects identify a unique component of basis spreads that is uncorrelated with conventional liquidity proxy variables, particularly for highly-rated investment-grade bonds. Furthermore, nondefault bond spread is relatively high at the short end of the maturity and increasing with the bond age. The impacts of transaction based liquidity measures are robust to whether swap yield or Treasury yield is used as risk-free rate.

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†Capital Market Section, Federal Reserve Board, Mail Stop 89, Washington, DC 20551 USA. E-mail Song.Han@frb.gov, phone 202-736-1971, fax 202-728-5887.

‡Risk Analysis Section, Federal Reserve Board, Mail Stop 91, Washington, DC 20551 USA. E-mail hao.zhou@frb.gov, phone 202-452-3360, fax 202-728-5887.

1 Introduction

There is a large component of bond spread that is unrelated to firm's default risk (Jones, Mason and Rosenfeld, 1984; Elton, Gruber, Agrawal and Mann, 2001; Eom, Helwege and Huang, 2004), and only a small fraction of the total spread can be explained by the credit risk, especially for high investment grade bond at the short maturity (Huang and Huang, 2003). Recent empirical studies have found strong connection between the appropriately defined non-default spreads and various measures of bond liquidity (Longstaff, Mithal and Neis, 2005; Ericsson, Reneby and Wang, 2006; Nashikkar and Subrahmanyam, 2006)[1] and that liquidity risk factors may be priced in bond expected returns under a linear APT setting (see Chacko (2005), de Jong and Driessen (2004), and Downing, Underwood and Xing (2005), among others). These results are consistent with the theoretical framework that liquidity risk is driving the bond yield and is allowed to be correlated with the credit risk factor (see Liu, Longstaff and Mandell (2004) for a reduced-form model and Ericsson and Renault (2006) for a structural model).[2] We contribute to this literature by using direct liquidity measures constructed from intraday transaction data to explain the non-default spreads of individual bonds with appropriate control for the firm-specific credit risk and other unobserved heterogeneity. Our evidence across bond ratings and maturities relates directly the so-called credit spread puzzle that high investment grade bonds with short maturities have a relatively larger non-default spread component.

Due to the lack of direct liquidity measurements, most existing empirical studies typically focus on bond characteristics such as coupon, size, maturity, and age. However, since these characteristics are either constant or change deterministically with the passage of time, this approach may not identify the stochastic variation of the liquidity effect on non-default bond spreads. In contrast, we construct a set of direct measures of bond liquidity using the intraday transactions data from NASD's Trading Reporting and Compliance Engine, or TRACE. We consider three types of such measures: variables measuring price impact

[1] See also Chen, Lesmond and Wei (2005), Houweling, Mentink and Vorst (2005), and Perraudin and Taylor (2003) for direct evidence that total bond spreads are partly explained by the cross-sectional proxies for individual bond liquidity.

[2] Alternative explanations of the large non-default spreads include tax differential, market risk premia, and jump risk premia, etc. (Elton et al., 2001; Delianedis and Geske, 2001; Collin-Dufresne, Goldstein and Helwege, 2003; Cremers, Driessen, Maenhout and Weinbaum, 2005), although the magnitudes of these components are still subject to debate.

of trades, estimated transaction costs, and trading frequency variables.[3] Although these measures have been frequently used in the studies on stock market liquidity (see, e.g, Amihud and Mendelson (1986), Brennan, Chordia and Subrahmanyam (1998), Hasbrouck and Seppi (2001), Amihud (2002) and Hasbrouck (2005), among others), they only become available more recently for corporate bond market with the introduction of TRACE in 2001 and have already fostered the rapid growth in the research on corporate bond market liquidity (Downing et al., 2005; Edwards, Harris and Piwowar, 2004; Bessembinder, Maxwell and Venkataraman, 2006; Goldstein, Hotchkiss and Sirri, 2007). We complement the existing literature by examining the effect of *observed* bond trading illiquidity on the nondefault components of bond spreads and provide clear evidence that such an effect is positive and statistically significant.[4]

To control for the default component of bond spread, we follow Longstaff et al. (2005), Ericsson et al. (2006), and Nashikkar and Subrahmanyam (2006) by using the credit default swap (CDS) spread.[5] Under a CDS contract the protection seller promises to buy the reference bond at its par value when a pre-defined default event occurs. In return, the protection buyer makes periodic payments to the seller until the maturity date of the contract or until a credit event occurs. This periodic payment, usually expressed as a percentage of the notional value underlying a CDS contract, is called the CDS spread. Compared with corporate bond spreads, CDS spreads are a relatively pure pricing of default risk of the underlying entity, abstracting from numerous bond characteristics, such as seniority, coupon rates, embedded options, and guarantees. Thus, using CDS spreads to control for the default component of bond spread avoids the actual estimation of default probability and recovery rate, which would typically suffer from potential model misspecification problem. Also, unlike corporate bond spreads, CDS contracts are unfunded and do not face short-sale restrictions,

[3]Earlier papers have also studied bond liquidity effects based on other transaction data sets (Alexander, Edwards and Ferri, 2004; Hong and Warga, 2000; Schultz, 2001; Hotchkiss and Ronen, 2002; Hotchkiss, Warga and Jostova, 2002; Chakravarty and Sarkar, 2003).

[4]Recent studies by Chacko (2005), Chacko, Mahanti and Mallik (2005) and Nashikkar and Subrahmanyam (2006) have advocated an approach of "latent liquidity"—the weighted average turnover of investors who hold a particular bond by their fractional holdings of the amount outstanding—to measure the accessibility of bond to market participants.

[5]Duffie (1999) and Duffie and Liu (2001) show that using CDS spread as a direct measure of the default component may result in a small bias, and Longstaff et al. (2005).

reducing much the liquidity concerns in the CDS market.[6]

Unlike in previous studies where only 5-year CDS spreads were used, we utilize the entire term structure of CDS spreads provided by Markit. Thus, we are able to match exactly the maturities of all bonds and avoid using the conventional "bracket" method in approximating bond yields. More importantly, this method allows us to exploit the variations in our liquidity measures across different bonds issued by the *same firm*, which contrasts with many existing approaches that select only one bond for each firm. Using a fixed-effect approach, we can swipe away the common variations attributed to the unobserved firm characteristics and economic conditions that may be related to firm credit risk, thus recover the *bond specific* liquidity effect on nondefault spread and eliminate the potential estimation bias caused by unobservable firm heterogeneity.[7] In theory, bond liquidity can be intimately related to the issuer's credit risk, firm-wide funding risk, or systematic risks across the economy. Using the fix-effect approach and time series dummies plus controlling for various bond characteristics, we effectively orthogonalize the bond specific liquidity effects with respect to the firm specific credit or other risk factors, therefore discover the pure liquidity effects due to the stochastic transaction shocks.

We find a positive and significant relationship between the illiquidity of intraday trading and the nondefault bond spread. Such a estimated relationship become much weaker if the unobservable firm heterogeneity is not controlled for by the fixed effects, which suggests that there exists correlation between firm-specific liquidity and credit risks but the sign may be mixed, depending on firm's (unobserved) characteristics. The explaining power of these trading-based liquidity measures, in terms of regression R^2, seems to be the strongest for high investment grade (rated A- or higher) as 12-14 percent, less strong for the low investment grade (rated BBBs) as 9-11 percent, and the weakest for the speculative grade (rated BB or lower) as 3-4 percent. The positive liquidity effect coefficient is also uniformly significant across the rating groups for the price impact and trading frequency measures, but not significant across the low grades for the transaction cost measures. Additional diagnostics indicates that the non-default component or basis spread is increasing in the bond age and

[6] Tang and Yan (2006) examines the liquidity effects on CDS premium. See also Nashikkar and Subrahmanyam (2006).

[7] The empirical evidence on the relation between credit risk on liquidity effect can be mixed (Chen et al., 2005)—some positive (Alexander et al., 2004) and others non-existent (Schultz, 2001).

decreasing in the bond maturity. Our result is consistent with the findings of some calibration studies that while credit risk can explain most of the yield spread for speculative-grade bonds, a larger fraction (percentage-wise) of investment-grade bond spreads cannot be accounted for by the credit risk, especially at the short maturities—the so-called "credit premium puzzle" (e.g., Huang and Huang (2003)).

Controlling for the conventional proxy variables of bond liquidity, such as coupon rate, issues size, time-to-maturity, and age, does not diminish the sign and significance of the liquidity measures based on transaction data. In fact, now all of the eight measures are significant, as opposed to six when bond characteristics are not controlled for. There are more dramatic differences across the rating groups—as seven out of eight measures remain significant for high investment grade, three significant for low investment grade, and only one significant for speculative grade. Further diagnostics indicate that the most significant liquidity measures based on price impact of trades are almost orthogonal to the bond characteristics, while the lest significant liquidity measure based on trading frequency are highly collinear with the bond characteristics. These results suggest that conditional on predictable changes in bond liquidity associated with bond characteristics, our transaction based measures identify a unique component of the nondefault bond spreads due to the stochastic variations in bond liquidity with the passage of time. On the other hand, bond characteristics may vary cross-sectionally but only evolve deterministically or remain constant through time. Note also that bond characteristics like coupon rate, although indicating bond liquidity, may also proxy for the tax effect or credit risk (Elton et al., 2001; Longstaff et al., 2005), therefore their interpretation can be vague.

Finally, we find that the estimated liquidity effects of our transaction based liquidity measures are robust to using either swap rate or Treasury rate as alternative risk-free rate measures, but that the effects on the conventional liquidity proxy variables vary notably with different risk-free rate measures, which is consistent with the finding in Longstaff et al. (2005). One important implication is that our transaction based liquidity measures are uncorrelated with the differences in computed nondefault bond spreads resulting from alternative risk-free rates, which may be due to the differential tax effects (Longstaff et al., 2005). However, the conventional approach of using bond characteristics as liquidity proxies is not robust to the alternative risk-free rates, and is not separately identifiable from the differential tax effects.

The pronounced positive effects of illiquidity on the nondefault bond spread are consistent with recent studies showing that liquidity is an important pricing factor for corporate bonds (Chen et al., 2005; Downing et al., 2005; Bessembinder et al., 2006; Goldstein et al., 2007; Chacko et al., 2005). It is also consistent with the finding that CDS market usually leads bond market in the short-run price discovery process (Blanco, Brennan and Marsh, 2005; Zhu, 2005).[8] The lead-lag studies clearly point to an explanation that the CDS market is more liquid, due to its synthetic nature for pure credit risk pricing; while the bond market is relative illiquid, possibly due to the short sale constraint, clientele effect, and other transaction costs. Our evidence suggests that this statistical lead-lag relationship has its economic interpretation in that bond market trading liquidity does explain the dynamics of the difference between bond spread and CDS spread, or the so-called "basis spread".

The rest of the paper is organized as follows: Section 2 describes the constructions of our bond liquidity measures and discusses the summary statistics; Section 4 presents our main empirical findings; and Section 5 concludes.

2 Market Trading Liquidity Measures and Data Description

In this section, we first define three types of market trading liquidity measures, including price impact of trades, estimated trading cost, and trading frequency, based on intraday bond transactions data. We then describe our data sources and sampling scheme.

2.1 Constructing Market Trading Liquidity Measures

2.1.1 Liquidity Measures Based on Price Impact of Trades

We consider three measures of price impact of trades. The first one is the Amihud illiquidity measure, defined as the ratio of the absolute percentage change in bond price to the dollar

[8] Although in the long-run, CDS and bond spreads are in line with each other, as predicted by the no-arbitrage relationship (Duffie, 1999).

size of a trade (in million dollars). That is, for each trade j of bond i at day t, we define

$$\text{Amihud}_{j,t}^{i} = \frac{\frac{|p_{j,t}^{i} - p_{j-1,t}^{i}|}{p_{j-1,t}^{i}}}{Q_{j,t}^{i}}$$

where $p_{j,t}^{i}$ (in \$ per \$100 par) and $Q_{j,t}^{i}$ (in \$ million) are the transaction price and the size of the trade, respectively. Intuitively, this measure reflects how much prices move due to a given value of trade. Such measure has been used extensively in the literature on stock market liquidity (Amihud, 2002).

Following Hasbrouck (2005), we also consider the following modified Amihud measure to minimize the influence of outliers:

$$\widetilde{\text{Amihud}}_{j,t}^{i} = \sqrt{\text{Amihud}_{j,t}^{i}}.$$

For each day t, we calculate these Amihud-type measures for each trade and then average over all trades to form daily measures.

The third measure is defined as the ratio of daily price range, normalized by daily mean price, to the total daily dollar trading volume,

$$\text{Range}_{t}^{i} = \frac{\frac{\max_j p_{j,t}^{i} - \min_j p_{j,t}^{i}}{\overline{p}_{t}^{i}} \times 100}{Q_{t}^{i}}$$

where $Q_{t}^{i} = \sum_j Q_{j,t}^{i}$ and $\overline{p}_{t}^{i}$ is the daily average price. Intuitively, this "Range" measure, which is similar to the volatility impact measure used by Downing et al. (2005), reflects how much volatility in price is caused by a given trade volume.

The above measures reflect price impact of trades or market depth. Larger values suggest more illiquid bonds, as a trade of a given size would move prices more. By construction, daily Amihud-type measures are nonmissing only for bonds traded at least twice on the day. For the range measure to be reasonably informative while avoiding losing too many observations, we require a bond traded at least three times a day. We use medians of daily measures in a month as our monthly measures, since median is more robust to outliers than mean.

2.1.2 Liquidity Measures Based on Trading Cost

A commonly used measure for trading costs is bid-ask spreads. Unfortunately, our data do not have information on bid-ask quotes or on the side of a transaction initiating the trade– which potentially could be used to trace out effective bid-ask spreads. Instead, we construct two estimates for bid-ask spreads.

First, we use Roll's (1984) model to estimate the effective bid-ask spread, which is the square root of the negative covariance of adjacent price changes (Roll, 1984). That is,

$$\text{BidAsk}_t^i = 2\sqrt{-\text{Cov}(\tilde{p}_{j,t}^i - \tilde{p}_{j-1,t}^i, \tilde{p}_{j-1,t}^i - \tilde{p}_{j-2,t}^i)},$$

where $\tilde{p}_{j,t}^i = \log p_{j,t}^i$. The idea is that assuming informational efficiency and no news on a bond's fundamental values, bond prices should bounce back and forth within the band formed by bid-ask spreads. The price changes for adjacent trades should be negatively correlated because a current bid (ask) is more likely followed by an ask (bid). The extent of this negative correlation depends on the the width of the band.

Second, we also construct an indirect proxy for bid-ask spreads using the inter-quartile range (IQR) of trade prices, defined as the difference between the 75th percentile and 25th percentile of prices for the day normalized by daily average price . That is,

$$\text{IQR}_t^i = \frac{p_t^{i,75th} - p_t^{i,25th}}{\overline{p}_t^i} \times 100,$$

The idea is that assuming no news about fundamentals, price volatility is mostly due to the bid-ask spread as trades occur at bid and ask prices. The IQR measure captures intraday volatility but is less sensitive to outliers than the price range.

To compute the above two measures, we require a bond traded at least three times a day, and monthly observations are the medians of daily values.

2.1.3 Liquidity Measures Based on Trading Frequencies

Trading frequencies have been widely used as indicators for asset liquidity (see, e.g., Vayanos (1998), among others). Intuitively, all else equal, bonds that are more illiquid would trade less frequently. We consider the following three variables: (a) monthly turnover rate, which is the ratio of total trading volume in a month to bond outstanding; (b) the number of days that a bond traded at least once during a month; and (c) the total number of trades that occurred during a month.

2.2 Data Sources

Since the nondefault component of bond spread is measured by the difference between bond spread and CDS spread, we need data on bond yields, risk-free rates, and CDS spreads. We obtain daily secondary market yields as well as rating on corporate bonds in the Merrill Lynch Global Bond Index universe.[9] Our main risk-free rate measure is swap rate.[10] For robustness, we also compare results with using Treasury yields as the risk-free rate. The par yields of these risk-free bonds, estimated using Nelson and Siegel method, are used in bond spread calculations. The entire term structure of both rates are available from the Federal Reserve Board's public website. The CDS spreads are obtained from Markit, which provides composite quotes on CDS contracts with maturities at 6 month, 1, 2, 3, 5, 7, 10, 20, and 30 years. We linearly interpolate CDS spreads at immediately adjacent two of above maturity points to match the maturity of each bond issued by the corresponding firm.

To compute market trading liquidity measures, we use intraday transaction data of corporate bonds provided (through MarketAxess) by NASD's Trading Reporting and Compliance Engine, or TRACE, reporting system. The TRACE dissemination of corporate bond transaction data started on July 1, 2002 for a small number of selected bonds; but it gradually expanded to cover almost entire over-the-counter secondary market transactions in corporate bonds. More details on these data are presented in Appendix A.

2.3 Sampling

As most bonds are traded sparsely and the daily liquidity measures discussed above exhibit high variability, we decide to carry out our analysis at monthly frequencies as discussed above. The period of our analysis starts from July 2001 and ends December 2006. We keep only senior unsecured bonds issued by U.S. firms with term-to-maturity ranging from 1 year

[9] According to Merrill Lynch, the yields are option-adjusted in that the implied values of options written in the debt contracts, such as call or put, are presumably removed in the yield calculations.

[10] As suggested by the existing studies, swap rate is the preferred risk-free rate measure for the studying on liquidity effect because it reduces the impacts of factors such as tax on bond spreads (e.g., Longstaff et al. (2005); Blanco et al. (2005); Zhu (2005)).

to 20 years.[11]

In constructing our transaction based measures, we restrict our sample to trades occurring between 10:30AM and 3:30PM to further remove the impacts of news-driven trades and price movements, as company news usually arrives in the after-market hours and major economic data are generally released no later than 10AM. Finally, we follow the practice of existing studies using the TRACE data to remove trades with "price errors" (see, e.g., Downing et al. (2005); Edwards et al. (2004)).[12]

As shown in Panel A of Table 1, our final sample consists of 439 firms–identified by unique Merrill Lynch ticker–with total 1877 bonds–identified by bond CUSIPs, that is, about 4 bonds per firm. On average, each bond appears about 20 months during the total 54 months of our sampling period. In addition, as shown in Panel B of Table 1, the number of available bonds varies significantly by bond rating and, due to the phasing-in approach of TRACE dissemination (discussed in Appendix A), by time periods. Specifically, investment-grade bonds rated BBB and A are by far the most available, and AA and BB-rated bonds come next, with the fewest bonds in the both tails of the rating distribution (i.e., AAA and CCC/below). Still, the number of bonds, especially the speculative grade ones, is far greater than any of the existing studies, such as Longstaff et al. (2005). Finally, the number of bonds in each rating category increased substantially since Phase III of TRACE dissemination (which started from October 1, 2004).

3 Summary Statistics

Table 2 presents summary statistics of key variables used in this paper. As shown on Line 1, the mean of basis spreads computed using swap rate as risk-free rate is -13 basis points for the overall sample, with a median of -2 basis points and an interquartile range of 22 basis points and the 95th-5th percentile range of about 1 percent. The relatively wide range

[11] In addition, bonds that are putable, convertible, defaulted, with floating rate and sink fund features are deleted. Bonds with call options are kept, because otherwise, it will reduce the sample significantly (about 60 percent of bonds are callable. See Table 2). Note that Merrill's yields are option-adjusted, and we use callability as a control variable in our analysis. Moreover, excluding callable bonds does not change our main conclusions, and the results are available upon request.

[12] Specifically, we delete a trade if the trade size is missing or zero, or if its price is less than $1 or greater than 500, or if price is more than 20 percent away from median price in a day, or if price is more than 20 percent away from previous trading price.

with the small median value suggests that while on average basis spreads don't deviate much from zero, there exist large temporary variations away from zero. As shown in Line 2, such variations are also evident when basis spreads are computed using Treasury rate as risk-free rate, though both mean (25bps) and median (37bps) become positive as Treasury rates are always lower than comparable maturity swap rates. Our main goal is to understand whether and to what extent liquidity is a driving force of these variations.

These variations in basis spreads exist both across bonds and over time. Cross-sectionally, we show a selected set of summer statistics by three broad bond rating groups. As indicated by the statistics on the numbers of bonds, bonds rated A- or higher account for more than half of our total sample and BBB-rated bonds for about one-third. Comparing to the rating distribution of the overall corporate bond outstanding, our sample has modestly more investment-grade bonds.[13] Surprisingly, BBB bonds have largest median basis spreads while speculative grade bond the lowest. Over time, Figure 1 plots monthly median basis spreads by rating groups with swap rate as the risk free rate over the sample period. All three series show significant time variations, although interpretation of the behavior of the series before Phase III (October 2004) is tricky due to small sample sizes, especially for speculative-grade bonds (see Panel B of Table 1). Even so, since then, basis spreads for speculative grade bonds lingered just below zero, but basis spreads for investment grade bonds trended up over zero.

The summary statistics on liquidity measures are reported on Lines 3 through 10 of Table 2. For the overall sample, the median Amihud measure is 0.11, suggesting that a median trade, at about $50,000 (Line 16), would move price by roughly $0.5 percent. As a result of taking squared root, the median and mean values of the modified Amihud measure come closer than those of its original formula. The median price range measure is 1.46, suggesting that a median daily volume, at about $0.27 million (Line 17), would associate a roughly $0.4 percent price range relative to daily average price. The median estimated bid-ask spread is $0.77 on a par bond, and the median IQR measure is about 0.47 percent of daily average price. Corporate bonds are traded sparsely in that the median monthly

[13]Two factors contribute this "unbalanced" sample. First, as discussed in Appendix A, TRACE took three phases to reach full dissemination with the earlier phases disseminating transaction data on mostly highly rated investment-grade bonds (see Panel B of Table 1). Second, there are fewer firms with relatively complete term structure of CDS quotes for speculative-grade bonds.

turnover rate is 0.02, meaning that on average it takes about 50 months for a bond to turn over once. The median number of traded days is 10 days, and the median number of trades in a month is 22.

By rating, it is clear that by all price impact measures, BBB bonds appear to be the most liquid, though speculative-grade bonds are close to BBB bonds, except by the price range measure. A or above rated investment-grade bonds appear to be the least liquid by these measures. By transaction cost measures, A or above rated investment-grade bonds appear to be the most liquid and are similar to BBB bonds. Surprisingly, the median turnover rates are almost the same across rating categories. But for other two trading frequency measures, BBB bonds appear to be the most illiquid rating group, opposite to the pattern observed in price-related liquidity measures. Later on, we attribute this puzzle to the fact that trading frequencies are more correlated with the bond characteristics.

Average bond characteristics are shown in Lines 11 to 15 of Table 2. For the overall sample, the median bond in a typical month has a coupon rate of 6.4 percent, is just over 3 years since issuance, has just over 5.5 years left to maturity, and has $400 million dollars outstanding. About 60 percent of bonds are callable. Not surprisingly, median coupon rate increases in bond rating. In addition, speculative-grade bonds tend to be smaller, older, and more likely callable, but comparisons of remaining maturity across rating groups are mixed.

Figure 2 shows the overall sample distributions of bond age, remaining maturity, and maturity at issuance. The number of bonds decreases quickly for those older than 9 years or those with more than 10 years of remaining maturity. These distributions suggest that in interpreting results related to age and remaining term-to-maturity, we have to be cautious about the reliability over the range greater than 10 years. In addition, while there are wide variations in the maturity at issuance, over half of the bonds are issued at around 10 years, with other mass points at 3, 5, 7, 15, 20, and 30 years.

It is interesting to examine unconditionally how basis spreads and our liquidity measures are related to each other and to bond characteristics. Figure 3 plots basis spreads and liquidity measures–only three of them to save space–by 7 finer bond rating groups. Interestingly, median basis spreads appear to be constant for bonds rated A or higher and then move higher for BBB- and BB-rated bonds, they drop sharply for B or lower rated bonds. While basis spreads appear to be negatively correlated with bond turnover rate, as conjectured, they also appear to be negatively correlated with illiquidity measures, as opposite to common views. In addition, these correlations are mostly driven by observations at deep junk rating groups, where as alerted above the number of bonds is small.

Figures 4 plots basis spreads and selected liquidity measures by bond age. It shows that basis spreads increase very much linearly in age, so do the Amihud measure and the estimated bid-ask spread. Turnover rates decrease in bond age, especially sharply at the short end of the age range. Figure 5 plots basis and selected liquidity measures by remaining maturity. Interesting, basis spreads decrease quickly at the short term-to-maturity and remain roughly flat until reaching the tail of the maturity distribution. The pattern at the short maturity confirms unconditionally the findings by previous studies such as Huang and Huang (2003) that credit risk accounts smaller fraction of bond spreads when approaching the shorter end of maturity. Both Amihud measure and the estimated bid-ask spread increase in remaining maturity, while turnover rate does so only up to 10 years and then fell sharply. Again, as a cautious note, we have to keep in mind that the number of bonds fall substantially for bond age older than 9 years and remaining maturity greater than 10 years.

4 Regression Results

We now report regression results on the impact of liquidity on basis spreads. First, as a benchmark, we present results from OLS regressions of basis spreads on our trading liquidity measures using the overall sample, where basis spreads are computed using swap rate as risk-free rate. Particularly, we show that the richness of our data allows us to use firm and time fixed effect models to better identify liquidity effects. These results are followed by regressions by rating groups. Then we add into our models bond characteristics that previous studies used as proxies for bond liquidity, showing that trading liquidity measures remain significant in explaining variations in basis spreads. Finally, we show results using Treasury rate as the alternative risk-free rate measure and caution the usefulness of previous approach gauging the effect of tax on bond spreads. Note that to avoid the impact of outliers, we windsorize the sample at 5 percent of both basis spreads and liquidity measures used in each regression. In addition, we convert all liquidity measures to log scale in all regressions.

4.1 Benchmark Results

Table 3 reports our results on the impact of trading liquidity on basis spreads. Panel A shows simple univariate OLS regressions of basis spreads on our trading based liquidity measures using the overall sample. Standard errors of the estimated coefficients are computed using the Huber/White robust method assuming that regression residual terms may be correlated across bonds issued by the same firm but uncorrelated across firms.

The results show that the estimated coefficients on all three trading frequency measures have expected negative signs and are statistically significant at the 95 percent confidence level. However, only one of the three price impact variables, the price range measure, is statistically significant with an expected positive sign, and neither of the two transaction cost measures is significant. Moreover, the largest R^2 among all regressions is just 3 percent.

Intuitively, these simple OLS regressions use total variations–across bonds and firms and over time–in the liquidity measures to identify the impact of liquidity. These estimates may be flawed if there are unobservable firm characteristics or market conditions that are correlated to both trading liquidity measures and basis spreads. For example, clientele effects among institutional investors associated with differently rated firms may generate liquidity impacts on bond spreads (see, e.g., Chacko et al. (2005)). These unobservable heterogeneities may bias the simple OLS estimates in an unpredictable direction.

To reduce the impact of these unobservable factors, we use a fixed effect model to reestimate the above models, essentially by including firm dummy variables indicating bond issuers and time dummy variables indicating the month of the observation. These fixed effect models remove the impacts of both firm- and time-specific factors which may affect bond basis spreads and be correlated with trading liquidity measures. Thus, the impact of trading liquidity measures on basis spreads is identified by temporary variations across bonds, both within and across firms, and over time that are unrelated to macroeconomic conditions. The richness of our data, especially with the full term structure of CDS spreads that allows multiple bonds for a single firm at any given time, gives us enough degree of freedom to estimate these fixed effect models.

As shown in Panel B of Table 3, after controlling for unobservable heterogeneity, not only do all coefficients have expected signs, they are also mostly statistically significant at the 95 percent confidence level. In addition, all R^2 (based on the within effect result) increase to about 7 percent.

Note that all liquidity measures are in log scales. Economically, the magnitude of the impact of liquidity appears to be modest. For example, the coefficient on Amihud measure, column (9), is 0.27. So suppose Amihud measure changes from its median 0.11 (Line 3 of Table 2) by the size of its interquartile range 0.35–meaning the price impact of a median trade, at about $\$50,000$ (Line 15 of Table 2), increases roughly from 0.5 percent ($= 0.11*0.05$) to about 2 percent ($= (0.11+0.35)*0.05$). Then the nondefault components of bond spreads would increase by about 0.4 basis points ($= 0.27*\log[(0.11+0.35)/0.11]$) with a 95 percent confidence interval of $[0.3, 0.5]$ basis points. Similarly, if the speed of turnover increases from its median level 0.02 by the size of its interquartile range 0.03, the nondefault components of bond spreads would decrease roughly 1 basis point with a 95 percent confidence interval of $[0.9, 1.2]$ basis points. While all these numbers are rather small in absolute values, they are nontrivial relative to the near zero unconditional median of basis spreads.

4.2 Liquidity Effects By Rating

How does the impact of liquidity on the nondefault component of bond spreads vary with bond rating? To answer this question, we divide our sample by three broad rating groups, including bonds rated A- or higher, bonds rated BBB+, BBB, or BBB-, and bond rated speculative grade, and reestimate the fixed effect models. The results are reported in Table 4.

Overall, the liquidity effects are pronounced for all rating groups. Let us first look at the signs and statistical significance of the estimates. As shown in Panel A, for bonds rated A- or higher, all estimated coefficients have expected signs and are statistically significant at the 95 percent confidence level, with R^2 ranging from 12 to 14 percent. For both BBB-rated and speculative-grade bonds, the estimated coefficients on the price impact and the trading frequency measures all have have expected signs and are statistically significant, with R^2 equal to roughly 10 percent for BBB bonds and 4 percent for speculative-grade bonds. Estimates on transaction cost variables, though, are not significant and may have "wrong" signs.

In term of economic magnitude, basis spreads move the most for speculative-grade bonds for a given size of change in any liquidity measure; but comparison among investment-grade bonds depends on which measure is used. Roughly speaking, liquidity effects appear to be more pronounced for A- or higher-rated bonds when using trading frequency measures, and for BBB-rated bonds when using price impact measures. The results are qualitatively the same if we calculate the magnitude by assuming that a liquidity measure increases from its median by the size of its interquartile range. Our finding that the effects of trading liquidity on speculative grade bonds are more pronounced than investment-grade bonds when not controlling for other bond characteristics is consistent with some of the existing literature and conventional view (e.g., Downing et al. (2005)).

It is worth noting again that to reach the above conclusions, our study is different from previous work in two key areas. First, our rich data on the term structure of CDS spreads allow us to better control the default component of bond spreads and, more importantly, to better control for unobservable firm or economic risk factors. To the extent these factors may be correlated with liquidity and bond spreads, previous estimates on the liquidity effects such as by Longstaff et al (2005) may be biased. The richness of our data gives us enough degree of freedom to use fixed effect models to remove such potential biases. Second, we use transaction based measures for liquidity while previous work mostly used bond characteristics as proxies. Since bond characteristics are predictable, previous work relies mainly on cross bond variations to identify the liquidity effects and cannot identify the impact of stochastic variations over time in liquidity on bond spreads. Our transaction based liquidity measures solve this issue as they vary both over time and across bonds stochastically. Below we study the additional explanatory power of our trading liquidity measures after controlling the commonly-used liquidity proxies, showing that the impact of stochastic variations in trading based liquidity measure is robust.

4.3 Impacts of Conventional Proxies for Liquidity

Bond characteristics that were commonly used as proxies for liquidity measures in existing studies include coupon rate, bond age, remaining maturity, and the size of bonds. To allow more flexible and potentially nonlinear functional forms, we use a 4-order polynomials for bond age and remaining maturity.[14] Briefly speaking, coupon is believed to be a reasonable proxy because bonds with large coupons may be more likely subject to buy-and-hold investors and thus may be less liquid. There is also evidence that trading frequency is highly correlated with bond age, term-to-maturity, and issue size (Alexander et al., 2004; Hotchkiss and Ronen, 2002; Edwards et al., 2004; Downing et al., 2005). In addition to the above variables, we also include a dummy variable indicating whether a bond is callable.

Note that with these additional proxies, controlling unobservable firm or economic factors using fixed effect methods may become even more important because these proxies may be correlated with credit risk, which in turn may be correlated the unobservable factors affecting basis spreads. For example, coupon is obviously correlated with credit risk as lower credit quality issuers have to price higher yields to compensate investors for taking extra risks. Also, bond size may also be correlated with credit risk as only larger and better credit quality firms can issue larger bonds. Thus, to the extent that the unobservable firm or economic factors may be correlated with credit risk, the estimates on these proxies may be biased if such unobservables are not appropriately controlled for.

In Table 5, we report estimation results from fixed effect models after adding liquidity proxies to our benchmark models using the overall sample. Comparing with Panel B of Table 3, we see that all of our transaction based liquidity measures, including transaction cost measures, are now statistically significant and have expected signs. Also, coefficients on trading frequency measures are now significantly lower (in absolute values), but coefficients in price impact measures are largely similar. These observations suggest that first, the trading liquidity measures are important to understand stochastic variations in basis spreads; second, both transaction costs and trading frequency measures may be highly, while price impact measures may be less, correlated with the liquidity proxies. Such conjecture is confirmed in Table 6 where we regress our liquidity measures on the liquidity proxies. In particular, R^2s for trading frequency measures range from 13 to 33 percent. R^2s for Amihud type measures are only 4 percent while R^2s for the rest regressions range from 12 to 16 percent.

The liquidity proxy variables are mostly statistically significant in these regressions. Note

[14] We also experimented using dummy variables to indicate each year (up to 20) of bond age and remaining maturity and using dummy variables to indicate brackets of bond age and remaining maturity using conventional cutoff points at 1, 3, 5, 7, and 10 years. The results are roughly the same as reported here.

that the significance of liquidity proxy variables change little after adding our transaction based liquidity measures (i.e., from column (1) where only proxies are used to columns 2 to 9), suggesting that our trading liquidity measures identify a distinct component of basis spreads associated with stochastic variations in bond trading liquidity. Overall, basis spreads are positively associated with coupon rate and bond size but negatively with call option. Basis spreads are also statistically significantly related to bond age and remaining maturity. As plotted by the solid lines in Figure 6, basis spreads increase almost linearly in bond age, but decrease sharply in remaining maturity but stay flat after 5 years.

It is worth to point out that some of our results are opposite to what is found in the literature. For example, we find that basis spreads are positively, not negatively, related to bond size. Given our fixed effect approach, this finding suggests that large bonds may be less liquid than small bonds among bonds issued by the same firm conditional on same economic conditions. It also suggests that previous findings may pick up the correlation between bond size and nondefault component of bond spreads partly by comparing large bonds issued by one firm to small bonds issued by another firm. If credit quality or unobservable firm or economic factors are not well controlled for, those findings may just reflect the correlation between bond size and credit risk.

As before, we also conduct the same analysis by rating group, and the results are reported in Table 7. The striking result is that all trading liquidity measures, except the number of trades, are statistically insignificant for speculative-grade bonds. For A- or higher-rated bonds, our trading liquidity measures, except the number of days with trades, continue to be statistically significant, while for BBB-rated bonds, only Amihud-type measures and estimated bid-ask spreads are statistically significant. Compared with Table 4 where liquidity impacts appear more pronounced for speculative-grade bonds, these results suggest that most of the correlation between basis spreads and trading liquidity are closely associated with bond characteristics. Such association becomes weaker as bond rating improves, as evident by the continued significance of trading liquidity measures for A- or higher-rated bonds. These results suggest that our trading liquidity measures identify a unique component of basis spreads that is orthogonal to conventional liquidity proxies for A- or higher-rated bonds.

Among regressors that are not shown in the table, coupon continues to be positive and statistically significant for all rating groups. The dummy variable indicating callability remain negative for all regressions but only statistically significant for A- or higher-rated bonds. Coefficients on bond size are mixed in signs and none of them is statistically significant, suggesting that conditionally other regressors, issue size is highly correlated with bond rating. Coefficients on bond age and on remaining maturity are, respectively, jointly significant, and their relations with basis spreads are plotted in Figure 6. We only plot the functions for age and remaining maturity up to 10 years, because standard errors of the fitted values beyond 10 years become too high due to the small number of observations. As shown in Plot A, basis spreads increase almost linearly in bond age for both groups of investment-grade bonds; but for speculative-grade bonds, basis spreads decrease in bond age until at about 4 years and then rose gradually. As shown in Plot B, for A- or higher-rated bonds, basis spreads decrease sharply in remaining maturity until about 4 years and then rose slowly. For BBB-rated bonds, basis spreads also decrease sharply initially but stay roughly flat after 5 years. For speculative-grade bonds, basis spreads decrease all the way over the plotted range.

Our findings on remaining maturity are consistent with previous studies suggesting that a large fraction of investment-grade bond spreads, especially at the short end of the maturity range, cannot be accounted for by credit risk (e.g., Huang and Huang 2003). Our results also suggest that this may also be true for speculative-grade bonds. In addition, our findings on bond age suggest that credit risk may not account for the bond spreads for young speculative-grade bonds either.

4.4 Robustness Analysis

4.4.1 Treasury Rate as Risk-Free Rate

Swap rate has been regarded as the appropriate risk-free rate measure for studying liquidity impacts on basis spreads, as it offers better control for tax effects. Nonetheless, using swap rate has its own drawbacks. For example, swap rate has a component compensating for counterparty default risks and the benchmark Libor rate also has a credit risk component. For robustness, we repeat our estimations with basis spreads computed using Treasury rate as the risk-free rate measure. In Table 8, we report the results on the estimations that mirror those in Table 5.

We find that the coefficients on our transaction based liquidity measures are the same in both sign and statistical significance as those with swap rate as the risk-free rate. The magnitudes of the coefficients are also close. These findings suggest strongly that the difference in computed basis spreads resulting from alternative risk-free rate measures, which are possibly due to such effects as differential tax treatment, is uncorrelated with our transaction based liquidity measures.

Interestingly, coefficients on many of the conventional liquidity proxy variables change notably. In particular, coefficients on coupon are smaller now in all regressions. On a related note, (Longstaff et al., 2005) argued that one can use the difference in estimated coefficients on coupon rates between using Treasury rate and using swap rate as a measure of tax effect on bond spread. Based on our estimates, though, coefficients on coupon are smaller when using Treasury rate as risk free rate, which would result a negative tax effect! Our results thus suggest that the said method of identifying tax effect may be not robust to the controlling of trading based liquidity effect or unobservable firm-specific heterogeneity in credit risk. Clearly, there remains more structural research to do to understand the tax effect.

4.4.2 Robustness Analysis

We also conduct a number of other robustness analysis, and our main conclusions are unchanged. These analyses include using only the TRACE full dissemination periods, using basis spreads relative to bond spreads or coupon rate as dependent variable, using only bonds with original maturity of 10 years (including remaining maturity but not bond age as regressors), using only bonds whose yields are close to par to reduce the coupon effect in computing the bond yields, and using a sample excluding AAA and CCC or lower rated bonds.

5 Conclusion

In this paper we examine the relationship between the nondefault component of corporate bond spreads and bond liquidity. We control default component of bond spreads using a rich term-structure of CDS spreads, and measure bond liquidity using newly available intraday bond transaction data. We construct three types of transaction based liquidity measures: price impact of trades, estimated transaction costs, and trading frequency variables. The richness of our data set allow us to use fixed effect models to control for the unobservable firm and economic factors that may be correlated with both the nondefault components of bond spreads and bond liquidity. In addition, we also control for conventional liquidity proxy variables such as coupon rate, issue size, time-to-maturity, and bond age.

We find clear positive and significant relationship between the nondefault bank spreads and illiquidity of intraday trading. We show that such estimated relationship would appear weaker if the unobservables firm and economic factors were not well controlled for. We also find that the trading liquidity effect is not correlated with conventional liquidity proxy variables for the highly rated investment-grade bonds, but weakly correlated with those proxies for BBB-rated bonds and highly correlated with those proxies for the speculative-grade bonds. These results are consistent with previous bond pricing studies that while credit risk can explain most of the yield spread for speculative-grade bonds, a larger fraction of investment-grade bond spreads cannot be accounted by credit risk.

Since changes in the conventional liquidity proxies are predictable, mostly existing studies rely on cross-sectional variations to identify the liquidity effects. Our transaction based liquidity measures vary stochastically both over time and cross sectionally. Empirically, we find that our measures identify a distinct component of basis spreads due to the stochastic variations in bond liquidity. We also find that the estimated liquidity effects of our transaction based liquidity measures are robust to using Treasury yield as alternative risk-free rate measures.

For future research, the strong statistic evidence for the positive relationship between the nondefault bond spreads and trading liquidity suggests that it is important to incorporate factors such as price impact of trades and transaction costs into the bond pricing models, at least in the studies on short-term behavior of bond spreads. In addition, our results call for further reevaluations on the impact of tax on bond spreads.

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Appendix

A Data Sources

Our paper uses four main sources of data to study the impact of bond liquidity on basis spreads, including data on corporate bond yields, CDS spreads, risk-free rates, and intraday bond transactions. We discuss these data sources below.

A.1 Bond Yields

We obtain daily secondary market prices and yields on corporate bonds in the Merrill Lynch Global Bond Index universe. The prices are bids, either indicative or "live" quotes, collected from dealers at the close of business days, and the yields are option-adjusted in that the values of options written in the debt contracts, such as call or put, are removed in the yield calculations. Our monthly bond yield measures are just average of daily effective yields in a month. We also use Merrill's composite ratings for bond ratings, which may only change at rebalancing at the end of each month.

The advantage of using these quotes as bond price measures is twofolds. First, because all quotes are on the bid sides, the daily changes in prices are not caused by the side of transactions. Since the publicly disseminated TRACE data don't include the side of transactions, changes in observed transaction prices may simply be because one price is on the bid side and the other on ask side, even if there is no change in the bond's fundamental value or in the bid-ask spreads. Second, because most bonds are traded sparsely, using daily transaction prices for valuation purpose would result in many missing values. To the extent that the quotes in Merrill's data reflect market participants' valuations of the bonds, they preserve better continuity of market valuation.

A.2 CDS Data

Data on CDS spreads are from Markit, a comprehensive data source that assembles a network of industry-leading partners who contribute information across several thousand credits on a daily basis. Using the contributed quotes, Markit creates the daily composite quote for each CDS contract that has sufficient quotes.

We create the monthly CDS spread by calculating the average composite quote in each month. To avoid measurement errors, we remove those observations for which huge discrepancies (above 20 percent) exist between CDS spreads with modified restructuring clauses and those with full restructuring clauses. We also removed CDS spread higher than 20 percent because they are often associated with the absence of trading or a bilateral arrangement from an upfront payment.

We use CDS contracts on maturities at 1,2,3,5,7,10,30 years with modified restructuring clauses. These rich maturity structures allow us to interpolate CDS spreads at any maturity within the range.

A.3 Bond Trading Data

We create liquidity measures using the intraday transaction data on corporate bond tradings. The data are from NASD's Trading Reporting and Compliance Engine, or TRACE, reporting system. As a bid to increase the transparency of corporate bond market, the NASD now requires its members to report report OTC secondary market transactions in eligible fixed income securities to the NASD through TRACE. In addition, the NASD adopted three phases to incrementally disseminate these trade reports to the public.

- Phase I: July 1, 2002, only about 500 bonds were subject to dissemination to the public. These included all investment-grade bonds with an original issue size of $1 billion or more and the 50 high-yield bonds that were rolled over from the Fixed Income Pricing System (FIPS). While small in number, these bonds reportedly accounted for about 50 percent of total trading volume at the time.

- Phase II: March 3, 2003, the NASD disseminated all investment-grade bonds with original issue size of $100 million or more and rating A3/A- or higher. Subsequently, an additional 120 BBB-rated bonds (40 each for BBB-, BBB, BBB+) were added on April 14, 2003. Total number of bonds subjected to dissemination reached about 5000 in this phase.

- Phase III: two stages leading to complete dissemination. On October 1, 2004, about 17,000 bonds were added to the dissemination list, bringing the total number of disseminated bonds to about 21,600. Later on February 7, 2005, all bonds, except the TRACE-eligible Rule 144A bonds which account for about one-sixth of all eligible bonds, became subject to dissemination, bringing the total number of disseminated bonds to about 29,300.

More details on TRACE rules can be found in NASD (2004). We obtain the publicly disseminated intraday transaction data through MarketAccess. The data include transaction price (including the effect of any dealer commission), trade size, settlement time, bond CUSIP, and other trade related variables. Our data, however, do not have some critical transaction information such as whether the trade was initiated by the buyer or by the seller. An additional limitation is that the trade size in our data is capped at $1 million for high-yield bonds and $5 million for investment-grade bonds.

A.4 Risk Free Rates

While it is safe to say that Treasury securities are risk free, the Treasury yields may be affected by a number of factors, such as liquidity of Treasury market, taxation, and regulation. For example lower capital requirements for financial institutions to hold Treasury securities and higher demand for holding Treasury securities to fulfill regulatory requirements make give addition values to Treasuries beyond a pure risk-free rate instruments (Duffee, 1996; Reinhart and Sack, 2001).

Because of these reasons, a number of studies have argued that swap zero-coupon curve is the preferred risk-free rate measure for the study of liquidity effect because it reduces the impacts of factors such as taxation on bond spreads as swaps don't have any special tax or regulatory treatments (e.g., Houweling and Vorst (2005); Longstaff et al. (2005); Blanco et al. (2005); Zhu (2005)).

Nonetheless, swap rate may be still a distorted risk-free rate measure because at least counterparty credit risk would affect its pricing. For robustness, we compare the results with Treasury rate as the risk-free rate to those with swap rate. We obtain the entire term structure of both rates from the Fed Reserve Board's public website. In particular, the swap rate is the International Swaps and Derivatives Association (ISDA) mid-market par swap rates. Rates are for a fixed rate payer in return for receiving three month LIBOR, and are based on rates collected at 11:00AM. Again monthly data are just average of daily values of these rates in a month.

Table 1: **Sample Description**

Our sample period is from July 2001 to December 2006. We keep only senior unsecured bonds issued by U.S. firms with remaining maturity at any time in the range of 1 to 20 years. Also, bonds that are putable, convertible, defaulted, with floating rate and sink fund features are deleted, but bonds with call options are kept. For bond transaction data, we only use trades occurring between 10:30AM and 3:30PM. In addition we remove trades with "price errors" as in Downing et al. (2005) and Edwards et al. (2004).

Panel A: Overall Sample Accounting

Variable	Mean	Std. Dev.	Min	Median	Max	N
N. of months per bond	20	13	1	20	54	1877
N. of bonds per firm	4	5	1	3	44	439

Panel B: Sample Accounting by Bond Rating and TRACE Dissemination Phases

	Average number of bonds				N. of unique	
	Phase I	Phase II	Phase III.1	Phase III.2	bonds	firms
Bond rating	Jul02-Feb03	Mar03-Sep04	Oct04-Jan05	Feb05-Dec06	Jul02-Dec06	
AAA	0	7	10	7	15	4
AA	26	58	61	79	216	27
A	53	379	363	273	681	131
BBB	31	82	467	349	782	220
BB	6	7	97	165	375	118
B	4	5	45	73	167	72
CCC/lower	1	2	36	22	81	26
Total	121	540	1079	968	2317	598

Data sources: Merill Lynch, Markit, and NASD TRACE.

Table 2: **Summary Statistics for Whole Sample. Monthly Data from July 2001 to June 2006.**

Variable definitions. Basis spreads=bond yield − risk-free rate − CDS spread, where risk-free rate may be swap rate or Treasury rate; Amihud measure: Amihud = $\frac{|p^i_{j,t}-p^i_{j-1,t}|}{p^i_{j-1,t}}/Q^i_{j,t}$; Modified Amihud measure: $\text{Amihud}^m = \sqrt{\text{Amihud}}$; Estimated effective bid-ask spread: $\text{BidAsk}_{it} = 2\sqrt{-\text{Cov}(\tilde{p}_{it+1}-\tilde{p}_{it}, \tilde{p}_{it}-\tilde{p}_{it-1})}$ with $\tilde{p}_{it} = \log p_{it}$; Interquartile price range measure: $\text{IQR} = \frac{p_t^{i,75th}-p_t^{i,25th}}{\overline{p_t^i}} \times 100$; Other variables are self-explanatory.

	Entire Sample							**A- or higher**				**BBB**				**High-yield**			
Variables	N	Mean	P5	P25	P50	P75	P95	N	P25	P50	P75	N	P25	P50	P75	N	P25	P50	P75
Basis spreads:																			
1. Corp. yield-swap-CDS (bps)	37768	-12.90	-66.30	-12.10	-1.91	9.75	35.20	19065	-10.60	-3.65	5.39	11687	-6.77	3.83	14.00	7016	-63.00	-12.10	14.70
2. Corp. yield-Treas-CDS (bps)	37768	25.40	-26.30	24.10	36.80	50.40	72.70	19065	24.60	33.80	44.10	11687	32.80	44.70	56.20	7016	-21.50	29.10	56.80
Price impact of trades:																			
3. Amihud illiq. (abs(ret)/$M)	34558	0.29	0.00	0.01	0.11	0.34	1.01	18072	0.04	0.14	0.34	10033	0.00	0.06	0.31	6453	0.00	0.07	0.41
4. Sqrt. Amihud illiq.	34558	0.33	0.02	0.10	0.27	0.47	0.82	18072	0.17	0.30	0.47	10033	0.05	0.20	0.45	6453	0.06	0.20	0.50
5. P range/mean(P)/vol (%/$MM)	29253	6.96	0.03	0.33	1.46	5.24	27.50	15999	0.58	1.87	5.64	7733	0.12	0.79	4.43	5521	0.22	1.14	5.13
Transaction costs:																			
6. Estimated bid-ask spread (%)	24866	1.04	0.13	0.40	0.77	1.38	2.79	14081	0.41	0.73	1.23	6178	0.32	0.72	1.39	4607	0.50	1.07	1.88
7. Price IQR/mean price (%)	29253	0.69	0.06	0.24	0.47	0.94	2.00	15999	0.24	0.44	0.82	7733	0.20	0.45	0.94	5521	0.29	0.68	1.28
Trading frenquency:																			
8. Turnover rate	36443	0.04	0.00	0.01	0.02	0.04	0.11	18334	0.01	0.02	0.04	11275	0.01	0.02	0.05	6834	0.01	0.02	0.05
9. Number of traded days	37243	11	2	5	10	17	21	18915	7	13	19	11408	3	7	13	6920	5	10	16
10. Number of trades	37243	61	2	9	22	61	236	18915	12	30	79	11408	5	13	33	6920	9	22	53
Bond characteristics:																			
11. Coupon (%)	37768	6.31	3.88	5.25	6.38	7.25	8.88	19065	4.88	5.88	6.88	11687	5.38	6.38	7.13	7016	6.75	7.50	8.50
12. Age (year)	37768	3.95	0.37	1.57	3.07	5.43	11.00	19065	1.50	3.05	5.54	11687	1.55	2.91	4.77	7016	1.80	3.45	6.29
13. Term-to-maturity (year)	37768	6.07	1.46	3.21	5.46	8.13	13.50	19065	2.95	4.96	8.09	11687	3.50	6.00	8.26	7016	3.54	5.75	8.01
14. Callable (1 if yes)	37768	0.60	0	0	1	1	1	19065	0	0	1	11687	1	1	1	7016	0	1	1
15. Bond size ($100mm)	37768	5.45	1.50	2.50	3.99	6.00	15.00	19065	2.50	4.00	7.50	11687	2.71	3.50	5.27	7016	2.00	3.00	5.00
Memo items:																			
16. Median trade size ($MM)	37243	0.34	0.01	0.02	0.05	0.20	1.80	18915	0.02	0.03	0.06	11408	0.03	0.09	0.55	6920	0.03	0.10	0.71
17. Median daily volume ($MM)	37243	0.95	0.02	0.08	0.27	1.00	4.60	18915	0.07	0.18	0.53	11408	0.10	0.42	1.81	6920	0.13	0.62	1.00
18. Monthly trading vol ($MM)	37243	23.30	0.16	2.57	9.33	25.00	91.40	18915	2.44	9.45	26.00	11408	2.84	10.20	27.50	6920	2.55	7.83	19.20

Data sources: Merill Lynch, Markit, TRACE, Federal Reserve Board.

Table 3: **The Effect of Bond Liquidity on Bond Spreads**

(1) Variable definitions. Amihud measure: Amihud $= \frac{|p^i_{j,t} - p^i_{j-1,t}|}{p^i_{j-1,t}} / Q^i_{j,t}$; Modified Amihud measure: Amihud^m $= \sqrt{\text{Amihud}}$; Estimated effective bid-ask spread: BidAsk$_{it}$ $= 2\sqrt{-\text{Cov}(\tilde{p}_{it+1} - \tilde{p}_{it}, \tilde{p}_{it} - \tilde{p}_{it-1})}$ with $\tilde{p}_{it} = \log p_{it}$; Interquartile price range measure: IQR $= \frac{p_t^{i,75th} - p_t^{i,25th}}{\overline{p_t^i}} \times 100$; Other variables are self-explanatory. (2) Figures in parentheses are robust standard errors. * and ** indicate the coefficient is statistically significant at the 90 and the 95 percent confidence levels, respectively.

Dependent variable = Bond yield − swap rate − CDS spread								
	Corresponding [Il]liquidity measure used =							
	Amihud Illiquid.	Sq. root Ami. Illiq.	Prc rng/ volume	Bid-ask spreads	IQR/ m(p)	Turnover rate	N of days w. trades	N of trades
Panel A. OLS regressions with clustering and robust standard errors								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOG([Il]liquidity)	-0.20	-0.27	0.50**	-1.09	-0.76	-1.61**	-3.56**	-2.01**
	(0.32)	(0.63)	(0.17)	(1.07)	(0.79)	(0.34)	(0.60)	(0.36)
Constant	-3.45**	-3.32**	-3.73**	-4.18**	-3.83**	-8.76**	5.40**	4.16**
	(1.44)	(1.54)	(0.83)	(1.23)	(1.35)	(1.83)	(1.05)	(1.08)
Observations	28237	28237	23766	20281	24056	29855	32352	31256
R^2	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02
Panel B. OLS regressions with firm and time fixed effects and robust standard errors								
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
LOG([Il]liquidity)	0.27**	0.61**	0.54**	0.10	0.11	-1.12**	-1.92**	-1.19**
	(0.05)	(0.10)	(0.06)	(0.14)	(0.12)	(0.07)	(0.14)	(0.10)
Constant	3.06**	3.27**	1.25**	1.27**	2.16**	-1.58**	7.20**	6.89**
	(0.27)	(0.28)	(0.25)	(0.28)	(0.27)	(0.38)	(0.36)	(0.37)
Observations	28237	28237	23766	20281	24056	29855	32352	31256
R^2	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.07
Number of firms	404	404	382	365	383	416	421	415

Table 4: **The Effect of Bond Liquidity on Bond Spreads by Bond Ratings**

(1) Variable definitions. Amihud measure: Amihud $= \frac{|p^i_{j,t} - p^i_{j-1,t}|}{p^i_{j-1,t}} / Q^i_{j,t}$; Modified Amihud measure: Amihud^m = $\sqrt{\text{Amihud}}$; Estimated effective bid-ask spread: BidAsk$_{it}$ = $2\sqrt{-\text{Cov}(\tilde{p}_{it+1} - \tilde{p}_{it}, \tilde{p}_{it} - \tilde{p}_{it-1})}$ with $\tilde{p}_{it} = \log p_{it}$; Interquartile price range measure: IQR = $\frac{p^{i,75th}_t - p^{i,25th}_t}{\overline{p^i_t}} \times 100$; Other variables are self-explanatory. (2) Figures in parentheses are robust standard errors. * and ** indicate the coefficient is statistically significant at the 90 and the 95 percent confidence levels, respectively.

Dependent variable = Bond yield − swap rate − CDS spread								
	Corresponding [Il]liquidity measure used =							
	Amihud Illiquid.	Sq. root Ami. Illiq.	Prc rng/ volume	Bid-ask spreads	IQR/ m(p)	Turnover rate	N of days w. trades	N of trades
Panel A. Bonds rated A- or higher								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOG([Il]liquidity)	0.14**	0.38**	0.49**	0.25*	0.28**	-1.10**	-1.92**	-1.11**
	(0.06)	(0.12)	(0.06)	(0.15)	(0.13)	(0.09)	(0.17)	(0.11)
Observations	16235	16235	14519	12805	14618	16527	17343	17210
Number of firms	144	144	139	139	141	147	147	147
R^2	0.12	0.12	0.13	0.13	0.13	0.14	0.13	0.12
Panel B. Bonds rated BBB-, BBB, BBB+								
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
LOG([Il]liquidity)	0.28**	0.60**	0.33**	0.00	-0.33*	-0.79**	-1.63**	-0.98**
	(0.07)	(0.14)	(0.09)	(0.27)	(0.20)	(0.11)	(0.21)	(0.18)
Observations	8196	8196	6110	4978	6431	9196	10545	9756
Number of firms	195	195	180	163	178	202	208	203
R^2	0.11	0.11	0.09	0.09	0.10	0.11	0.11	0.12
Panel C. Speculative-grade bonds								
	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
LOG([Il]liquidity)	0.50**	1.00**	1.16**	-0.60	0.10	-2.31**	-3.29**	-2.69**
	(0.20)	(0.41)	(0.26)	(0.67)	(0.53)	(0.37)	(0.60)	(0.45)
Observations	3806	3806	3137	2498	3007	4132	4464	4290
Number of firms	138	138	129	126	130	139	143	142
R^2	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04

Table 5: **Estimating Liquidity Impacts with Both Transaction Based Liquidity Measures and Liquidity Proxies**
Each column is a regression model of the form:

$$\text{Basis spread} = c + \alpha \log \text{[il]liquidity} + \beta \, \text{liq. proxies} + \text{firm and time fixed effects} + \epsilon,$$

where [il]liquidity measure used for the corresponding model is indicated in the row above the column numbers. Ploynomials of order 4 are used for the effects of bond age and remaining maturity in each model. The results of tests of joint significance of the age coefficients and the remaining maturity coefficients are shown here, and their functional forms are plotted in Figure 6. Figures in parentheses are robust standard errors standard errors. * and ** indicate the coefficient is statistically significant at the 90 and the 95 percent confidence levels, respectively.

(Dependent variable: Bond yield − swap rate − CDS spread)									
	Corresponding [Il]liquidity measure used =								
	N/A	Amihud Illiquid.	Sq. root Ami. Illiq.	Prc rng/ volume	Bid-ask spreads	IQR/ m(p)	Turnover rate	N of days w. trades	N of trades
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LOG([Il]liq.)		0.32**	0.67**	0.47**	0.82**	0.80**	-0.38**	-0.60**	-0.24**
		(0.05)	(0.10)	(0.06)	(0.14)	(0.12)	(0.07)	(0.15)	(0.12)
Coupon	1.34**	1.40**	1.40**	1.33**	1.26**	1.28**	1.52**	1.38**	1.34**
	(0.12)	(0.12)	(0.12)	(0.13)	(0.14)	(0.13)	(0.11)	(0.11)	(0.12)
Log(Bond size)	0.54**	0.46**	0.51**	0.91**	0.61**	0.68**	0.36*	0.78**	0.84**
	(0.21)	(0.21)	(0.21)	(0.23)	(0.24)	(0.22)	(0.20)	(0.22)	(0.24)
Callable bond	-0.78**	-0.77**	-0.77**	-0.45	-0.49	-0.78**	-0.68**	-0.81**	-1.00**
	(0.30)	(0.30)	(0.30)	(0.33)	(0.36)	(0.33)	(0.29)	(0.28)	(0.28)
Bond age polynom(4)	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**
Rem. mat polynom(4)	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**
Constant	9.38**	11.01**	10.93**	7.06**	9.91**	9.85**	9.31**	9.56**	8.40**
	(1.41)	(1.44)	(1.43)	(1.53)	(1.65)	(1.50)	(1.40)	(1.35)	(1.37)
Observations	27621	27621	27621	23202	19793	23490	29855	31721	30644
Number of firms	402	402	402	379	363	380	416	419	413
R^2	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17

Table 6: **Relationship between Transaction Based Liquidity Measures and Liquidity Proxies**
Each column is a regression model of the form:

$$[\text{il}]\text{liquidity} = \alpha + \beta\,\text{liq. proxies} + \text{firm and time fixed effects} + \epsilon,$$

where [il]liquidity measure used for the corresponding model is indicated in the row above the column numbers. Figures in parentheses are robust standard errors standard errors. * and ** indicate the coefficient is statistically significant at the 90 and the 95 percent confidence levels, respectively.

	Dependent variable = LOG([Il]liquidity measure)							
	With corresponding [Il]liquidity measure used =							
	Amihud Illiquid.	Sq. root Ami. Illiq.	Prc rng/ volume	Bid-ask spreads	IQR/ m(p)	Turnover rate	N of days w. trades	N of trades
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Coupon	-0.20**	-0.10**	-0.14**	-0.04**	-0.04**	-0.06**	-0.09**	-0.15**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
Log(Bond size)	0.23**	0.03**	-0.65**	-0.13**	-0.21**	0.35**	0.52**	0.95**
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Callable	-0.03	-0.02	-0.04	0.03	0.02	0.04*	-0.01	-0.05**
	(0.04)	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Bond age/10	3.02**	1.68**	5.15**	0.48**	0.46**	-2.83**	-0.65**	-1.32**
	(0.32)	(0.15)	(0.30)	(0.15)	(0.15)	(0.19)	(0.09)	(0.13)
$(\text{Bond age}/10)^2$	-1.71**	-1.19**	-6.39**	-0.03	0.22	3.73**	1.86**	3.47**
	(0.74)	(0.36)	(0.72)	(0.35)	(0.35)	(0.46)	(0.22)	(0.30)
$(\text{Bond age}/10)^3$	0.54	0.52*	3.68**	-0.19	-0.39	-2.27**	-1.59**	-2.79**
	(0.63)	(0.30)	(0.62)	(0.31)	(0.29)	(0.39)	(0.18)	(0.25)
$(\text{Bond age}/10)^4$	-0.09	-0.11	-0.75**	0.06	0.11	0.48**	0.39**	0.67**
	(0.17)	(0.08)	(0.17)	(0.08)	(0.08)	(0.10)	(0.05)	(0.07)
TTM/10	6.61**	3.44**	7.63**	3.31**	4.75**	-1.99**	-0.78**	-0.57**
	(0.55)	(0.27)	(0.53)	(0.25)	(0.25)	(0.33)	(0.16)	(0.22)
$(\text{TTM}/10)^2$	-10.31**	-5.35**	-12.70**	-4.05**	-6.49**	4.58**	2.31**	1.83**
	(1.18)	(0.58)	(1.16)	(0.54)	(0.55)	(0.71)	(0.35)	(0.48)
$(\text{TTM}/10)^3$	7.01**	3.65**	8.94**	2.49**	4.18**	-3.80**	-2.40**	-2.11**
	(0.97)	(0.48)	(0.96)	(0.44)	(0.46)	(0.58)	(0.29)	(0.39)
$(\text{TTM}/10)^4$	-1.70**	-0.89**	-2.17**	-0.58**	-0.98**	1.00**	0.72**	0.67**
	(0.26)	(0.13)	(0.26)	(0.12)	(0.12)	(0.16)	(0.08)	(0.10)
Constant	-5.09**	-2.32**	2.86**	-0.40**	-0.71**	-5.18**	-0.39**	-1.65**
	(0.17)	(0.08)	(0.16)	(0.08)	(0.08)	(0.10)	(0.05)	(0.07)
Observations	27621	27621	23202	19793	23490	29855	31721	30644
Number of firms	402	402	379	363	380	416	419	413
R^2	0.04	0.04	0.13	0.12	0.16	0.13	0.24	0.33

Table 7: **The Effect of Bond Liquidity on Bond Spreads by Bond Ratings by Controlling Liquidity Proxies**

For the sample of each rating category, each column is a regression model of the form:

$$\text{Basis spread} = c + \alpha \log[\text{il}]\text{liquidity} + \beta\,\text{liq. proxies} + \text{firm and time fixed effects} + \epsilon,$$

where [il]liquidity measure used for the corresponding model is indicated in the row above the column numbers. Ploynomials of order 4 are used for the effects of bond age and remaining maturity in each model. Their functional forms are plotted in Figure 6. To save space, coefficients on other regressors are not shown. Figures in parentheses are robust standard errors standard errors. * and ** indicate the coefficient is statistically significant at the 90 and the 95 percent confidence levels, respectively.

Dependent variable = Bond yield − swap rate − CDS spread								
	Corresponding [Il]liquidity measure used =							
	Amihud Illiquid.	Sq. root Ami. Illiq.	Prc rng/ volume	Bid-ask spreads	IQR/ m(p)	Turnover rate	N of days w. trades	N of trades
Panel A. Bonds rated A- or higher								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOG([Il]liq.)	0.29**	0.58**	0.39**	0.47**	0.49**	-0.40**	0.11	0.53**
	(0.06)	(0.12)	(0.07)	(0.15)	(0.13)	(0.08)	(0.19)	(0.13)
Observations	15751	15751	14077	12422	14174	16527	16849	16721
Number of firms	144	144	138	139	140	147	147	147
R^2	0.24	0.24	0.25	0.25	0.25	0.25	0.24	0.24
Panel B. Bonds rated BBB-, BBB, BBB+								
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
LOG([Il]liq.)	0.19**	0.36**	0.14	0.64**	0.26	0.07	-0.31	0.10
	(0.06)	(0.13)	(0.09)	(0.25)	(0.18)	(0.11)	(0.21)	(0.17)
Observations	8110	8110	6028	4908	6347	9196	10458	9683
Number of firms	194	194	179	162	177	202	207	202
R^2	0.26	0.26	0.23	0.22	0.24	0.27	0.27	0.28
Panel C. Speculative-grade bonds								
	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
LOG([Il]liq.)	-0.09	-0.18	0.19	-0.28	0.14	0.14	-0.98	-1.40**
	(0.19)	(0.39)	(0.25)	(0.62)	(0.49)	(0.37)	(0.63)	(0.47)
Observations	3760	3760	3097	2463	2969	4132	4414	4240
Number of firms	137	137	128	125	129	139	142	141
R^2	0.17	0.17	0.18	0.18	0.18	0.17	0.17	0.17

Table 8: **Estimating Liquidity Impact Using Treasury Rate as Risk-Free Rate**
Each column is a regression model of the form:

$$\text{Basis spread} = c + \alpha \log[\text{il}]\text{liquidity} + \beta\,\text{liq. proxies} + \text{firm and time fixed effects} + \epsilon,$$

where [il]liquidity measure used for the corresponding model is indicated in the row above the column numbers. Ploynomials of order 4 are used for the effects of bond age and remaining maturity in each model. The results of tests of joint significance of the age coefficients and the remaining maturity coefficients are shown here. Figures in parentheses are robust standard errors standard errors. * and ** indicate the coefficient is statistically significant at the 90 and the 95 percent confidence levels, respectively.

(Dependent variable: Bond yield − Treasury rate − CDS spread)									
	Corresponding [Il]liquidity measure used =								
		Amihud Illiquid.	Sq. root Ami. Illiq.	Prc rng/ volume	Bid-ask spreads	IQR/ m(p)	Turnover rate	N of days w. trades	N of trades
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LOG([Il]liq.)		0.30**	0.65**	0.48**	0.85**	0.74**	-0.53**	-0.80**	-0.38**
		(0.05)	(0.10)	(0.06)	(0.15)	(0.12)	(0.08)	(0.16)	(0.12)
Coupon	1.11**	1.17**	1.17**	1.10**	1.08**	1.07**	1.40**	1.24**	1.24**
	(0.12)	(0.12)	(0.12)	(0.13)	(0.14)	(0.13)	(0.12)	(0.12)	(0.12)
Log(Bond size)	0.23	0.16	0.20	0.73**	0.29	0.40*	-0.01	0.40*	0.37
	(0.21)	(0.21)	(0.21)	(0.23)	(0.25)	(0.23)	(0.21)	(0.23)	(0.25)
Callable	-1.16**	-1.15**	-1.14**	-0.99**	-1.00**	-1.26**	-0.83**	-1.03**	-1.20**
	(0.30)	(0.30)	(0.30)	(0.34)	(0.37)	(0.34)	(0.30)	(0.29)	(0.29)
Bond age polynom(4)	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**
Rem. mat polynom(4)	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**	Yes**
Constant	36.23**	37.76**	37.72**	32.69**	36.01**	35.89**	35.86**	37.19**	36.37**
	(1.47)	(1.49)	(1.49)	(1.60)	(1.74)	(1.58)	(1.46)	(1.40)	(1.43)
Observations	27598	27598	27598	23184	19778	23460	29820	31701	30644
Number of firms	401	401	401	381	366	379	414	417	411
R^2	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.25

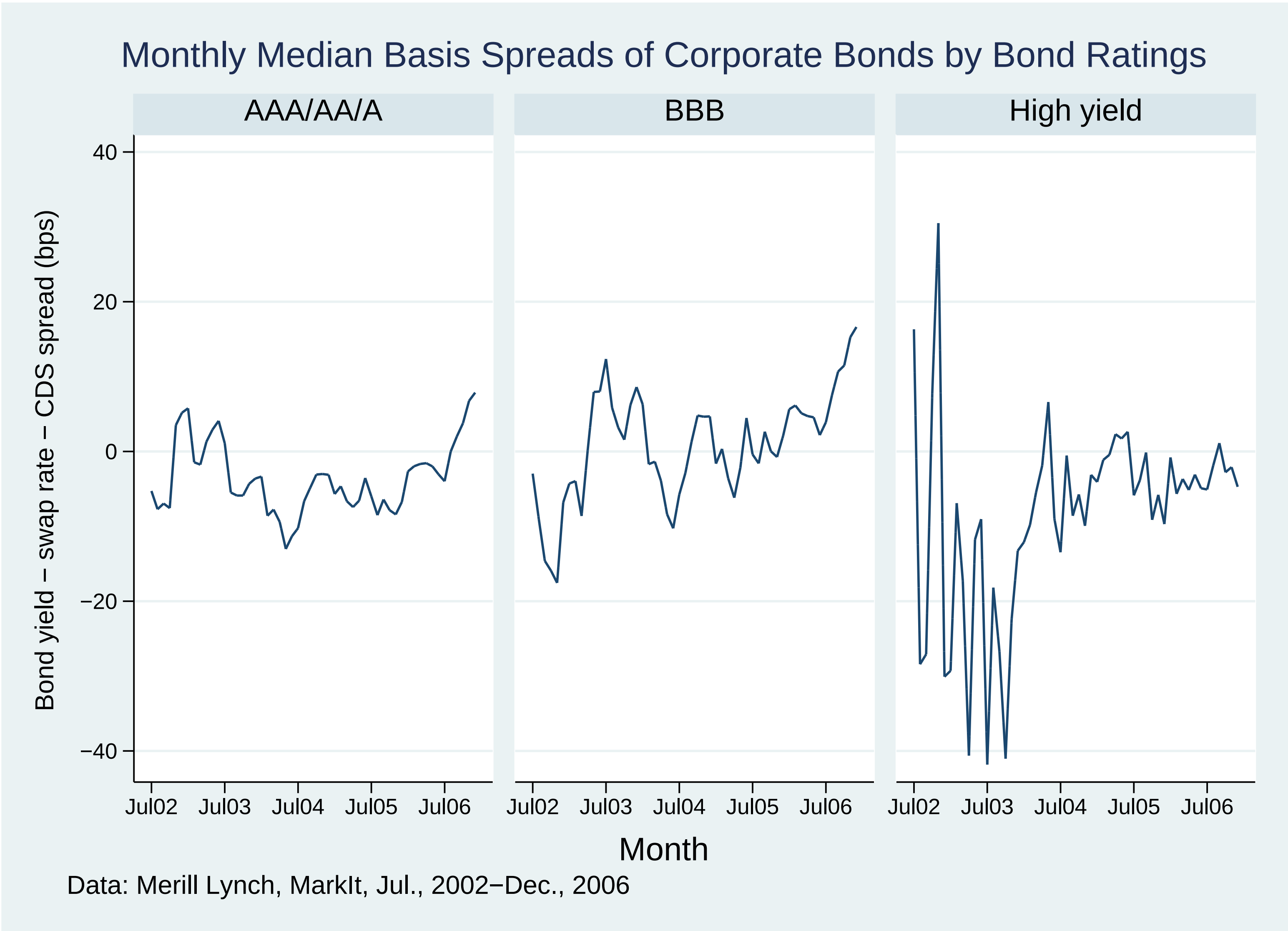
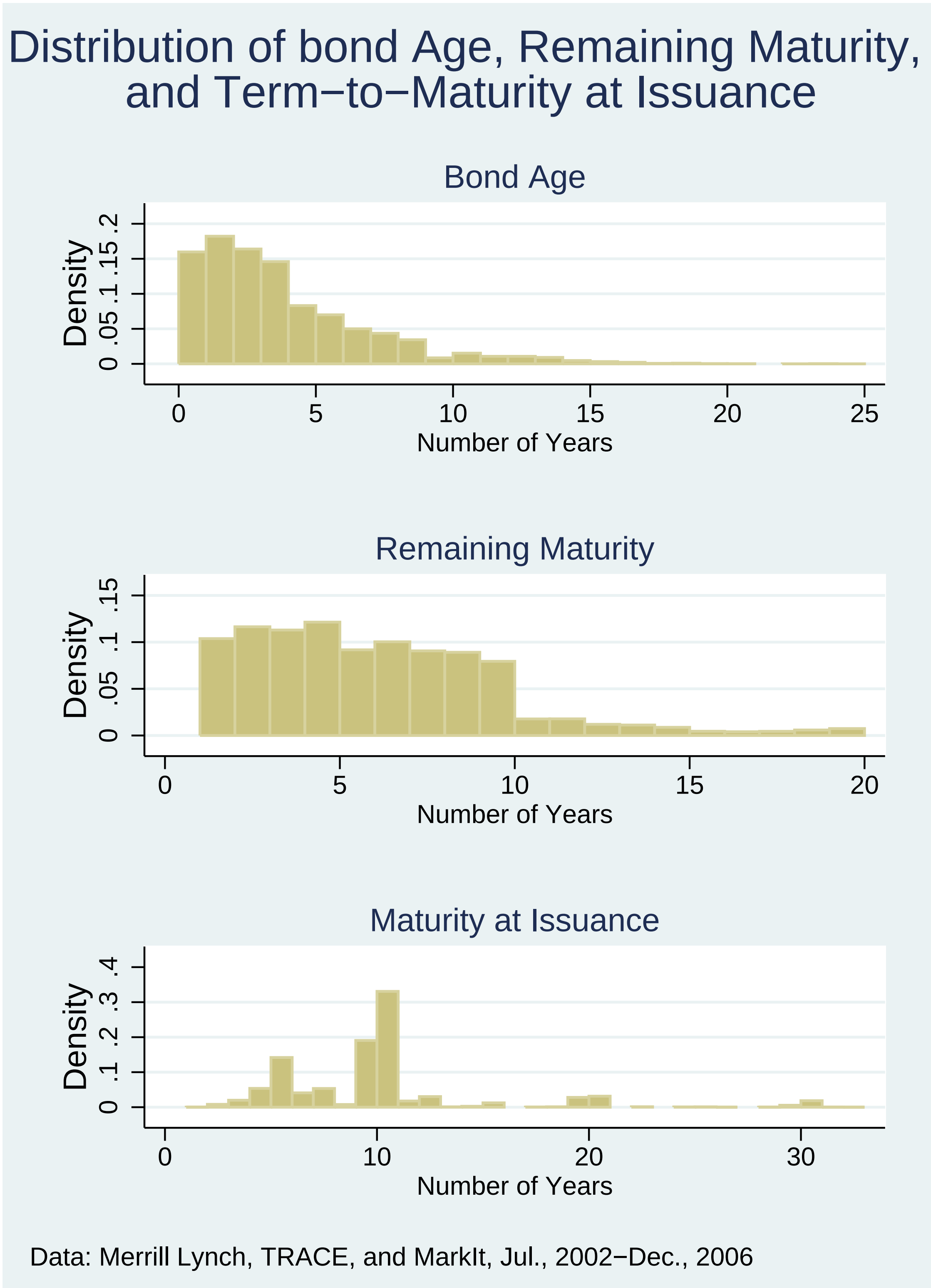


Figure 1: Time Series Plots of Basis Spreads of Corporate Bonds by Bond Ratings

Figure 2: Distributions of Bond Age, Remaining Maturity, and Maturity at Issuance



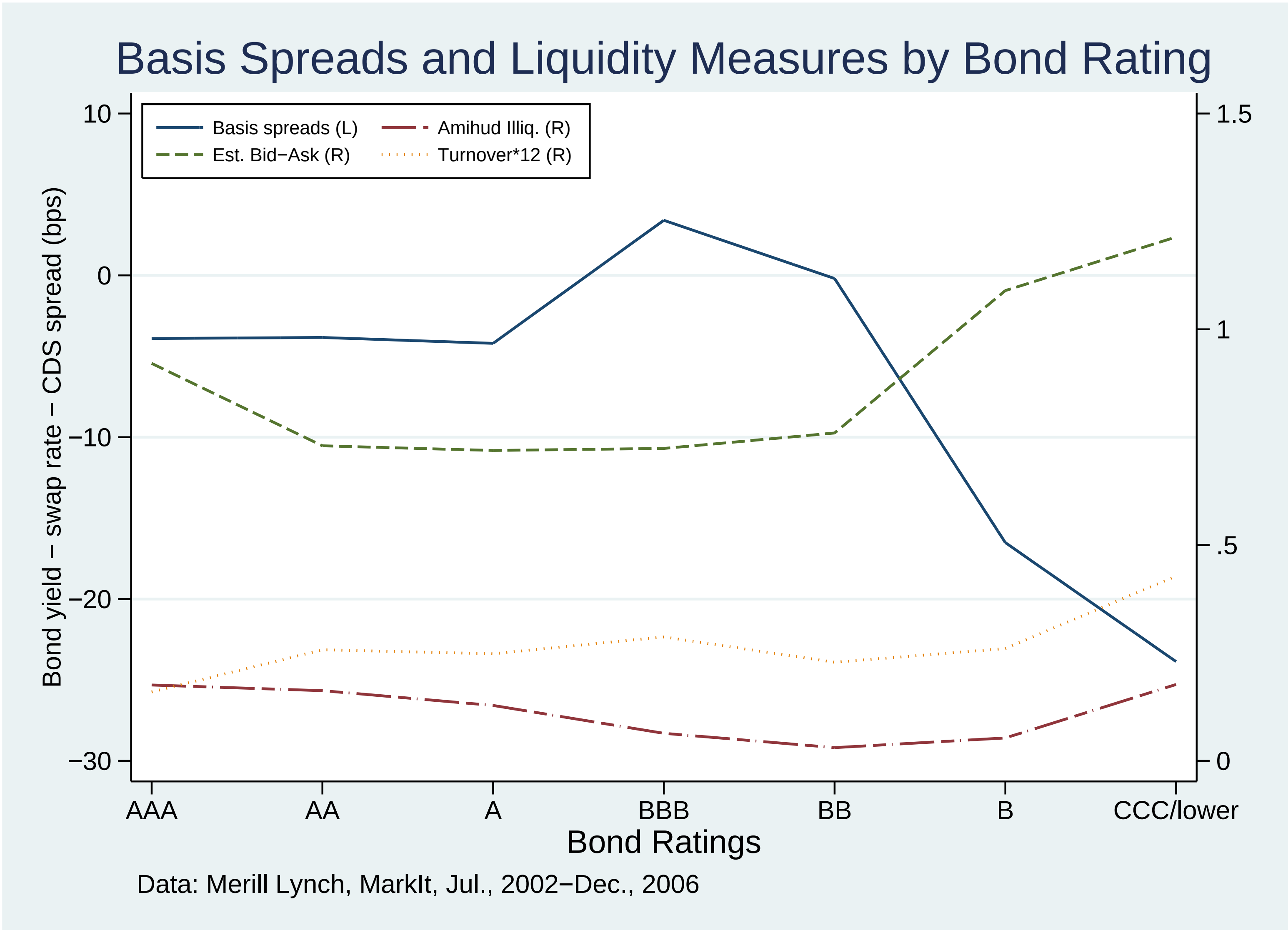


Figure 3: Basis Spreads and Liquidity Measures by Bond Ratings

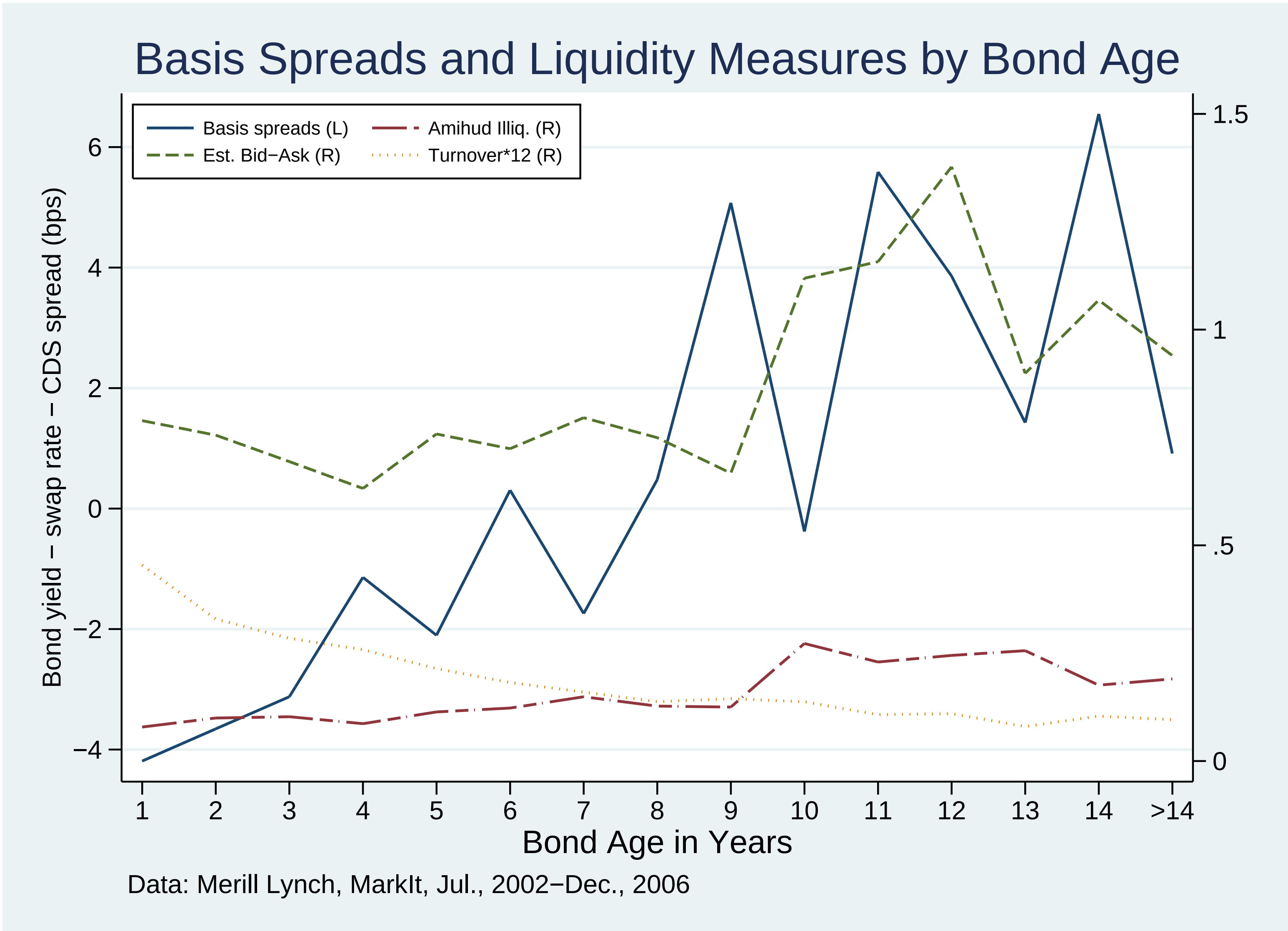


Figure 4: Basis Spreads and Liquidity Measures by Bond Age

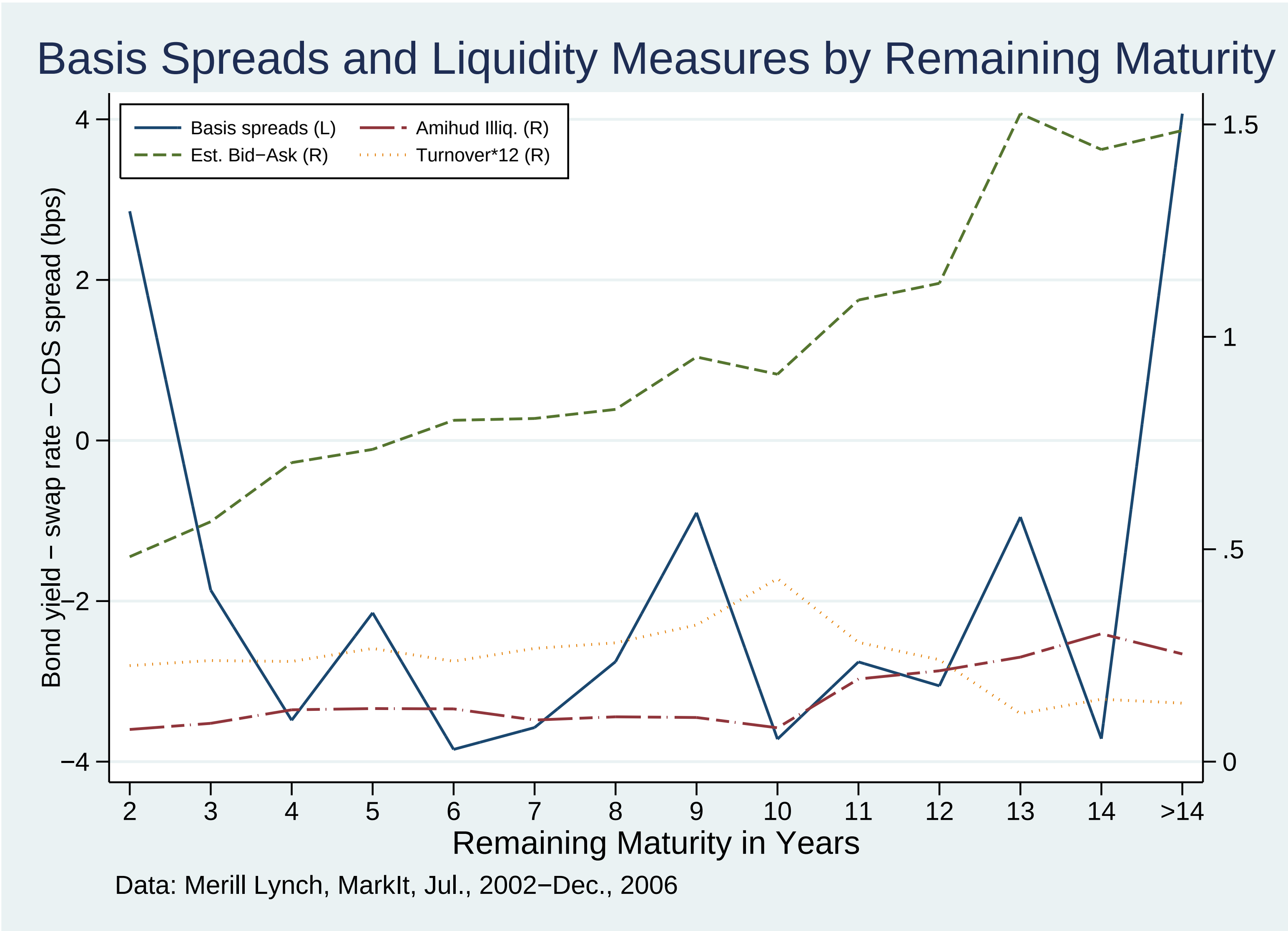
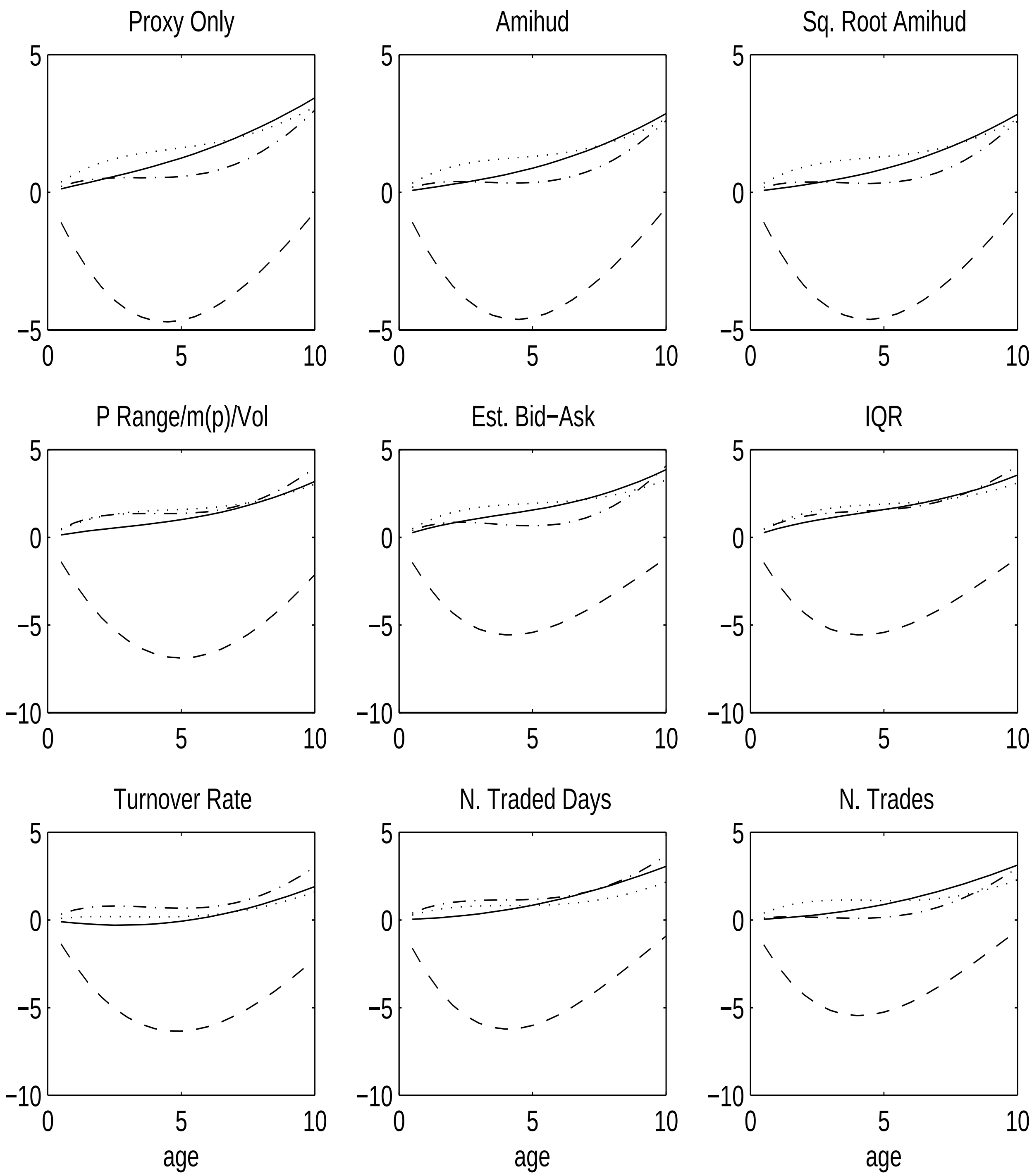


Figure 5: Basis Spreads and Liquidity Measures by Remaining Maturity

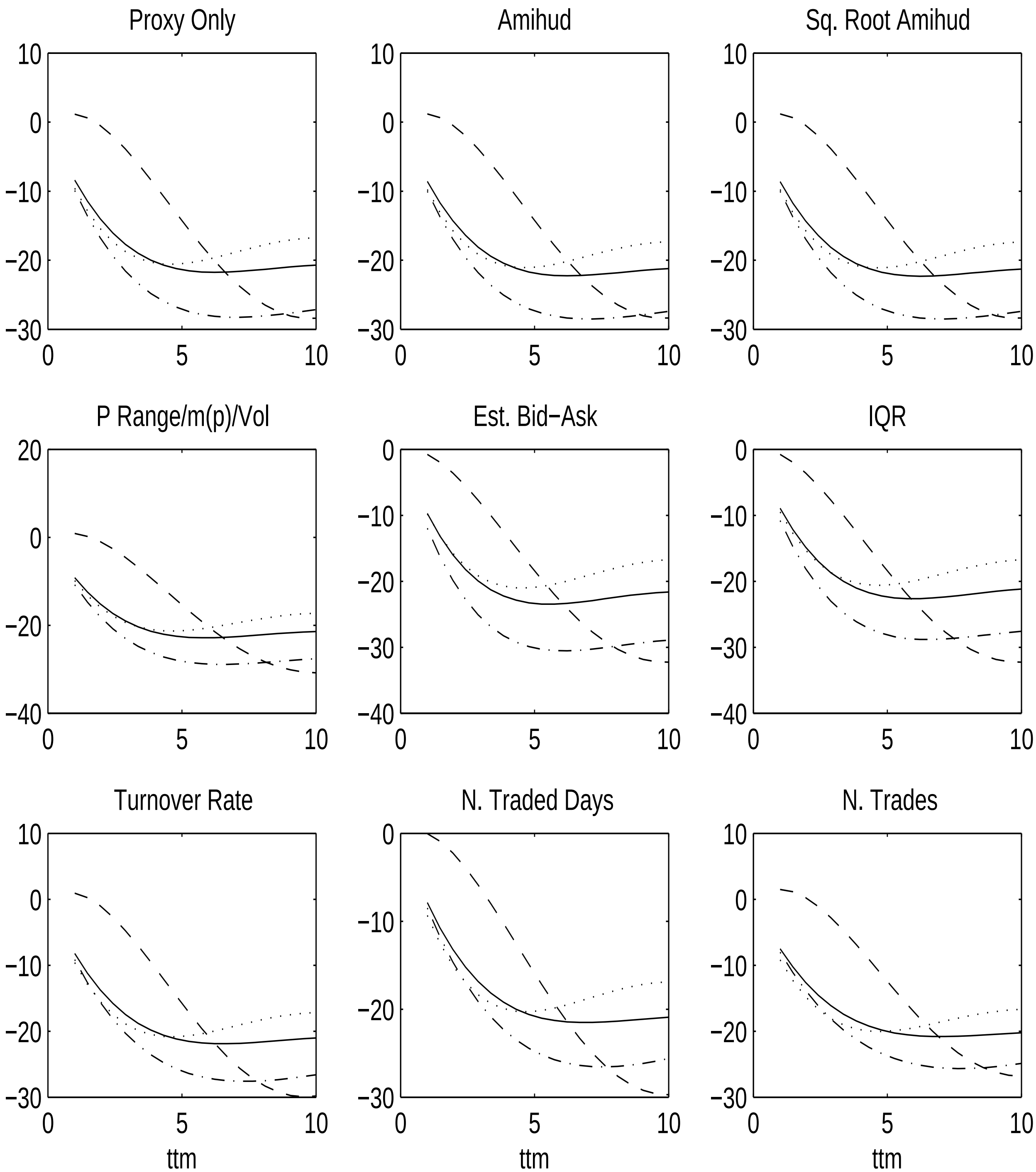
Figure 6: Relations between Basis Spreads and Bond Age and Remaining Maturity After Controling Liquidity Measures

Plot A. Basis Spreads and Bond Age



Legend: — all ratings · · · AAA/AA/A − · BBB − − high yield

Plot B. Basis Spreads and Remaining Maturity



Legend: — all ratings · · · AAA/AA/A − · BBB − − high yield