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Liquidity risk and expected corporate bond returns ☆

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A B S T R A C T

This paper studies the pricing of liquidity risk in the cross section of corporate bonds for the period from January 1994 to March 2009. The average return on bonds with high sensitivities to aggregate liquidity exceeds that for bonds with low sensitivities by about 4% annually. The positive relation between expected corporate bond returns and liquidity beta is robust to the effects of default and term betas, liquidity level, and other bond characteristics, as well as to different model specifications, test methodologies, and a variety of liquidity measures. The results suggest that liquidity risk is an important determinant of expected corporate bond returns.

1. Introduction

Financial theory suggests that expected asset returns are related to systematic risk associated with common factors. In equilibrium, an asset whose returns are more sensitive to risk factors should offer higher returns to compensate investors for holding the asset. The literature has presented several stock market and term structure factors important for the cross section of asset returns (see, for example, Fama and French, 1992, 1993; Gebhardt, Hvidkjaer, and Swaminathan, 2005a). Recent studies have further suggested liquidity as another good candidate for a priced state variable. Liquidity is often viewed as an important feature of the investment environment. All else equal, investors should require higher returns on assets whose returns have greater sensitivities to marketwide liquidity.

Pastor and Stambaugh (2003) investigate whether marketwide liquidity is a state variable important for pricing stocks. Their study focuses on a particular dimension of liquidity associated with temporary price fluctuations induced by order flow. They find that expected stock returns are positively related cross-sectionally to the sensitivities of returns to fluctuations in aggregate liquidity. Acharya and Pedersen (2005) develop a liquidity-adjusted capital asset pricing model (CAPM) under time-varying liquidity and demonstrate that the required return of an asset depends on expected liquidity and covariances of its returns and liquidity with market returns and liquidity. Empirical evidence shows that liquidity risk is important beyond the effects of market risk and the level of liquidity in the equity market.

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While both studies provide insight into the role of liquidity in equity pricing, neither examines the effect of liquidity risk on expected returns of corporate bonds. Pastor and Stambaugh (2003) suggest that "[i]t would also be useful to explore whether some form of systematic liquidity risk is priced in other financial markets, such as fixed income markets or international equity markets." The corporate bond market is much less liquid than the equity market with most corporate bonds trading infrequently. Thus, the level of liquidity is a serious concern for participants in the corporate bond market. However, it remains unclear whether unanticipated shocks to aggregate liquidity translate into a significant premium for liquidity risk for corporate bonds.[1]

Understanding how corporate bonds are priced is essential for developing a unified theory of asset pricing. The corporate bond market is a large sector of the US financial system with an outstanding issuance totaling more than $5 trillion.[2] How financial markets price corporate bonds and what are the key determinants of required returns are issues of fundamental importance to academics and practitioners. For academics, exploring the role of liquidity risk in corporate bond pricing is a necessary step toward understanding the determinants of the cost of borrowing. For financial managers, knowledge of sensitivities of bond prices to liquidity and other risk factors aids in firms' issuance decisions.

Our focus on liquidity risk in corporate bond pricing differentiates our work from previous studies that examine the effect of liquidity level or transaction cost on asset returns (see, for example, Amihud and Mendelson, 1986, 1991; Brennan and Subrahmanyam, 1996; Brennan, Chordia, and Subrahmanyam, 1998; Amihud, 2002).[3] Chen, Lesmond, and Wei (2007) examine the cross-sectional relation between corporate yield spreads and liquidity. Using bond-specific liquidity measures as explanatory variables, they find that liquidity is priced in corporate bond yield spreads. That the level of liquidity can affect expected bond returns or yield spreads is not surprising because investors incur transaction cost, which lowers the bond value by reducing its cash flow. In this paper, we focus on the issue of whether expected corporate bond returns are significantly related to systematic liquidity risk in returns, as opposed to the level of liquidity. The liquidity risk investigated is not the risk that liquidity will be low when investors need to trade but that the bond's value will drop when aggregate liquidity deteriorates. More specifically, this risk is determined by how a corporate bond's return fluctuates in association with a state variable and not by how the bond's liquidity fluctuates.

Corporate bonds provide fertile ground for studying the effect of liquidity risk relative to other variables on asset pricing because risk factors are easier to identify. Fama and French (1993) first show that default and term premia are important factors for corporate bond pricing, and Gebhardt, Hvidkjaer, and Swaminathan (2005b) confirm this finding. These studies have laid a solid foundation for the pricing model of corporate bonds. Built on these frameworks, we explore the effects of the liquidity factor and bond characteristics on corporate bond pricing. De Jong and Driessen (2007) find that corporate bond returns are sensitive to fluctuations in liquidity of the Treasury and equity markets. Beber, Brandt, and Kavajecz (2009) and Li, Wang, Wu, and He (2009) show that persistent liquidity shocks have pervasive impacts on government bond pricing. Our work complements these studies by examining the sensitivities of corporate bond returns to fluctuations in marketwide liquidity and assessing their importance in the pricing of corporate bonds.

This paper provides comprehensive empirical analysis on the effect of liquidity risk on expected corporate bond returns using an extensive transaction data sample. We consolidate transaction data sets from the Trade Reporting and Compliance Engine (TRACE) of the National Association of Securities Dealers (NASD) and National Association of Insurance Commissioners (NAIC). This results in a long-span, large data sample that permits estimation of reliable aggregate liquidity and systematic liquidity risk measures to conduct cross-sectional tests on corporate bond pricing more efficiently. We construct aggregate liquidity measures using the Amihud (2002) and Pastor and Stambaugh (2003) methods, which are two of the most widely used techniques for extracting the latent liquidity factor in the literature. Based on these liquidity measures, we examine the effect of liquidity risk on expected corporate bond returns using the regression approach of Fama and MacBeth (1973) and the portfolio-based approach, which can be dated back to Black, Jensen, and Scholes (1972). In regression analysis, we employ both the linear factor model and the extended Acharya and Pedersen model to assess the importance of liquidity risk relative to the effects of other risk factors, liquidity level, and bond characteristics on expected corporate bond returns. In portfolio-based analysis, we create portfolios whose liquidity betas are sufficiently disperse to examine the cross-sectional variation in corporate bond returns related to liquidity beta.

Empirical evidence from both analyses strongly suggests that the liquidity risk factor is priced in corporate bond returns. We find significant monotonic variations in returns of beta-sorted portfolios related to liquidity risk, which are independent of the effects of default and term betas and ratings. The average return on bonds with high sensitivities to innovations in aggregate liquidity exceeds that for bonds with low sensitivities by about 4% annually. A significant positive relation exists between expected corporate bond returns and liquidity beta in the cross-sectional regression. A one standard deviation of Pastor and Stambaugh liquidity beta above the cross-sectional mean is associated with a return increase of 97 basis

[1] Assets with low liquidity tend to have high liquidity risk. This is especially the case if drops in market liquidity cause investors to flee to more liquid assets.

[2] See the *Global Financial Stability Report* of the International Monetary Fund (IMF), October 2008.

[3] Also, Chordia, Roll, and Subrahmanyam (2000, 2001) and Hasbrouck and Seppi (2001) find commonality in liquidity. Chordia, Subrahmanyam, and Anshuman (2001) uncover a significant cross-sectional relation between equity returns and liquidity variability.

points per annum, which accounts for 20% of the standard deviation of monthly corporate bond excess returns. More important, we show a strong positive relation between liquidity risk and expected corporate bond returns even after controlling for the effects of other risk factors, expected liquidity, and bond characteristics. This positive relation is robust to different empirical specifications of corporate bond pricing models and choices of a variety of proxies for the liquidity factor.

Our paper contributes to the current literature of corporate bond pricing. Our empirical analysis provides three major findings. First, the paper shows that liquidity risk is priced in the cross section of corporate bond returns using the Amihud and the Pastor and Stambaugh measures estimated via bond transaction data. Second, the same equity-based liquidity factors that price the cross section of equity returns (see Amihud, 2002; Pastor and Stambaugh, 2003; Sadka, 2006) also price the cross section of bond returns. This result shows the robustness of liquidity-risk pricing in different markets, consistent with findings of Sadka (2010) for hedge funds and Franzoni, Nowak, and Phalippou (2009) for private equity funds. Third, liquidity risk can explain part of the credit spread related to investors' flight-to-quality during illiquid periods.

The remainder of the paper is organized as follows. Section 2 describes the data and liquidity measures used for empirical tests. Section 3 examines whether liquidity risk is priced in the cross section of individual bond returns, and Section 4 further investigates whether liquidity risk pricing is an intra- or inter-rating effect. Section 5 reports results of liquidity-beta portfolio sorts on individual bonds and bonds within each rating group. Section 6 provides additional tests to check robustness of our results to alternative model specifications, portfolio sorts, and liquidity factors. Finally, Section 7 summarizes our main findings and concludes the paper.

2. Data and liquidity measures

In this section, we first discuss the data used in our empirical analysis. Following this, we describe the procedure to construct liquidity measures.

2.1. Data

Our data come from three major sources: the TRACE and NAIC transaction databases and the Fixed Investment Securities Database (FISD). Price and trade data of corporate bonds are from the first two databases, and ratings and bond-specific characteristic information are from the FISD. We consolidate the databases of TRACE and NAIC to create a long-span transaction data sample.

In an attempt to increase the transparency of the corporate bond market, beginning July 1, 2002, the NASD requires dealers to report their transactions through the TRACE system. The TRACE database contains price, time, and size of transactions for publicly traded over-the-counter corporate bonds. When first introduced in July 2002 (Phase I), the TRACE database included about five hundred US investment-grade corporate bonds with an original issue size of at least $1 billion. On March 1, 2003 (Phase II), TRACE expanded its coverage of transactions to include bonds rated A and above with issue size greater than $100 million and 120 Baa bonds with issue size less than $1 billion. This and subsequent changes in the criteria for reporting transactions in TRACE resulted in 17 thousand corporate bond issues being included in the database by October 2004, which contains most high-yield bonds. On October 1, 2004 (Phase III), the TRACE database was expanded further to cover all publicly traded corporate bonds. The only trades omitted from the TRACE database are those executed on exchanges, most of which occur on the NYSE's Automated Bond System. Because fewer than 5% of all bonds are listed on the NYSE, the current TRACE data set includes the vast majority of corporate bond trades in the US fixed-income market.

The NAIC database consists of all transactions of publicly traded corporate bonds beginning in January 1994 by life insurance companies, property and casualty insurance companies, and health maintenance organizations (HMOs). According to the Flow of Fund accounts published by the Federal Reserve Bank, about one-third of outstanding corporate bonds are held by insurance companies. Thus, the NAIC database covers a good amount of corporate bond transactions (Warga, 2000). Previous studies indicate that NAIC data are adequately representative of transactions in the corporate bond market (see, for example, Campbell and Taksler, 2003; Krishnan, Ritchken, and Thomson, 2005; Cai, Helwege, and Warga, 2007).

The FISD database provides issuance information for all fixed-income securities that have a Committee on Uniform Security Identification Procedures (CUSIP) number and those likely to receive one soon. This database contains issue- and issuer-specific information such as coupon rate, maturity, issue amount, provisions, and credit ratings for all US corporate bonds maturing in 1990 or later.

The TRACE database covers a relatively short horizon. The short sample period not only gives noisy parameter estimates but also produces empirical tests that lack statistical power. Moreover, TRACE initially covered only a small subset of investment-grade corporate bonds, which are not representative of the whole market. These data limitations pose a significant challenge to performing efficient tests on long-term equilibrium bond pricing. To remedy these shortcomings, we pool TRACE and NAIC data together. Pooling both data sets extends the sample period considerably and greatly increases the number of bonds and transactions in the study sample, particularly at the early stage of the TRACE coverage, to facilitate efficient empirical estimation. To avoid double-counting, we keep transaction records reported by TRACE only if transactions of the same bond are included in both NAIC and TRACE databases after July 2002. A distinct advantage of our sample is that it is free from the data problem associated with matrix prices encountered by Gebhardt, Hvidkjaer, and

Swaminathan (2005b) because both TRACE and NAIC databases contain actual transaction prices.[4]

Our final sample includes corporate bond transaction records from January 1994 to March 2009. We first remove those data that are apparently recorded with errors. To prevent the confounding effects of embedded options, we exclude callable, puttable, convertible, and sinking fund bonds, as well as bonds with a floater or odd frequency of coupon payments. In addition, we eliminate short-maturity (less than one year) bonds because liquidity is low for these issues, which subjects these bonds to high pricing errors. We also drop bonds whose ratings we cannot identify from the FISD. We employ primarily the Moody's rating, but, if it is not available, we use the Standard and Poor's (S&P) rating when possible. Finally, we require bonds with at least 15-month transaction records for regression estimation. After these data screenings, we have a total of 11,729 bonds in our final sample: 1,016 Aaa bonds, 1,833 Aa bonds, 3,390 A bonds, 2,610 Baa bonds, and 2,880 speculative bonds.

The monthly corporate bond return as of time t is computed as

$$r_t = \frac{(P_t + AI_t) + C_t - (P_{t-1} + AI_{t-1})}{P_{t-1} + AI_{t-1}}, \tag{1}$$

where P_t is the transaction price, AI_t is accrued interest, and C_t is the semiannual coupon payment, if any, in month t. We use the last transaction price at the end of each month to calculate the bond's monthly return. If the transaction does not fall in the last trading day of the month, we calculate the return by interpolating the last transaction price of the month and the first transaction price of the following month.

Monthly returns of the long-term government bond index and one-month Treasury bill are obtained from the Federal Reserve Board. The default premium (*DEF*) is the difference between the monthly returns of long-term investment-grade bonds and long-term government bonds. The long-term investment-grade bond returns are based on a value-weighted market portfolio that includes all investment-grade bonds (Aaa to Baa3) in the sample with at least ten years to maturity. The weight is determined by the market value of a bond, which equals the number of units outstanding multiplied by market price of the bond.[5] The term premium (*TERM*) is the difference between the monthly returns of the long-term government bond and the one-month Treasury bill. Default and term premium data are used to estimate betas associated with these two risk factors. Besides default and term betas, we estimate betas associated with the Fama-French three factors. The stock market and *SMB* (small minus big) and *HML* (high minus low) factors are downloaded from Ken French's website http://mba.tuck.dartmouth.edu/ pages/faculty/ken.french/.

Furthermore, we collect data for bond characteristics such as coupon, issue size, age, and ratings for each individual bond from FISD. Traditionally, these characteristic variables were used as proxies for the level of liquidity or default risk of bonds (see, for example, Green and Odegaard, 1997; Longstaff, Mithal, and Neis, 2005). An important issue is whether these variables contain additional information beyond that conveyed by liquidity and default betas. We examine this issue later in cross-sectional tests. In empirical tests, we employ two marketwide liquidity proxies for the corporate bond market: the Pastor and Stambaugh (2003) measure and the Amihud (2002) measure.

2.2. Estimates of liquidity factors

In this subsection, we describe the empirical methodology and estimation procedure for the liquidity measures.

2.2.1. The Pastor-Stambaugh liquidity measure

The Pastor-Stambaugh liquidity measure captures temporary price changes associated with order flow. It is formulated on the premise that lower liquidity is associated with a larger price reversal next trading day resulting from the order flow in a given direction on a particular day. The liquidity level for an individual bond in period t (e.g., month) can be obtained from the least squares estimate of $\pi_{i,t}$ associated with the signed volume in the following regression:

$$r^e_{i,j+1,t} = \rho_0 + \rho_1 r_{i,j,t} + \pi_{i,t}\, sign(r^e_{i,j,t}) Vol_{i,j,t} + \varepsilon_{i,j+1,t}, \tag{2}$$

where $r_{i,j,t}$ is the return of bond i on day j in month t, $r^e_{i,j,t}$ is the bond's return in excess of the bond market return, $sign(r^e_{i,j,t})$ is an indicator function whose value is equal to 1 if $r^e_{i,j,t}$ is positive and -1 if it is negative, and $Vol_{i,j,t}$ is the dollar volume. The order flow is proxied by volume signed by the contemporaneous excess return on a particular bond.

The unbalanced order flow is expected to be accompanied by a return, which is partially reversed if the market is not perfectly liquid, or $\pi_{i,t}$ is negative. The greater the expected reversal for a given volume, the lower the bond liquidity. $\pi_{i,t}$ is estimated for individual bonds each month t using daily return and volume data. A bond's liquidity is computed in a given month only if there are at least ten return observations with which to estimate the regression above. Individual liquidity measures are aggregated month by month to generate the marketwide liquidity series:

$$\pi_t = \frac{1}{N_t} \sum_{i=1}^{N_t} \pi_{i,t}, \tag{3}$$

where N_t is the number of corporate bonds in month t. To account for the effects of changes in the growth in size of the bond market and the sample size, we scale the difference in monthly aggregate liquidity measures by the ratio of capitalizations of the bonds in the sample, i.e.,

[4] Matrix prices are set according to some algorithm based on prices of bonds with similar characteristics. These price data are regarded as less reliable than dealer quotes.

[5] The number of bonds outstanding is provided by the FISD. The weight for a bond is equal to the proportion of its market value to the total market value aggregated across all long-term investment-grade bonds in the sample.

$\Delta\pi_t=(M_t/M_1)(\pi_t-\pi_{t-1})$, where M_t is the total dollar value at the end of month $t-1$ of the bonds included in month t. This scaling procedure follows the logic of Pastor and Stambaugh (2003). Liquidity innovations are then obtained from the following differenced regression, which includes a lag term and the lagged value of the scaled level series on the right-hand side:

$$\Delta\pi_t = a_0 + a_1\,\Delta\pi_{t-1} + a_2\left(\frac{M_{t-1}}{M_1}\right)\pi_{t-1} + e_t. \tag{4}$$

Because the residual term for bond liquidity is typically small, we multiply residual estimates $\hat{e}_t$ by one hundred:

$$L_t = 100\hat{e}_t. \tag{5}$$

This scaling on the liquidity innovation has no effect on empirical tests. It is merely intended to produce a desirable range for the liquidity index and the estimated systematic liquidity risk. Eqs. (2) to (5) are used to construct the Pastor-Stambaugh liquidity factor.

Panel A of Fig. 1 plots the Pastor-Stambaugh liquidity innovations, L, for the corporate bond market. As indicated, there are occasional downward spikes, pointing to months with unusually low liquidity. These spikes are associated with significant financial events during the sample period. The first two largest downward spikes in October 2008 and March 2009 occur when the market takes a nosedive in the midst of the subprime financial crisis. The spike in the spring of 2008 is due to the collapse of Bear Stearns. The spike in the fall of 1998 is associated with the Russian financial crisis. The episode involving Long-Term Capital Management (LTCM) significantly deteriorates market liquidity. The spike, however, shows up in October instead of September, when the LTCM collapsed. Fleming (2003) finds a similar pattern using alternative liquidity variables such as price impacts, bid-ask spreads, trading volume and frequency, on- and off-the-run yield spreads, and yield volatility of treasuries. Corporate bonds trade much less frequently than stocks, and this could have caused the full effect of this liquidity event to lag behind the equity market. The spike in late 1994 is linked to the peso crisis and the Orange County event. Another three spikes are associated with the Asian financial crisis in 1997, the September 11 event in 2001, and WorldCom's default in 2002. Finally, a few mild spikes arise between 2004 and 2006 when the Federal Reserve Board's policy shifts toward higher interest rates. Overall, the Pastor and Stambaugh measure does a good job in capturing significant events.

The first-order autocorrelation of the Pastor-Stambaugh liquidity measure is close to zero (see Panel B, Table 1), suggesting that the model in Eq. (4) is effective in filtering out serial correlation in $\Delta\pi_t$. Thus, the AR(2) specification for the dynamics of the Pastor-Stambaugh aggregate liquidity appears to be suitable for the corporate bond market as well.[6]

2.2.2. *The Amihud illiquidity measure*

The Amihud illiquidity measure focuses on the price impact of trades. Liquidity for a security is high if a large volume can be traded with little impact on price, and vice versa. The Amihud (2002) illiquidity measure is defined as

$$ILLIQ_{it} = \frac{1}{Days_{it}}\sum_{j=1}^{Days_{it}}\frac{|r_{i,j,t}|}{Vol_{i,j,t}}, \tag{6}$$

where $r_{i,j,t}$ is the return for bond i on day j of month t and $Days_{it}$ is the number of days for which transaction data are available for bond i in month t.

We first obtain the marketwide $ILLIQ_{Mt}$ by aggregating individual illiquidity measures over the entire sample month by month,

$$ILLIQ_{Mt} = \frac{1}{N_t}\sum_{i=1}^{N_t} ILLIQ_{it}. \tag{7}$$

In calculating $ILLIQ_{Mt}$, we Winsorize individual $ILLIQ_{it}$ data using the 1st and 99th percentiles of the distribution each month to reduce the impact of outliers. Similar to the Pastor-Stambaugh measure, we scale the monthly difference in the Amihud illiquidity series by the ratio of capitalizations of the bonds included in the sample in each month t, i.e., $\Delta ILLIQ_{Mt}=(M_t/M_1)(ILLIQ_{Mt}-ILLIQ_{Mt-1})$. We then obtain innovations from the following time series regression:

$$\Delta ILLIQ_{Mt} = \alpha_0 + d_1 + d_2 + \phi_1\,\Delta ILLIQ_{Mt-1} + \phi_2\left(\frac{M_{t-1}}{M_1}\right)ILLIQ_{Mt-1} + \varepsilon_t + \theta_1\varepsilon_{t-1} + \theta_2\varepsilon_{t-2}. \tag{8}$$

Unlike Eq. (4), we incorporate moving average components to account for the autocorrelation in the residual term.[7] We also add two dummy variables to capture the shifts in March 2003 and October 2004 associated with the two implementation phases (II and III) of TRACE. In each phase, a substantial proportion of the bonds newly included in the database have small issuance size and low trading volume. This causes shifts in the level of illiquidity aggregated across individual bonds in these two months. The dummy variables catch these impacts.

Panel A of Table 1 reports the estimates of Eq. (8). As shown, ϕ_2 and θ_2 are significant at the 5% level and θ_1 is significant at the 10% level. In addition, the two dummy variables, d_1 and d_2, are significant at the 1% level. We convert the innovations ($\hat{\varepsilon}_t$) of illiquidity by adding a negative sign. This conversion makes it easier to compare with the Pastor-Stambaugh measure and to interpret the results later in cross-sectional tests. We henceforth refer to the converted innovation series ($-\hat{\varepsilon}_t$) as the Amihud liquidity factor as it now measures market liquidity. This

[6] We perform robustness checks by examining alternative specifications for the model. The dependent variable in Eq. (2) can be either excess or total bond returns. Similarly, the first regressor can be either total or excess returns, or it can be absent. In addition, the excess return can be adjusted by the corporate bond market return or by the combined corporate bond and stock market return. In all, we consider 12 model specifications and find that the Pastor-Stambaugh specification of Eqs. (2) and (4) produce the best results.

[7] The moving average components are essential for removing the serial correlation in the residuals of the Amihud measure. The orders of autoregressive and moving-average components are determined by the Bayesian Information Criterion.

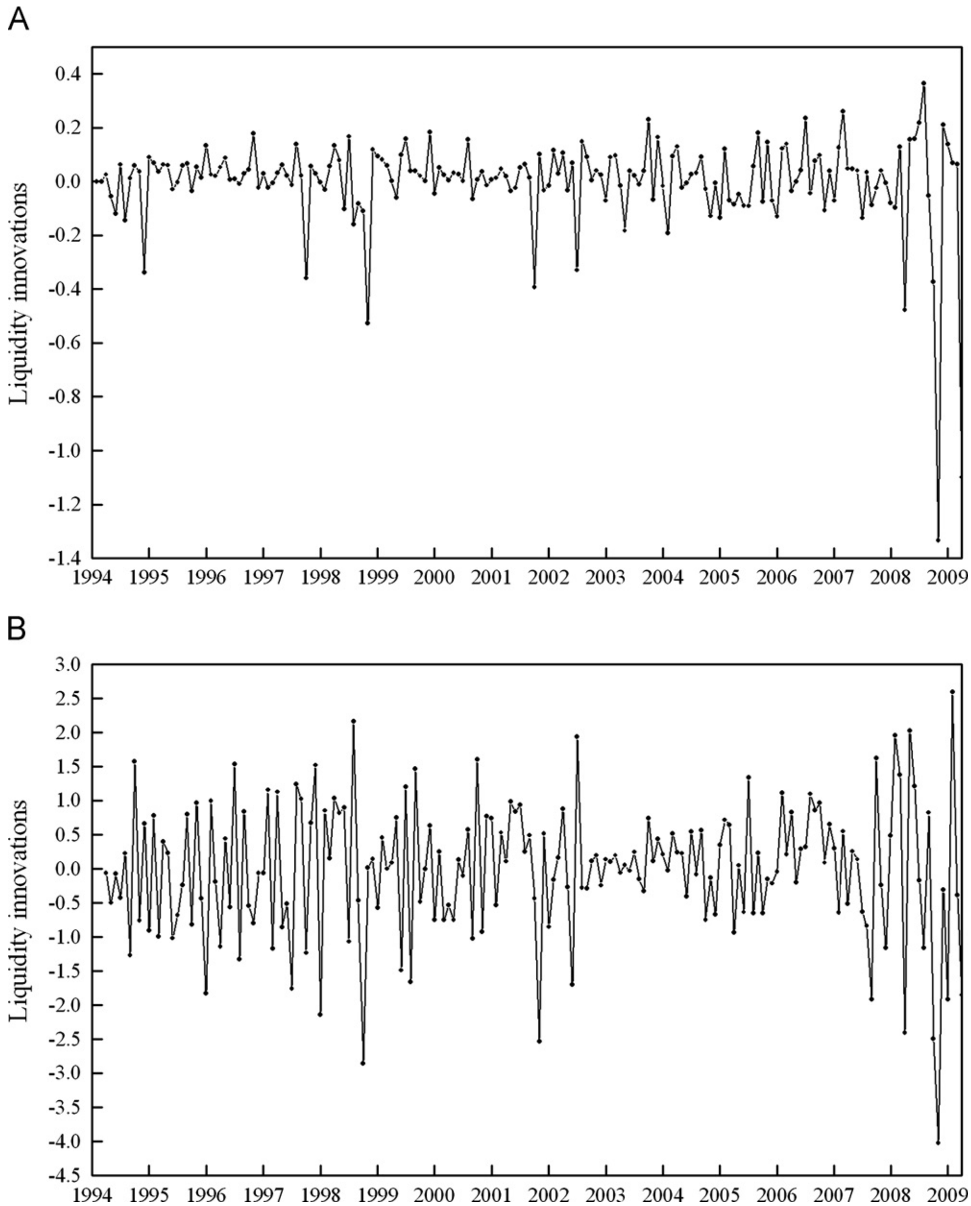

Fig. 1. Liquidity innovations of the corporate bond market. Panel A plots the Pastor-Stambaugh liquidity innovations, and Panel B plots the Amihud liquidity innovations. The sample period is from January 1994 to March 2009. The innovations are estimated from Eqs. (4) and (8), respectively. The Amihud liquidity measure is converted by adding a negative sign to the original illiquidity measure.

converted measure is used as a liquidity factor in the remaining analysis.

Panel B of Fig. 1 plots the time series of the Amihud liquidity factor. We scale the Amihud liquidity innovations to have unit standard deviation (see also Acharya and Pedersen, 2005). The Amihud liquidity series is stationary with the first-order autocorrelation close to zero (-0.01). The Amihud liquidity measure also reflects key liquidity events associated with the subprime, Russian and Asian financial crises, the September 11 and the Orange County events, WorldCom's default, and the Federal Reserve Board's policy shift around 2004–2006. Like the Pastor-Stambaugh measure, the aggregate Amihud illiquidity level peaks in October 1998 but the innovation ends up larger in September 1998.

Panel B of Table 1 reports contemporaneous and lagged correlations among different liquidity measures. In addition to the Pastor-Stambaugh and Amihud liquidity measures for the corporate bond market, we include the Pastor-Stambaugh stock market liquidity measure and the Sadka (2006) permanent variable and transitory fixed liquidity factor components for the stock market.[8] The

[8] These data are from Wharton Research Data Services. The sample period for the Pastor-Stambaugh stock liquidity measure ends in

Table 1
Estimation of the Amihud illiquidity innovations and correlations among liquidity factors.

This table reports the estimation of the Amihud bond illiquidity innovations (Panel A) and correlations among different liquidity measures (Panel B). The sample period is from January 1994 to March 2009, except for the Sadka factor and the Pastor-Stambaugh stock market liquidity measure, which end in December 2005 and 2008, respectively.

In Panel A,

$$\Delta ILLIQ_{Mt} = \alpha_0 + d_1 + d_2 + \phi_1\, \Delta ILLIQ_{Mt-1} + \phi_2 \left(\frac{M_{t-1}}{M_1}\right) ILLIQ_{Mt-1} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2},$$

where $\Delta ILLIQ_{Mt}$=$(M_t/M_1)(ILLIQ_{Mt}-ILLIQ_{Mt-1})$ is the scaled difference in monthly aggregate illiquidity measure, M_t is the dollar value at the end of month $t-1$ of the bonds included in month t, ε_t is the innovation (disturbance) term, d_1 is a dummy variable equal to one for March 2003 and zero otherwise, and d_2 is another dummy equal to one for October 2004 and zero otherwise. The time series model includes a lagged scaled difference term, the lagged value of the scaled level series, and two moving average components. The first two variables account for the effects of changes in size of the bond market and the sample size over the study period, and the moving average terms capture the serial correlation in the residuals. The two dummy variables reflect the sudden increases in the coverage of small illiquid bonds in Phases II and III of the TRACE system implementation and the associated jumps in the Amihud illiquidity series.

In Panel B, the liquidity measures are the Pastor-Stambaugh corporate bond market liquidity measure (*PSB*), the Amihud corporate bond market liquidity measure (*A*), the Pastor-Stambaugh stock market liquidity measure (*PSS*), and the Sadka transitory fixed (*STF*) and permanent variable (*SPV*) components of the equity-based liquidity factor. The Amihud liquidity measure is converted from the original illiquidity measure from Panel A by adding a negative sign ($-\hat{\varepsilon}_t$).

Panel A: Estimates of the Amihud illiquidity innovations

Parameters	α_0	d_1	d_2	ϕ_1	ϕ_2	θ_1	θ_2
Coefficients	−0.009	8.566	22.973	0.152	0.012	0.181	0.339
t-value	(−0.07)	(3.21)	(8.30)	(1.58)	(2.05)	(1.67)	(4.62)
Adj. R^2	0.351						

Panel B: Contemporaneous and lead-lag correlations among liquidity measures

Lag	Variable	PSB_t	A_t	PSS_t	STF_t	SPV_t
0	PSB_t	1.00				
	A_t	0.31	1.00			
	PSS_t	0.13	0.28	1.00		
	STF_t	0.11	0.17	0.08	1.00	
	SPV_t	0.05	0.18	0.17	0.26	1.00
1	PSB_{t-1}	0.00	0.09	−0.12	0.09	0.12
	A_{t-1}	0.14	−0.01	−0.02	−0.07	−0.03
	PSS_{t-1}	−0.03	−0.08	−0.15	0.04	0.18
	STF_{t-1}	0.13	0.08	−0.02	0.11	0.19
	SPV_{t-1}	0.12	0.01	−0.02	−0.15	0.09
2	PSB_{t-2}	−0.08	0.04	0.08	0.06	0.04
	A_{t-2}	−0.08	−0.02	−0.05	0.02	−0.13
	PSS_{t-2}	0.08	0.07	0.01	0.12	0.08
	STF_{t-2}	−0.10	0.07	0.10	−0.10	−0.03
	SPV_{t-2}	0.03	0.17	0.18	−0.07	−0.13

contemporaneous correlation between the Pastor-Stambaugh and Amihud bond liquidity measures is 0.31, suggesting that the two measures share common variations in corporate bond market liquidity. Correlations between bond and stock liquidity measures are moderate and higher between the Amihud bond liquidity measure and Pastor-Stambaugh stock liquidity measure. Cross correlations between markets for liquidity measures are generally weak. Only the first-order cross correlation between the Pastor-Stambaugh bond liquidity measure and lagged Sadka's liquidity components are slightly higher.

We estimate the sensitivity of returns to marketwide liquidity innovations for each individual bond. Liquidity beta is then used along with other risk variables to explain cross-sectional variations in expected corporate bond returns.

3. Is liquidity risk priced in the cross section of individual bonds?

In this section, we investigate whether a bond's expected return is positively related to liquidity risk using a linear factor model, which includes standard risk factors in the corporate bond literature and a liquidity factor. Fama and French (1993) study common factors of corporate bonds and find that term and default premia capture most of the variation in corporate bond returns. Using more recent data, Elton, Gruber, Agrawal, and Mann (2001) incorporate the Fama-French three factors, in addition to default and term premia, in their pricing model and find that these factors explain corporate bond returns. There are two reasons to incorporate the stock

(*footnote continued*)
December 2008, but Sadka's liquidity factor data end in December 2005. Separately, we follow the procedure in Sadka (2006) to update the estimates of the permanent variable and transitory fixed components to December 2008 and find similar results.

market factors in the bond pricing model. First, because both bond and stock are the firm's claims on the value of the same underlying assets, stock market factors such as size and book-to-market equity could share common variations in stock and bond returns. Second, expected default loss of corporate bonds changes with equity price. Default risk decreases as the equity value appreciates, and this induces a systematic factor that affects corporate bond returns. Following Elton, Gruber, Agrawal, and Mann (2001), we incorporate the Fama-French three factors in the corporate bond pricing model.

More specifically, we adopt the following factor model:

$$r_{it}-r_{ft}=\alpha_i+\beta_{iMKT}MKT_t+\beta_{iSMB}SMB_t+\beta_{iHML}HML_t +\beta_{iDEF}DEF_t+\beta_{iTERM}TERM_t+\beta_{iL}L_t+\varepsilon_{it}, \tag{9}$$

where MKT_t is the stock market excess return, SMB_t is the size factor, HML_t is the book-to-market factor, DEF_t is the default premium, $TERM_t$ is the term premium, and L_t is the liquidity factor. β_{iL} captures the sensitivity of individual bond returns to innovations in marketwide liquidity conditional on standard stock market and term structure factors.

In equilibrium, bonds' expected returns are related to factor loadings cross-sectionally:

$$r_{it}-r_{ft}=\gamma_0+\gamma_1\beta_{iMKT}+\gamma_2\beta_{iSMB}+\gamma_3\beta_{iHML}+\gamma_4\beta_{iDEF} +\gamma_5\beta_{iTERM}+\gamma_6\beta_{iL}+u_i. \tag{10}$$

Corporate bonds with higher systematic risks should have higher expected returns. Our main interest is to see if liquidity risk is priced. If liquidity risk is important for corporate bond pricing, γ_6 should be significantly positive. Besides the base model above, we consider bond characteristics such as issue size, coupon rate, age, and ratings in the cross-sectional regression. Previous studies find that these characteristic variables have some explanatory power for cross-sectional variations in bond returns.[9] It would be interesting to see how liquidity beta fares against conventional factor betas and bond characteristics. In empirical investigation, we assess importance of liquidity beta relative to other betas and bond characteristics in the cross section of expected corporate bond returns.

3.1. Summary statistics of individual bond betas

Table 2 provides summary statistics of factors and betas where betas are estimated by the linear factor model in Eq. (9) using the full sample. The liquidity factor of corporate bonds can be either the Pastor-Stambaugh or Amihud measure. Panel A shows the descriptive statistics of market returns and other risk factors and correlations among these factors. Over the sample period, the monthly average stock market return is 0.25%, and its volatility is 4.61%. Mean monthly returns of *SMB* and *HML* factors are −0.10% and 0.39%, respectively. The average monthly term premium is 0.36% and the average monthly default premium is 0.12%. Both the Pastor-Stambaugh measure (*PS* bond liquidity) and the Amihud bond market liquidity measure have mean close to zero because they are innovations by construction. Correlations among standard risk factors are generally modest. Correlations between the liquidity measures and other factors are low, which justifies the inclusion of liquidity as an additional factor to the return space spanned by the factors of standard corporate bond pricing models.

Panel B summarizes the full-period estimates of betas associated with market return, *SMB*, *HML*, default, term and liquidity factors, bond ratings, and excess returns. The left side of Panel B shows the results when using the Pastor-Stambaugh bond market liquidity measure as the liquidity factor. Default and term betas have average values of 0.74 and 0.69, and liquidity beta has a mean of 0.63. By contrast, average beta values of the Fama-French factors are small. Aggregate *T* statistics indicate that mean values of all variables are significantly different from zero. *T* statistics are computed based on the standard errors of mean. We also report the mean and median *t* statistics from the time series regressions for individual bonds. On average, default, term, and liquidity betas are significant at the 5% level or better, whereas betas of the Fama-French factors are not.

The right side of Panel B summarizes the full-period estimates of betas using the Amihud bond market liquidity measure as the liquidity factor. Betas of the Fama-French three factors and default and term factors change slightly when the Amihud measure is used as the liquidity factor. Results show that default and term beta estimates are not sensitive to alternative measures of the liquidity factor. On average, betas of liquidity, term, and default factors are again significant at the 5% level.

3.2. Cross-sectional regression tests on individual bonds

We conduct cross-sectional regression tests for individual bonds using the Fama and MacBeth (1973) methodology. Betas are first estimated over rolling past five-year periods for each bond and then used in the cross-sectional regression in the following month. We estimate betas for each corporate bond that has at least 15 monthly returns over the rolling 60-month windows. Beta estimates are subject to sample errors and, to resolve this errors-in-variables problem, we correct standard errors for the bias in all pricing tests using the Shanken (1992) method. In the following, we report results of cross-sectional tests on individual bond returns using different liquidity measures. For ease of comparison for the regression result, each explanatory variable is normalized by its cross-sectional standard deviation every month. This results in coefficients that represent the impact per unit standard deviation of each variable on expected bond returns. The normalization makes it easier to compare the premia of different variables, especially for alternative liquidity measures.

3.2.1. Tests using the Pastor-Stambaugh liquidity measure

The first two rows of Table 3 report the results of cross-sectional regressions where betas are estimated using the Pastor-Stambaugh bond liquidity measure as the liquidity

[9] Green and Odegaard (1997) find that coupon, age, time to maturity and issue size explain bond returns. Brennan, Chordia, and Subrahmanyam (1998) examine the relation between security characteristics and the cross section of expected stock returns.

Table 2
Summary statistics.

Panel A reports summary statistics and correlations for the six factors: market, *SMB*, *HML*, default, term, and liquidity. Market, *SMB*, and *HML* are Fama-French three factors downloaded from Kenneth French's data library, http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/. The default factor (*DEF*) is the difference between the return of a value-weighted portfolio of long-term investment-grade bonds in the sample and the return of long-term government bonds. The term factor (*TERM*) is the difference between the long-term government bond return and the one-month T-bill rate. *PS* bond liquidity is the Pastor-Stambaugh corporate bond market liquidity factor, and Amihud bond liquidity is the Amihud corporate bond market liquidity factor normalized to have a unit standard deviation. Variables are expressed in percentage. Data for all variables are monthly, and the sample period is from January 1994 to March 2009.

Panel B reports summary statistics of the time series regression using the full sample. Betas are estimated from the following linear factor model:

$$r_{it} - r_{ft} = \alpha_i + \beta_{iMKT} MKT_t + \beta_{iSMB} SMB_t + \beta_{iHML} HML_t + \beta_{iDEF} DEF_t + \beta_{iTERM} TERM_t + \beta_{iL} L_t + \varepsilon_{it},$$

where L_t is the liquidity factor that can be either the Pastor-Stambaugh or Amihud bond market liquidity factor. The dependent variable is return r_{it} of an individual bond in excess of the one-month T-bill rate r_{ft} in month t. The rating is measured on a nominal scale with 0 being assigned to Aaa, 1 to Aa1, … and 15 to B3 and below. For the return variable, we first calculate the mean excess return for each bond over the sample period and then report the summary statistics based on the cross-sectional distribution of these mean returns. *Return* is the excess return in percentage terms. Betas are the full-period estimates by individual bonds. *T* is the aggregate *t*-statistic, which is mean divided by its standard error. Besides *T*, we report mean and median *t* values of the beta estimates for individual bonds.

Panel A: Summary statistics and correlations

Variable	Summary statistics of factors					Factor correlations					
	Mean	Median	Minimum	Maximum	Standard deviation	*SMB*	*HML*	*DEF*	*TERM*	*PS bond liquidity*	*Amihud bond liquidity*
Market	0.25	0.98	−18.55	8.76	4.61	0.18	−0.33	0.16	−0.07	0.11	0.02
SMB	−0.10	−0.20	−21.96	13.78	3.76		−0.42	0.15	−0.18	0.05	0.01
HML	0.39	0.33	−9.94	13.85	3.53			−0.18	0.19	−0.02	0.05
DEF	0.12	0.10	−3.19	2.43	1.36				−0.46	−0.06	0.02
TERM	0.36	0.44	−3.36	4.09	2.08					0.05	−0.13
PS bond liquidity	−0.00	0.03	−1.33	0.36	0.18						0.31
Amihud bond liquidity	−0.02	0.06	−4.02	2.60	1.00						

Panel B: Summary of time series regression estimates

	Pastor-Stambaugh bond market liquidity factor							Amihud bond market liquidity factor						
Variable	Mean	Maximum	Minimum	Standard deviation	*T*	Mean *t*	Median *t*	Mean	Maximum	Minimum	Standard deviation	*T*	Mean *t*	Median *t*
Return	0.1613	2.8742	−2.7643	0.4146	42.14									
β_{MKT}	0.0044	0.3356	−0.2892	0.1509	3.16	−0.07	−0.08	0.0076	0.3413	−0.2833	0.1510	5.45	−0.06	−0.07
β_{SMB}	0.0179	0.3834	−0.3352	0.1725	11.24	0.10	0.09	0.0185	0.3767	−0.3277	0.1702	11.75	0.09	0.09
β_{HML}	−0.0113	0.4011	−0.3767	0.1874	−6.51	−0.18	−0.19	−0.0122	0.4036	−0.3785	0.1883	−7.03	−0.19	−0.18
β_{DEF}	0.7366	3.5976	−0.4046	0.6899	115.63	2.75	2.51	0.6939	3.7373	−0.8229	0.7731	97.20	2.08	1.98
β_{TERM}	0.6922	3.4545	−0.2245	0.5400	138.82	2.54	2.18	0.6635	3.5804	−0.5276	0.6012	119.53	2.05	1.82
β_L	0.6298	2.7481	−0.0558	0.6704	102.59	2.96	2.31	0.1944	0.9013	−0.0441	0.2277	92.47	2.37	1.97
Rating	6.6557	15.0000	0.0000	4.0485	178.04									
Adj. R^2	0.3554	0.9253	0.0848	0.1655				0.3570	0.9065	0.0323	0.1666			

Table 3
Asset pricing tests of individual bonds.

This table reports results of cross-sectional regression tests of individual bonds using the Fama and MacBeth methodology in which betas are estimated over rolling past five-year periods for each bond. The sample period is from January 1994 to March 2009, except for the tests based on the Pastor-Stambaugh and Sadka stock liquidity factors, which end in December 2008 and 2005, respectively. The dependent variable is a bond's monthly return in excess of the one-month T-bill rate. β_{MKT}, β_{SMB}, β_{HML}, β_{DEF}, and β_{TERM} are betas of market, size, book-to-market, default, and term factors. Each right-hand-side variable of the regression is normalized by its cross-sectional standard deviation every month, and hence its coefficient is readily interpretable as the premium (or return) per unit of standard deviation of each variable. Five liquidity factors are used in beta estimation: the Pastor-Stambaugh (*PS*) corporate bond and stock market liquidity factors, the Amihud corporate bond market liquidity factor, and Sadka's permanent variable (*SPV*) and transitory fixed (*STF*) stock market liquidity components. β_{L1} and β_{L2} are the betas associated with the liquidity factors of the corporate bond and stock markets, respectively, for all cases except for the regression using the Sadka factor. For the regression using Sadka's liquidity factor, β_{L1} and β_{L2} are betas associated with the permanent variable (*SPV*) and transitory fixed (*STF*) liquidity components, respectively. We also include bond characteristics such as coupon rate, age, issue size, and ratings for robustness check. The *t*-values are given in parentheses. c^* is the coefficient estimated by the Shanken (1992) method to adjust standard errors.

Liquidity measure	Intercept	β_{MKT}	β_{SMB}	β_{HML}	β_{DEF}	β_{TERM}	β_{L1}	β_{L2}	Rating	Coupon	Size	Age	c^*	Adj. R^2
PS bond	−0.079	0.018	0.029	0.033	0.094	0.102	0.081						0.26	0.059
	(−0.99)	(0.78)	(1.44)	(1.59)	(2.33)	(2.10)	(5.48)							
	−0.258	0.014	0.021	0.034	0.071	0.115	0.069		0.026	0.029	−0.000	−0.003	0.20	0.078
	(−2.59)	(0.67)	(1.15)	(1.74)	(2.01)	(2.69)	(4.45)		(0.79)	(1.94)	(0.25)	(−0.20)		
Amihud bond	0.012	0.026	0.030	0.033	0.096	0.099	0.079						0.11	0.063
	(0.16)	(1.18)	(1.51)	(1.86)	(2.69)	(2.16)	(4.92)							
	−0.214	0.014	0.019	0.038	0.063	0.118	0.067		0.035	0.035	−0.002	−0.008	0.08	0.081
	(−2.48)	(0.74)	(1.04)	(2.29)	(2.14)	(3.04)	(4.27)		(1.06)	(2.60)	(−0.13)	(−0.59)		
PS stock	−0.069	0.021	0.018	0.041	0.100	0.098		0.055					0.37	0.053
	(−0.87)	(0.83)	(0.84)	(1.90)	(2.32)	(1.91)		(4.13)						
	−0.255	0.015	0.007	0.045	0.072	0.108		0.032	0.024	0.032	−0.002	−0.006	0.26	0.073
	(−2.71)	(0.69)	(0.37)	(2.25)	(2.02)	(2.53)		(4.03)	(0.67)	(2.19)	(−0.11)	(−0.42)		
PS stock and bond	−0.061	0.017	0.016	0.035	0.088	0.111	0.058	0.022					0.19	0.057
	(−0.90)	(0.76)	(0.87)	(1.82)	(2.14)	(2.32)	(4.76)	(1.81)						
	−0.199	0.017	0.010	0.037	0.075	0.114	0.049	0.017	0.014	0.027	−0.002	−0.007	0.14	0.077
	(−2.07)	(0.91)	(0.61)	(2.03)	(2.13)	(2.72)	(4.07)	(1.63)	(0.40)	(1.91)	(−0.15)	(−0.46)		
SPV and STF	0.081	0.021	0.009	0.055	0.095	0.111	0.054	0.036					0.08	0.057
	(1.12)	(0.88)	(0.39)	(2.32)	(2.12)	(2.01)	(2.64)	(2.16)						
	−0.267	0.009	0.005	0.057	0.076	0.102	0.046	0.030	0.057	0.042	−0.006	−0.008	0.06	0.079
	(−2.60)	(0.44)	(0.27)	(2.48)	(2.10)	(2.23)	(2.33)	(1.91)	(1.48)	(2.87)	(−0.39)	(−0.42)		

factor in the time series regression. The base model (Row 1) includes betas of default, term, liquidity, and the Fama-French three factors. Results show that expected returns are significantly related to default, term, and liquidity betas at least at the 5% level.

Liquidity risk (β_{L1}) has a positive effect on expected corporate bond returns with a *t* value of 5.48. Based on the point estimate of the liquidity beta coefficient, a one standard deviation above the cross-sectional mean of liquidity beta is associated with a change in an excess return of 8.1 basis points per month (or 97 basis points per annum), which accounts for about 20% of the standard deviation of monthly corporate bond excess returns (41 basis points). This is an economically meaningful and significant effect.

To see how betas of common factors fare against bond characteristics in the cross section of expected returns, we add ratings, coupon rates, issue size, and bond age as explanatory variables to the regression. Results show that these characteristic variables are insignificant except for the coupon rate, which could capture the tax effect (see Liu, Shi, Wang, and Wu, 2007). More important, the coefficient of liquidity beta remains positive and highly significant even after controlling for effects of bond characteristic variables. Thus, there is strong evidence that liquidity risk is priced in corporate bond returns.

3.2.2. Tests using the Amihud liquidity measure

We next turn to cross-sectional regression tests where betas are estimated from the time series regression in Eq. (9) using the Amihud bond liquidity measure as the liquidity factor. Row 3 of Table 3 reports the results of the regression for the base model, which are similar to those based on the Pastor-Stambaugh liquidity factor. The coefficient of the Amihud liquidity beta (β_{L1}) is significant at the 1% level. Based on the point estimate of the liquidity beta coefficient, a one standard deviation above the cross-sectional mean of the Amihud liquidity beta is associated with an increase in the excess return of 7.9 basis points per month (or 95 basis points per annum), which accounts for 19% of one standard deviation of monthly bond excess returns. Again, liquidity risk appears to be an economically important determinant of expected bond returns. Both term and default betas are significant at least at the 5% level. When bond characteristic variables are added to the regression (see Row 4), only the coupon rate is significant. Liquidity beta remains significant at the 1% level even when controlling for the effects of bond characteristics.

3.2.3. Tests using alternative market liquidity measures

In the preceding tests, market return beta of corporate bonds is estimated using the stock market return, but liquidity beta is estimated using the corporate bond market liquidity factor. Because both stocks and bonds are involved in the cross-sectional regression, this raises a concern of whether corporate bond returns are affected by the liquidity factor in the stock market. In particular, if there is a liquidity spillover from one market to another, stock market liquidity is relevant to the pricing of corporate bonds.

To address these concerns, we consider the Pastor-Stambaugh liquidity factor for the equity market. The beta (β_{L2}) associated with the Pastor-Stambaugh stock liquidity factor measures sensitivity of corporate bond returns to equity market liquidity. Rows 5 and 6 of Table 3 report the results based on the Pastor-Stambaugh stock liquidity factor. The coefficient of stock liquidity beta is significant at the 1% level, suggesting a possible cross-market liquidity risk effect. The coefficient of stock market liquidity beta remains significant after incorporating bond characteristic variables.

To assess the relative importance of corporate bond and stock liquidity betas, we include both in the cross-sectional regressions. Results in the next two rows show that the effect of corporate bond liquidity beta (β_{L1}) dominates that of stock liquidity beta (β_{L2}). The coefficient of β_{L2} becomes much smaller but still significant around the 10% level after adding β_{L1} in the cross-sectional regression. Results show that the own-market liquidity factor is more influential than the cross-market liquidity factor.

We also construct the Amihud stock market liquidity measure using the NYSE-listed stocks from the Center for Research in Security Prices tape and estimate stock liquidity betas associated with this factor. Used alone as a liquidity risk measure in the cross-sectional regression test, the Amihud stock liquidity beta has a coefficient of 0.065, which is significant at the 1% level (t=3.96). However, when we include both Amihud stock and bond liquidity betas, the stock liquidity beta coefficient becomes much smaller (0.023) with a *t*-value of only 1.36, whereas the bond liquidity beta has a coefficient of 0.062 with a *t*-value of 3.88. The result is similar to that based on the Pastor-Stambaugh stock market liquidity factor.

Overall, empirical evidence strongly supports the hypothesis that the liquidity risk factor is priced. Besides liquidity beta, default and term betas are important determinants of required corporate bond returns. Moreover, there is some evidence that the equity-based liquidity factors affect the cross section of corporate bond returns.

3.2.4. Cross-sectional tests using liquidity-adjusted excess returns of individual bonds

The preceding tests have excess returns as the dependent variable in the cross-sectional regression and the effect of expected liquidity is not explicitly taken into account. Acharya and Pedersen (2005) show that expected liquidity is important for stock returns and suggest an alternative pricing test based on the return adjusted for liquidity cost. To address this issue, we next perform cross-sectional tests of individual bonds using the excess return net of liquidity cost as the dependent variable in regressions.

The liquidity variable in the Acharya-Pedersen framework is the expected one-time liquidity cost over the investor's holding period. However, our return horizon is monthly, which deviates from a typical investor's holding period. This requires an adjustment for the liquidity cost to be consistent with the data interval. We set the monthly average liquidity cost equal to k times the average one-time liquidity cost where k is the average monthly turnover of corporate bonds. The average monthly turnover rate is 0.049 for our sample, which implies a holding period of a little less than two years. The net return for an individual bond in month t equals the excess return $r_{it}-r_{ft}$ less the monthly liquidity cost, $k \times ILLIQ_{it}$. This net return is then used as the dependent variable in the cross-sectional regression for each month t.

Table 4 reports the results based on the excess return adjusted for expected liquidity cost. Row 1 shows the results of the base model using the Pastor-Stambaugh bond liquidity measure as the liquidity factor. The coefficient of liquidity beta is significant at the 1% level though its magnitude is reduced. The coefficients for default and term betas have little change and both remain significant. Thus, incorporating the level of liquidity cost in the regression test is primarily at the expense of liquidity beta. Adding the bond characteristic variables does not change the result materially and liquidity betas remain significant. Results suggest that liquidity risk is important over and beyond the effects of expected liquidity cost and bond characteristics in corporate bond pricing.

The coefficient of the Amihud liquidity beta (see Rows 3 and 4) also becomes smaller when returns are adjusted for expected liquidity cost but remains significant at the 1% level, regardless of whether bond characteristic variables are included or not. Similar results are found when we use the Pastor-Stambaugh stock liquidity beta only or use it along with corporate bond liquidity beta (see Rows 5 through 8). Considering the liquidity cost lowers the coefficient of liquidity beta but has little impact on the coefficients of default and term betas. Corporate bond liquidity beta remains highly significant in cross-sectional regressions even after controlling for expected liquidity cost. Finally, when we replace the Pastor-Stambaugh stock liquidity beta by the Amihud stock liquidity beta, we find a similar pattern. The coefficient of the Amihud stock liquidity beta is smaller (0.049) with a t-value of 3.06. When we include both Amihud stock and bond liquidity betas in the base cross-sectional regression, the coefficient of stock liquidity beta further reduces to 0.022 and becomes insignificant (t=1.26). By contrast, the Amihud bond liquidity beta has a coefficient of 0.046, which remains significant at the 1% level (t=3.36).

4. Is liquidity risk pricing an intra- or inter-rating effect?

Bonds with lower ratings tend to have higher liquidity risk. This makes it difficult to disentangle the effects of ratings and liquidity risk in average corporate bond returns. In this section, we provide additional tests to determine whether liquidity risk pricing is an inter- or intra-rating effect.

4.1. Time series regressions of bond rating portfolios

We group individual bonds by rating to create 16 portfolios from Aaa to B3 and below. Rating portfolios are formed each month to account for possible rating changes for some bonds over time, and this generates a series of monthly portfolio returns. We then estimate betas using the portfolio excess returns over the entire sample period. The full-period estimates of portfolio betas are reported in Table 5. As shown, liquidity, default, and term betas are highly significant. The left side shows estimates when the Pastor-Stambaugh bond market liquidity measure is used as the liquidity factor. Default beta generally increases as the rating decreases and so does liquidity beta. Results show that low-quality bond excess returns are more sensitive to fluctuations in marketwide liquidity. Term beta also tends to be positively related to credit risk but does not increase monotonically as the rating decreases. Betas of stock market factors are higher for speculative bonds, consistent with the conventional view that junk bonds behave more like stocks. The right side shows the regression results using the Amihud bond market liquidity measure. The overall pattern of estimates is similar to that based on the Pastor-Stambaugh measure.

Fig. 2 plots the relation between mean portfolio excess returns and liquidity beta. The graphs show that portfolio excess returns increase with both Pastor-Stambaugh and Amihud portfolio liquidity betas. The statistical significance of these relations is tested in the second-step cross-sectional regression below.

4.2. Cross-sectional regressions of bond rating portfolios

We investigate whether liquidity risk explains the differences in expected returns across rating portfolios. The 16 rating portfolios give a very limited degree of freedom for cross-sectional tests involving risk factors and bond characteristics. To increase the sample size in the cross-sectional test, we further divide bonds within each rating category into three maturity groups: one to five, five to ten, and above ten years. We then calculate equal-weighted returns every month for each of the 48 portfolios. The cross-sectional regression tests on portfolio excess returns are again based on the Fama and MacBeth (1973) methodology with standard errors corrected by the Shanken (1992) method. We estimate betas from the time series regression model in Eq. (9) for each rating-maturity portfolio using the previous five years of monthly returns, and in the month immediately following the estimation period we perform cross-sectional regression tests using betas estimated for each portfolio. Portfolios are formed each month as maturity changes over time.

Table 6 reports results of cross-sectional regressions on rating portfolios. Adjusted R^2 increases substantially, reflecting the benefit of reducing noise in empirical estimation using portfolios. The bond liquidity beta coefficients are all significantly positive, indicating that liquidity beta explains the variation in returns across ratings. Most of the characteristic variables are insignificant at the 5% level, and liquidity beta remains significant when controlling for the effects of bond characteristics. Used alone as the liquidity risk measure, the Pastor-Stambaugh stock beta has a coefficient of 0.078, which is

Table 4
Asset pricing tests of individual bonds using excess returns adjusted for expected liquidity cost.

This table reports results of cross-sectional regression tests of individual bonds with an adjustment in returns for expected liquidity cost. Tests are based on the Fama and MacBeth methodology in which betas are estimated over rolling past five-year periods for each bond. The sample period is from January 1994 to March 2009, except for the tests based on the Pastor-Stambaugh and Sadka stock liquidity factors, which end in December 2008 and 2005, respectively. The dependent variable is a bond's monthly excess return net of expected liquidity cost. β_{MKT}, β_{SMB}, β_{HML}, β_{DEF}, and β_{TERM} are betas of market, size, book-to-market, default, and term factors. Each right-hand-side variable of the regression is normalized by its cross-sectional standard deviation every month, and hence its coefficient is readily interpretable as the premium (or return) per unit of standard deviation of each variable. Five liquidity factors are used in beta estimation: the Pastor-Stambaugh (*PS*) corporate bond and stock market liquidity factors, the Amihud corporate bond market liquidity factor, and Sadka's permanent variable (*SPV*) and transitory fixed (*STF*) stock market liquidity factor components. β_{L1} and β_{L2} are the betas associated with the liquidity factors of the corporate bond and stock markets, respectively, for all cases except the regression using Sadka's liquidity factor. For the regression using the Sadka liquidity factor, β_{L1} and β_{L2} are betas associated with the permanent variable (*SPV*) and transitory fixed (*STF*) liquidity components, respectively. We also include bond characteristics such as coupon rate, age, issue size, and ratings for robustness check. The *t*-values are given in parentheses. c^* is the coefficient estimated by the Shanken (1992) method to adjust the standard errors of cross-sectional regression parameter estimates.

Liquidity measure	Intercept	β_{MKT}	β_{SMB}	β_{HML}	β_{DEF}	β_{TERM}	β_{L1}	β_{L2}	Rating	Coupon	Size	Age	c^*	Adj. R^2
PS bond	−0.077	0.021	0.030	0.031	0.090	0.103	0.060						0.14	0.057
	(−1.11)	(0.81)	(0.74)	(1.33)	(2.12)	(2.09)	(5.65)							
	−0.275	0.015	0.021	0.031	0.066	0.117	0.049		0.029	0.033	0.004	−0.020	0.11	0.077
	(−2.81)	(0.73)	(1.14)	(1.58)	(1.96)	(2.87)	(4.67)		(0.83)	(2.18)	(0.27)	(−1.24)		
Amihud bond	−0.007	0.027	0.031	0.033	0.090	0.104	0.054						0.07	0.062
	(−0.10)	(1.23)	(1.53)	(1.83)	(2.52)	(2.33)	(3.21)							
	−0.247	0.014	0.020	0.038	0.060	0.123	0.042		0.033	0.040	0.012	−0.022	0.05	0.082
	(−2.79)	(0.75)	(1.06)	(2.21)	(2.04)	(3.24)	(2.65)		(0.96)	(2.73)	(0.71)	(−1.45)		
PS stock	−0.067	0.021	0.020	0.039	0.104	0.099		0.048					0.28	0.053
	(−0.89)	(0.83)	(0.91)	(1.79)	(2.34)	(1.95)		(4.03)						
	−0.284	0.016	0.009	0.043	0.081	0.110		0.026	0.021	0.036	−0.000	−0.008	0.19	0.073
	(−3.13)	(0.73	(0.46)	(2.11)	(2.19)	(2.58)		(3.91)	(0.59)	(2.34)	(−0.02)	(−0.48)		
PS stock and bond	−0.058	0.015	0.020	0.031	0.086	0.106	0.051	0.018					0.14	0.055
	(−0.86)	(0.67)	(1.07)	(1.51)	(2.11)	(2.31)	(5.63)	(1.45)						
	−0.217	0.013	0.012	0.034	0.070	0.114	0.042	0.012	0.026	0.029	0.007	−0.018	0.11	0.075
	(−2.28)	(0.64)	(0.71)	(1.70)	(2.00)	(2.83)	(4.82)	(1.16)	(0.72)	(1.92)	(0.45)	(−1.13)		
SPV and STF	0.057	0.018	0.010	0.054	0.087	0.119	0.051	0.035					0.08	0.057
	(0.72)	(0.77)	(0.43)	(2.36)	(1.95)	(2.32)	(2.46)	(1.06)						
	−0.282	0.009	0.007	0.054	0.069	0.111	0.045	0.031	0.042	0.033	−0.008	−0.015	0.06	0.080
	(−2.46)	(0.46)	(0.34)	(2.35)	(2.02)	(2.66)	(2.24)	(1.87)	(0.96)	(2.30)	(−0.19)	(−0.65)		

Table 5

Time series regression of rating portfolio excess returns.

This table reports the results of time series regressions for 16 rating portfolios from Aaa to B3 and below. The sample period is from January 1994 to March 2009. Portfolios are formed at the beginning of each month based on ratings of individual bonds. Excess returns (in percentage) of rating portfolios are regressed against the Fama-French factors, default and term factors, and a liquidity factor that can be either the Pastor-Stambaugh or Amihud bond market liquidity factor for the full sample period. Return is the mean portfolio return (percent) in excess of the one-month T-bill rate. The *t*-values are in parentheses.

		Pastor-Stambaugh liquidity measure								Amihud liquidity measure							
Rating	Return	α	β_{MKT}	β_{SMB}	β_{HML}	β_{DEF}	β_{TERM}	β_L	Adj. R^2	α	β_{MKT}	β_{SMB}	β_{HML}	β_{DEF}	β_{TERM}	β_L	Adj. R^2
Aaa	0.108	−0.049	−0.022	−0.021	−0.021	0.421	0.554	0.398	0.800	0.049	−0.021	−0.024	−0.020	0.417	0.550	0.101	0.801
		(−1.57)	(−2.70)	(−1.86)	(−1.74)	(11.48)	(19.70)	(2.45)		(1.61)	(−2.56)	(−2.10)	(−1.71)	(11.28)	(19.78)	(2.93)	
Aa1	0.122	−0.042	−0.008	−0.017	−0.021	0.513	0.658	0.434	0.595	0.047	−0.008	−0.022	−0.018	0.521	0.656	0.145	0.604
		(−0.69)	(−0.49)	(−0.76)	(−0.91)	(6.81)	(11.65)	(2.42)		(0.79)	(−0.50)	(−0.98)	(−0.79)	(7.00)	(11.92)	(2.14)	
Aa2	0.138	−0.047	−0.030	−0.013	−0.023	0.572	0.727	0.552	0.724	0.116	−0.025	−0.010	−0.016	0.501	0.651	0.177	0.733
		(−0.94)	(−2.28)	(−0.69)	(−1.19)	(9.72)	(16.08)	(3.16)		(1.34)	(−2.15)	(−0.60)	(−0.97)	(9.49)	(16.38)	(3.59)	
Aa3	0.143	−0.047	−0.037	−0.010	−0.036	0.589	0.699	0.565	0.789	0.101	−0.036	−0.011	−0.038	0.530	0.641	0.201	0.785
		(−1.18)	(−3.55)	(−0.68)	(−2.32)	(12.51)	(19.36)	(2.70)		(1.38)	(−3.70)	(−0.83)	(−2.67)	(11.88)	(19.08)	(4.82)	
A1	0.146	−0.032	−0.013	−0.004	−0.025	0.532	0.662	0.565	0.867	0.058	−0.011	−0.007	−0.023	0.525	0.655	0.161	0.869
		(−1.11)	(−1.77)	(−0.35)	(−2.21)	(15.61)	(25.33)	(2.80)		(1.05)	(−1.52)	(−0.65)	(−2.10)	(15.40)	(25.52)	(5.07)	
A2	0.150	−0.042	−0.017	0.005	−0.023	0.539	0.724	0.525	0.855	0.052	−0.015	0.001	−0.023	0.539	0.723	0.203	0.859
		(−1.37)	(−2.07)	(0.44)	(−1.96)	(14.92)	(26.10)	(2.62)		(1.75)	(−1.96)	(0.12)	(−1.98)	(14.93)	(26.59)	(6.01)	
A3	0.151	−0.041	−0.026	0.013	−0.018	0.597	0.759	0.471	0.847	0.060	−0.025	0.011	−0.019	0.596	0.758	0.200	0.848
		(−1.24)	(−2.95)	(1.10)	(−1.42)	(15.25)	(25.28)	(2.71)		(1.87)	(−2.86)	(0.92)	(−1.48)	(15.15)	(25.60)	(5.45)	
Baa1	0.154	−0.021	−0.018	0.008	−0.029	0.555	0.704	0.570	0.816	0.056	−0.013	0.005	−0.026	0.544	0.696	0.196	0.818
		(−0.63)	(−1.97)	(0.66)	(−2.21)	(13.78)	(22.78)	(2.39)		(1.69)	(−1.52)	(0.41)	(−2.01)	(13.42)	(22.81)	(5.17)	
Baa2	0.167	−0.031	−0.021	0.030	−0.023	0.580	0.713	0.575	0.786	0.058	−0.020	0.026	−0.022	0.583	0.713	0.221	0.790
		(−0.80)	(−2.13)	(2.12)	(−1.56)	(12.80)	(20.51)	(2.86)		(1.55)	(−2.02)	(1.85)	(−1.54)	(12.87)	(20.90)	(5.22)	
Baa3	0.182	0.019	−0.003	0.020	−0.025	0.591	0.721	0.614	0.799	0.111	−0.001	0.015	−0.023	0.584	0.710	0.230	0.801
		(0.49)	(−0.30)	(1.43)	(−1.73)	(13.31)	(21.17)	(3.11)		(1.53)	(−0.15)	(1.14)	(−1.62)	(13.23)	(21.35)	(5.58)	
Ba1	0.246	0.048	0.026	0.042	0.038	0.657	0.633	0.707	0.549	0.151	0.029	0.043	0.033	0.643	0.630	0.222	0.554
		(0.69)	(1.43)	(1.66)	(1.42)	(7.92)	(10.03)	(2.33)		(1.10)	(1.60)	(1.70)	(1.26)	(7.71)	(10.12)	(2.84)	
Ba2	0.272	0.145	0.026	0.026	0.042	0.796	0.732	0.735	0.473	0.244	0.030	0.025	0.040	0.774	0.722	0.272	0.480
		(1.04)	(1.44)	(1.02)	(1.56)	(9.48)	(11.49)	(2.39)		(1.78)	(1.64)	(1.00)	(1.52)	(9.25)	(11.57)	(3.50)	
Ba3	0.338	0.245	0.045	0.008	0.015	0.787	0.611	0.627	0.419	0.333	0.050	0.007	0.015	0.744	0.585	0.296	0.424
		(1.75)	(2.44)	(0.33)	(0.54)	(9.50)	(9.61)	(2.55)		(1.63)	(2.74)	(0.28)	(0.58)	(8.94)	(9.34)	(3.80)	
B1	0.386	0.137	0.077	0.050	0.076	1.064	0.795	0.772	0.428	0.179	0.080	0.045	0.074	0.915	0.715	0.285	0.475
		(1.47)	(3.11)	(1.47)	(2.09)	(9.58)	(9.33)	(2.35)		(1.15)	(3.84)	(1.56)	(2.43)	(9.65)	(10.01)	(3.21)	
B2	0.396	0.228	0.073	0.003	0.038	0.917	0.701	0.800	0.431	0.327	0.075	0.002	0.035	0.894	0.692	0.353	0.437
		(1.55)	(3.75)	(0.10)	(1.34)	(10.37)	(10.45)	(2.47)		(1.49)	(3.91)	(0.08)	(1.26)	(10.05)	(10.43)	(4.27)	
B3 and below	0.416	0.229	0.095	0.037	0.057	0.933	0.784	0.812	0.356	0.322	0.100	0.038	0.057	0.884	0.767	0.341	0.367
		(1.20)	(3.89)	(1.10)	(1.65)	(8.33)	(9.18)	(2.47)		(1.72)	(4.14)	(1.13)	(1.65)	(7.75)	(9.04)	(3.19)	

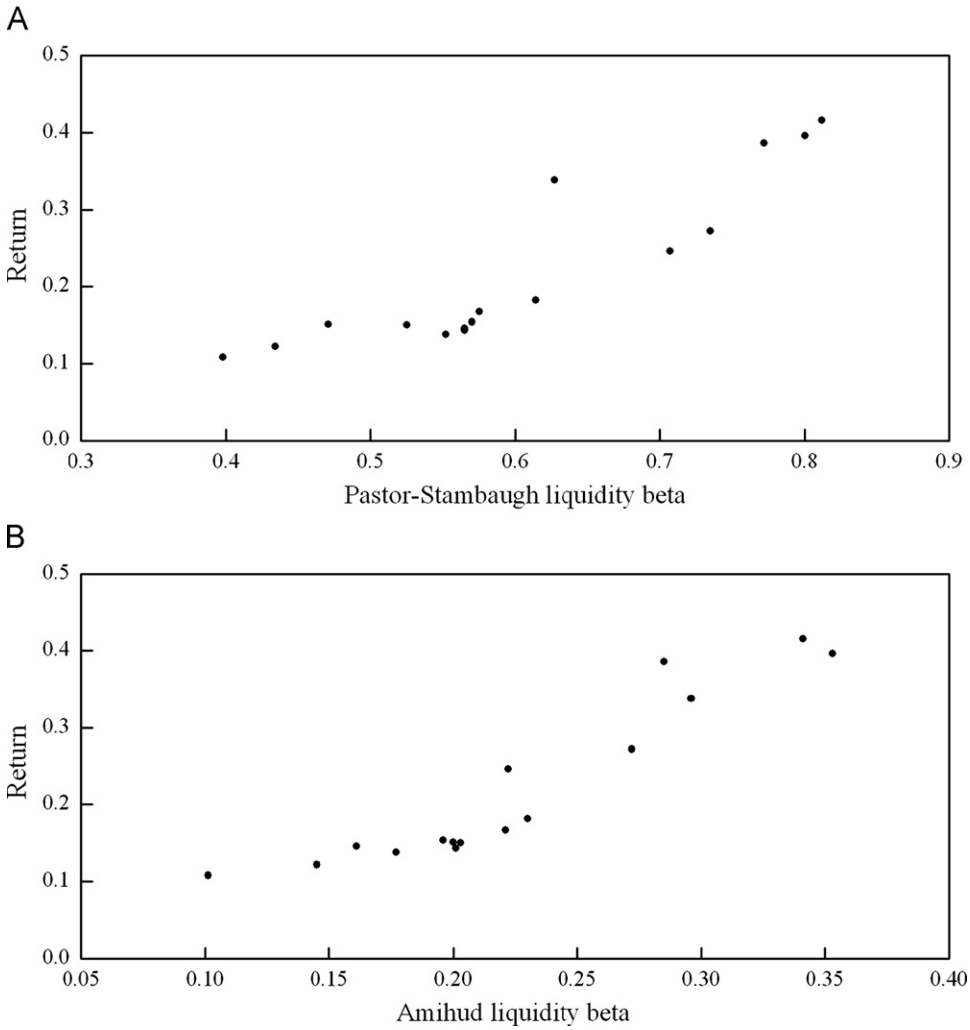

Fig. 2. The relation between bond excess returns and liquidity beta. Panel A plots the relation between excess returns and the Pastor-Stambaugh liquidity betas associated with rating portfolios from Aaa to B3 and below. Panel B plots the relation between excess returns and the Amihud liquidity betas of rating portfolios. Liquidity betas are full-sample estimates, and *Return* is the mean portfolio return in excess of the one-month Treasury bill rate by rating category. The sample period is from January 1994 to March 2009.

significant at the 1% level. But it becomes much smaller and insignificant when the bond liquidity beta is added to the regression. Using the Amihud stock liquidity beta gives similar results. The coefficient of the Amihud stock liquidity beta is 0.053 with a t-value of 2.81 and becomes much smaller (0.001) and insignificant (t=0.04) when the Amihud bond liquidity beta is added. We also add two dummy variables, D_1 and D_2, to see if bond maturity affects the premium of liquidity beta. D_1 (D_2) equals one if average maturity of the portfolio is less than or equal to five years (greater than ten years) and zero otherwise. Results show that maturity has no significant effect on liquidity risk price.

The liquidity risk premium can be estimated from the product of liquidity beta and liquidity risk price. The high-low liquidity-beta spread is 0.414 between the portfolios of Aaa and B3 and below when using the Pastor-Stambaugh liquidity measure (see Table 5). Given an unnormalized liquidity beta coefficient 0.12 in the cross-sectional regression, this results in a liquidity premium of 60 basis points per annum (or 5 basis points per month).[10] The return spread between Aaa and B3 and below portfolios is 3.7% per annum (or 31 basis points per month). The liquidity risk premium explains 16% of the high-low return spread. Likewise, the high-low liquidity beta spread is 0.24 when using the Amihud measure and with an unnormalized slope coefficient of 0.25 in the cross-sectional regression, the liquidity premium is 72 basis points per annum (6 basis points per month), which explains about 19% of the high-low return spread. Taken together, results show that liquidity risk can explain part

[10] Regression results based on unnormalized variables are omitted for brevity.

Table 6

Cross-sectional regressions of bond rating portfolios.

This table reports results of cross-sectional regression tests based on rating portfolios using the Fama and MacBeth method with five-year rolling windows. The sample period is from January 1994 to March 2009, except for the tests based on the Pastor-Stambaugh and Sadka stock liquidity factors, which end in December 2008 and 2005, respectively. Portfolios are formed each month by rating from Aaa to B3 and below, and bonds within each rating portfolio are further divided into three maturity groups: maturities shorter than or equal to five years, between five and ten years, and longer than ten years. The dependent variable is a portfolio's monthly excess return. β_{MKT}, β_{SMB}, β_{HML}, β_{DEF}, and β_{TERM} are betas of market, size, book-to-market, default, and term factors, and the coefficient is the premium per unit of standard deviation of each variable. β_{L1} and β_{L2} are the betas associated with the liquidity factors of the corporate bond and stock markets, respectively, for all cases except for the regressions using Sadka's liquidity factor. For the regression using the Sadka factor, β_{L1} and β_{L2} are betas associated with the permanent variable (*SPV*) and transitory fixed (*STF*) liquidity components, respectively. D_1 and D_2 are the dummy variables, which equal one for bonds with short (≤ 5 years) and long (> 10 years) maturities and zero otherwise. These dummy variables are used to test whether the liquidity risk premium is sensitive to maturity. $D_i\beta_L$, $i=1,2$, is the interactive dummy variable in which β_L stands for the corporate bond liquidity beta in the regressions using the Pastor-Stambaugh (*PS*) bond market liquidity factor, Amihud bond market liquidity factor, and *PS* stock and bond market liquidity factors, and it represents the stock liquidity betas in the regression based on the *PS* stock market liquidity factor. For the regression using Sadka's factor, β_L represents the beta of permanent variable liquidity component. We include portfolio characteristics such as coupon rate, age, issue size, and ratings for robustness check. *t*-values are given in parentheses, and c^* is the coefficient estimated by the Shanken (1992) method to adjust standard errors.

Liquidity measure	Intercept	β_{MKT}	β_{SMB}	β_{HML}	β_{DEF}	β_{TERM}	β_{L1}	β_{L2}	$D_1\beta_L$	$D_2\beta_L$	Rating	Coupon	Size	Age	c^*	Adj. R^2
	0.038	0.014	0.017	0.036	0.113	0.187	0.109		0.033	−0.031					0.42	0.390
PS bond	(0.45)	(0.26)	(0.66)	(1.02)	(1.84)	(3.62)	(4.40)		(0.96)	(0.95)						
	−0.387	0.016	0.015	0.069	0.110	0.159	0.074		−0.036	−0.022	0.010	0.069	−0.110	0.031	0.43	0.472
	(−1.57)	(0.43)	(0.59)	(1.97)	(1.72)	(3.32)	(2.27)		(−0.69)	(−0.58)	(0.70)	(1.79)	(−0.15)	(1.31)		
	0.104	0.012	0.027	0.027	0.128	0.164	0.075		−0.009	0.012					0.22	0.382
Amihud bond	(1.47)	(0.22)	(1.05)	(0.73)	(2.41)	(2.55)	(3.92)		(−0.18)	(0.39)						
	−0.222	0.023	0.008	0.046	0.139	0.147	0.055		−0.025	0.029	0.010	0.066	−0.117	0.011	0.24	0.463
	(−1.07)	(0.63)	(0.26)	(1.24)	(2.23)	(2.88)	(1.96)		(−0.39)	(0.67)	(0.75)	(2.08)	(−0.26)	(0.55)		
	0.102	0.016	0.026	0.039	0.165	0.192		0.078	0.013	−0.015					0.67	0.341
PS stock	(1.22)	(0.30)	(0.68)	(0.95)	(2.49)	(2.90)		(2.63)	(0.52)	(−0.46)						
	−0.070	0.014	0.003	0.027	0.118	0.157		0.070	−0.015	0.012	0.052	0.066	−0.002	0.026	0.70	0.451
	(−0.25)	(0.32)	(0.11)	(0.85)	(2.06)	(2.75)		(1.92)	(−0.56)	(0.23)	(0.75)	(1.57)	(−0.12)	(0.71)		
	0.113	0.008	0.006	0.044	0.121	0.167	0.054	0.024	0.041	−0.047					0.41	0.375
PS stock and bond	(1.31)	(0.19)	(0.22)	(1.30)	(1.94)	(2.67)	(2.02)	(0.95)	(1.04)	(−1.56)						
	−0.345	0.014	0.003	0.048	0.110	0.178	0.067	0.013	−0.009	−0.065	0.004	0.060	−0.152	0.024	0.40	0.470
	(−1.38)	(0.38)	(0.14)	(1.51)	(1.95)	(2.38)	(2.15)	(0.57)	(−0.19)	(−1.63)	(0.31)	(1.68)	(−0.37)	(0.97)		
	0.207	0.014	0.017	0.002	0.145	0.167	0.047	0.042	0.012	0.025					0.33	0.431
SPV and STF	(2.54)	(0.27)	(0.59)	(0.04)	(2.54)	(2.56)	(1.90)	(1.62)	(0.42)	(0.42)						
	−0.185	0.008	0.016	0.034	0.121	0.166	0.061	0.055	0.031	0.062	0.062	0.035	−0.000	0.030	0.34	0.518
	(−0.59)	(0.19)	(0.41)	(0.67)	(2.37)	(2.81)	(1.85)	(1.70)	(1.20)	(1.09)	(0.79)	(0.67)	(−0.02)	(1.05)		

of the variation in expected corporate returns across ratings.

4.3. Liquidity pricing within the cross section of each bond rating

To further investigate the model's ability to explain expected corporate bond returns, we run cross-sectional regressions for individual bonds in each rating category. The number of bonds varies across ratings and on average there are about 730 bonds in a rating group. Table 7 reports results of cross-sectional regressions of individual bonds within each rating group based on the model with bond characteristic variables. Because bonds in each cross-sectional regression have the same rating, the effect of the rating is under control. For brevity, we report only estimates of coefficients for default, term, and liquidity betas in the cross-sectional regression.

Panel A shows results of cross-sectional tests for each rating group when using the Pastor-Stambaugh liquidity measure. The liquidity risk effect varies across rating groups with the effect of liquidity risk on expected returns higher for lower-grade bonds. For example, the premium of liquidity beta is about 0.1% per unit of standard deviation for bonds with a rating of B3 and below but is only 0.053% for Aaa bonds. The average coefficient (liquidity risk price) for the Pastor-Stambaugh liquidity beta is 0.074%, which is significant at the 1% level in terms of both the aggregate T (18.0) and average individual t-statistic (2.64) across rating groups. Lower-grade bonds have higher liquidity premiums, which is consistent with the phenomenon of investors' flight-to-quality in illiquid periods.

When using the Amihud measure as the liquidity factor, we find a similar pattern of liquidity risk price from high- to low-grade bonds (see Panel B). The average premium of liquidity beta per unit of standard deviation across rating groups is 0.069% monthly, significantly different from zero at the 1% level in terms of the aggregate T (14.18) and at the 5% level based on average individual t-statistic (2.20). Again, the liquidity risk premium is generally higher when the rating is lower. The liquidity risk premium per unit of standard deviation ranges from 0.041% to 0.096% monthly.

The default beta coefficient becomes much smaller and insignificant after controlling for the rating effect regardless of liquidity factor choices. Results suggest that bond ratings and default beta share important common information on default risk. The effect of term beta is also lower, though not declining as much as that for default beta. Term beta is significant at the 5% level only for bonds in the groups of A2 and Ba3 when using the Pastor-Stambaugh measure as the liquidity factor (see Panel A) and is somewhat more significant when using the Amihud measure (see Panel B).

Used alone as the liquidity risk measure, the Pastor-Stambaugh stock liquidity beta is significant at least at the 5% level for five of the 16 rating groups (see Panel C). On average, stock liquidity beta is significant at the 10% level. However, when we include both Pastor-Stambaugh bond and stock liquidity betas in the cross-sectional regression, none of the stock liquidity betas is significant but bond liquidity betas are on average significant at the 5% level (see Panel D).

In summary, evidence exists that the liquidity risk factor is priced within the cross section of each bond rating. The effect of liquidity risk on expected returns of individual bonds tends to increase as the rating decreases, and the liquidity risk premium is generally larger for bonds with lower ratings.

5. Portfolio sorts

In this section, we investigate the role of liquidity beta in the cross section of corporate bond returns using portfolio sorts. Portfolio-based analysis provides more direct tests on the importance of liquidity and gives additional evidence.

5.1. Portfolio analysis based on liquidity betas of individual bonds

Liquidity and other betas are jointly estimated over rolling five-year periods for each individual bond similar to the regression approach. Individual bonds are sorted into ten portfolios each month, each with an equal number of bonds, by the pre-ranking liquidity beta. We then calculate average monthly excess returns, coupon, size, and rating for each ex post portfolio along with pre-ranking betas.

Panel A of Table 8 shows results of portfolio sorts by liquidity beta based on the Pastor-Stambaugh bond market liquidity measure. High liquidity beta portfolios tend to have high default and term betas and low ratings. Results show a strong positive relation between liquidity beta and average corporate bond excess returns. The high liquidity beta portfolio earns 0.34% per month (4.08% per annum) more than the low liquidity beta portfolio, and the t-statistic for this difference is 2.81. The contribution of liquidity premium to the return spread can be estimated by multiplying the high-low liquidity beta spread by the slope coefficient of beta. The 10–1 liquidity beta spread is 2.8. With a slope coefficient of 0.098 (unnormalized from Table 3), this yields a liquidity spread of 0.27% per month (or 3.29% per annum), which accounts for 81% of the 10–1 return spread.

Panel B of Table 8 reports results of portfolio sorts by liquidity beta based on the Amihud bond liquidity measure. Results show a pattern similar to Panel A, in that high liquidity beta portfolios have high default and term betas and low ratings. A positive relation exists between liquidity beta and average bond returns. The high-low return spread is 0.29% per month (3.48% per annum) with a t-statistic of 2.33. The 10–1 liquidity beta spread is 0.87. Given a slope coefficient of 0.257 (unnormalized from Table 3), this results in a liquidity risk spread of 0.22% per month (2.68% per annum), which explains 77% of the 10–1 return spread.

Results show that liquidity risk is an economically important determinant of expected corporate bond

Table 7
Cross-sectional regression tests of individual bonds in each rating category.

This table reports results of cross-sectional regression tests of individual bonds within each rating category based on the model including bond characteristic variables. Tests are based on the Fama and MacBeth methodology in which betas are estimated over rolling past five-year periods for each bond. The sample period is from January 1994 to March 2009, except for the tests based on the Pastor-Stambaugh and Sadka stock liquidity factors, which end in December 2008 and 2005, respectively. The dependent variable is a bond's monthly excess return in percentage. The independent variables include betas of market, size, book-to-market, default, term and liquidity factors, and bond characteristics. Each right-hand-side variable of the regression is normalized by its cross-sectional standard deviation every month within each rating category and hence its coefficient is readily interpretable as the premium (or return) per unit of standard deviation of each variable. For brevity, we report only the coefficients and *t*-statistics of betas associated with default, term, and liquidity factors. Five liquidity variables are used in beta estimation: the Pastor-Stambaugh corporate bond and stock market liquidity factors, the Amihud corporate bond market liquidity factor, and Sadka's permanent variable (*SPV*) and transitory fixed (*STF*) stock market liquidity components. The betas of these liquidity factors are used separately in each cross-sectional regression in Panels A to E. The *t*-values are given in parentheses. The Shanken (1992) method is used to correct the bias in standard errors. *T* is the aggregate *t*-statistic, which is mean divided by its standard error. Mean beta coefficients and *t*-values (in parentheses) are averages across individual rating groups.

Variable	*Aaa*	*Aa1*	*Aa2*	*Aa3*	*A1*	*A2*	*A3*	*Baa1*	*Baa2*	*Baa3*	*Ba1*	*Ba2*	*Ba3*	*B1*	*B2*	*B3 and below*	Mean	Aggregate *T*
Panel A: Tests of the factor model using the Pastor-Stambaugh bond market liquidity measure																		
Default	0.038	0.137	0.037	0.070	0.033	0.046	0.063	0.066	0.100	0.037	0.113	0.106	0.025	0.033	0.025	0.021	0.059	6.54
	(0.89)	(1.54)	(0.54)	(1.37)	(0.63)	(1.15)	(1.05)	(1.06)	(1.37)	(0.62)	(0.89)	(0.88)	(0.26)	(0.26)	(0.28)	(0.24)	(0.81)	
Term	0.052	0.028	0.073	0.072	0.102	0.096	0.076	0.032	0.061	0.111	0.080	0.045	0.191	0.055	0.071	0.111	0.079	7.99
	(0.73)	(0.58)	(0.95)	(1.29)	(1.74)	(2.01)	(1.05)	(0.49)	(0.89)	(1.78)	(0.92)	(0.44)	(2.28)	(0.63)	(0.61)	(1.34)	(1.11)	
Liquidity	0.053	0.055	0.064	0.072	0.054	0.055	0.075	0.073	0.080	0.077	0.067	0.095	0.069	0.093	0.103	0.099	0.074	18.00
	(4.23)	(1.62)	(2.39)	(4.05)	(2.73)	(3.08)	(2.78)	(2.83)	(2.17)	(2.70)	(1.91)	(1.59)	(2.82)	(1.90)	(2.79)	(2.59)	(2.64)	
Adj. R^2	0.115	0.144	0.111	0.076	0.083	0.072	0.087	0.080	0.077	0.066	0.077	0.041	0.045	0.054	0.058	0.039	0.077	
Panel B: Tests of the factor model using the Amihud bond market liquidity measure																		
Default	0.047	0.064	0.059	0.088	0.087	0.059	0.111	0.071	0.089	0.104	0.109	0.133	0.018	0.011	0.028	0.014	0.068	7.27
	(1.02)	(0.74)	(0.81)	(1.81)	(1.76)	(1.44)	(2.18)	(1.15)	(1.51)	(1.93)	(1.03)	(1.10)	(0.20)	(0.09)	(0.32)	(0.20)	(1.08)	
Term	0.146	0.078	0.084	0.051	0.100	0.105	0.163	0.031	0.090	0.057	0.044	0.028	0.167	0.089	0.090	0.135	0.091	8.30
	(2.31)	(0.77)	(0.93)	(0.95)	(1.83)	(2.15)	(2.52)	(0.49)	(1.31)	(0.86)	(0.54)	(0.29)	(1.74)	(0.82)	(0.94)	(1.86)	(1.27)	
Liquidity	0.045	0.062	0.054	0.073	0.056	0.041	0.043	0.051	0.089	0.072	0.095	0.088	0.076	0.068	0.094	0.096	0.069	14.18
	(2.47)	(1.77)	(1.57)	(4.15)	(2.68)	(1.85)	(1.24)	(2.01)	(2.37)	(2.17)	(2.01)	(2.17)	(2.75)	(1.34)	(2.11)	(2.61)	(2.20)	
Adj. R^2	0.115	0.179	0.138	0.083	0.084	0.084	0.096	0.088	0.080	0.052	0.088	0.037	0.054	0.037	0.064	0.044	0.083	
Panel C: Tests of the factor model using the Pastor-Stambaugh stock market liquidity measure																		
Default	0.048	0.082	0.076	0.091	0.043	0.065	0.055	0.057	0.061	0.078	0.099	0.091	0.070	0.015	0.013	0.025	0.061	9.13
	(0.98)	(1.07)	(1.17)	(1.96)	(0.78)	(1.53)	(0.10)	(0.77)	(0.93)	(1.10)	(0.89)	(0.78)	(0.67)	(0.13)	(0.12)	(0.24)	(0.83)	
Term	0.106	0.067	0.097	0.057	0.115	0.089	0.145	0.018	0.090	0.104	0.079	0.052	0.151	0.143	0.179	0.154	0.103	9.45
	(1.33)	(0.78)	(1.20)	(0.97)	(1.84)	(1.66)	(2.28)	(0.25)	(1.22)	(1.63)	(0.90)	(0.52)	(1.52)	(1.17)	(1.54)	(1.86)	(1.29)	
Liquidity	0.035	0.042	0.047	0.045	0.038	0.037	0.065	0.051	0.064	0.048	0.073	0.058	0.084	0.086	0.099	0.094	0.060	11.41
	(2.57)	(1.34)	(1.69)	(2.67)	(1.93)	(2.19)	(2.67)	(1.95)	(1.68)	(1.58)	(1.34)	(1.05)	(2.02)	(1.76)	(1.80)	(1.95)	(1.89)	
Adj. R^2	0.116	0.156	0.099	0.079	0.079	0.078	0.074	0.083	0.064	0.061	0.083	0.052	0.054	0.059	0.065	0.038	0.078	
Panel D: Tests of the factor model using the Pastor-Stambaugh bond and stock market liquidity measures																		
Default	0.042	0.112	0.045	0.044	0.033	0.040	0.073	0.025	0.026	0.037	0.062	0.092	0.063	0.031	0.010	0.022	0.047	7.00
	(0.82)	(1.30)	(0.53)	(0.99)	(0.57)	(0.82)	(1.44)	(0.44)	(0.33)	(0.54)	(0.53)	(0.64)	(0.62)	(0.25)	(0.12)	(0.25)	(0.64)	
Term	0.068	0.021	0.090	0.104	0.130	0.099	0.103	0.075	0.071	0.092	0.046	0.019	0.145	0.026	0.078	0.100	0.079	8.60
	(0.89)	(0.22)	(0.94)	(1.97)	(2.09)	(1.82)	(1.62)	(1.12)	(0.80)	(1.29)	(0.54)	(1.06)	(1.70)	(0.26)	(0.94)	(1.16)	(1.15)	
Bond liquidity	0.059	0.041	0.070	0.052	0.047	0.055	0.052	0.058	0.089	0.081	0.078	0.060	0.068	0.080	0.112	0.101	0.069	13.83
	(3.61)	(1.27)	(2.10)	(2.78)	(2.47)	(3.33)	(1.90)	(1.85)	(1.89)	(2.77)	(1.82)	(1.24)	(2.63)	(2.02)	(2.67)	(2.57)	(2.31)	

Table 7 (*continued*)

Variable	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa1	Baa2	Baa3	Ba1	Ba2	Ba3	B1	B2	B3 and below	Mean	Aggregate T
Stock liquidity	−0.004	0.033	−0.029	0.025	−0.012	−0.012	−0.005	0.029	−0.048	0.015	−0.019	−0.013	0.017	0.064	−0.011	−0.007	0.001	0.21
	(−0.26)	(0.91)	(−0.80)	(1.09)	(−0.57)	(−0.57)	(−0.18)	(0.90)	(−1.27)	(0.40)	(−0.37)	(−0.23)	(0.51)	(1.36)	(−0.17)	(−0.15)	(0.04)	
Adj. R^2	0.113	0.141	0.093	0.083	0.080	0.077	0.098	0.070	0.070	0.066	0.078	0.041	0.045	0.046	0.061	0.035	0.075	
Panel E: Tests of the factor model using the Sadka permanent variable (SPV) and transitory fixed (STF) liquidity components																		
Default	0.068	0.049	0.070	0.133	0.035	0.041	0.071	0.109	0.111	0.091	0.091	0.135	0.099	0.012	0.057	0.012	0.074	7.68
	(1.17)	(0.36)	(0.63)	(2.44)	(0.54)	(0.78)	(1.08)	(1.10)	(1.13)	(1.03)	(0.82)	(0.87)	(0.85)	(0.08)	(0.47)	(0.08)	(0.84)	
Term	0.126	0.046	0.074	0.034	0.136	0.113	0.051	0.034	0.060	0.100	0.077	0.032	0.137	0.177	0.025	0.173	0.087	6.82
	(1.28)	(0.29)	(0.55)	(0.41)	(1.72)	(1.59)	(0.55)	(0.38)	(0.58)	(1.06)	(0.61)	(0.20)	(1.25)	(1.79)	(0.18)	(2.03)	(0.90)	
SPV	0.048	0.035	0.040	0.052	0.067	0.058	0.070	0.072	0.063	0.075	0.090	0.079	0.082	0.069	0.083	0.081	0.067	16.53
	(2.17)	(0.48)	(0.85)	(3.15)	(2.85)	(3.22)	(1.82)	(2.28)	(2.16)	(1.64)	(1.84)	(1.49)	(2.37)	(1.53)	(0.88)	(1.98)	(1.92)	
STF	0.021	0.041	0.020	0.030	0.019	0.038	0.002	0.042	0.024	0.026	0.024	0.032	0.040	0.064	0.039	0.019	0.030	8.55
	(0.73)	(0.96)	(0.41)	(0.85)	(0.64)	(1.20)	(0.04)	(0.91)	(0.56)	(0.61)	(0.32)	(0.42)	(0.61)	(0.85)	(0.42)	(0.26)	(0.62)	
Adj. R^2	0.147	0.180	0.126	0.091	0.081	0.075	0.111	0.122	0.055	0.062	0.047	0.039	0.019	0.030	0.114	0.034	0.083	

returns. The premium for liquidity risk is positive, in that bonds with higher sensitivity to marketwide liquidity shocks offer higher returns. This finding is consistent with the notion that a pervasive drop in liquidity is viewed as undesirable by investors, so that they require compensation for holding bonds with greater exposure to this risk. Bonds with low ratings tend to have high liquidity betas. This relation is linked to the phenomenon of investors' flight-to-quality in illiquid periods. Default risk for low-grade bonds (e.g., junk bonds) typically becomes much higher compared with high-grade bonds when the economic condition deteriorates. Low-grade bonds thus lose more value in bad times. Because investors tend to flee such bonds and move to safer assets, these bonds are also more likely to be those whose values are most affected by drops in marketwide liquidity. As investors rush to exit their positions of low-grade bonds, the market for these bonds could suddenly become very illiquid. Liquidation of these bonds is therefore costly and prices could fall sharply when market liquidity dries up. This explains why low-grade bonds have high liquidity betas and investors require a high premium to hold these risky bonds.

5.2. *Portfolio analysis based on liquidity betas of bonds within each rating group*

Liquidity betas are negatively correlated with ratings. This causes a difficulty in disentangling rating and liquidity beta effects on average bond returns. One way to resolve this issue is to examine liquidity-beta portfolio spreads across individual bonds within each rating category. We first form 16 portfolios from individual bonds based on ratings from Aaa to B3 and below (or 0–15). To allow for variations in liquidity beta unrelated to the rating, we further subdivide each rating group into four portfolios based on pre-ranking liquidity betas for individual bonds within each group. We then calculate equal-weighted average monthly excess returns for each of the 64 ex post portfolios.

Panel A of Table 9 reports average returns of rating-β_L sorted portfolios based on the Pastor- Stambaugh bond liquidity measure. Results continue to show that high liquidity beta portfolios earn high average returns even after controlling for the rating effect. Convincing evidence exists of cross-sectional variations in average bond returns related to liquidity beta independent of ratings. All high-low return spreads are positive, ranging from a low of 0.12% to a high of 0.31% per month. Out of the 16 t-statistics of high-low return spreads, 11 are significant at least at the 5% level and four are significant at the 10% level. The average high-low spread across all rating groups is 0.2% per month with a t-statistic of 3.07.

Panel B reports the average portfolio returns sorted by the Amihud bond liquidity beta. Results show a similar pattern with high liquidity beta portfolios having high returns. Out of the 16 t-statistics of high-low return spreads, ten are significant at least at the 5% level and three at the 10% level. The average difference in returns

Table 8
Liquidity-beta portfolio sorts.

Bonds are sorted into ten portfolios each month, each with an equal number of bonds, by the pre-ranking Pastor-Stambaugh and Amihud liquidity betas in Panels A and B, respectively. The sample period is from January 1994 to March 2009. Liquidity betas are estimated using the Pastor-Stambaugh and Amihud bond market liquidity factor measures. Liquidity betas are estimated over rolling five-year periods for each individual bond along with default, term, and other betas in the time series regression. Average pre-ranking default, term, and liquidity betas are calculated for each liquidity beta portfolio. In addition, average excess returns, issue size, coupon rates, and ratings are calculated for each ex post liquidity beta portfolio. *Return* is average monthly returns (in percentage) of individual bonds in excess of the one-month T-bill rate. Differences in average excess returns (Diff) between the high and low liquidity-beta portfolios, and the corresponding *t*-statistics are reported.

Variable	Low	2	3	4	5	6	7	8	9	High	Diff	t
Panel A: Pastor-Stambaugh bond market liquidity measure												
β_{DEF}	0.77	0.77	0.76	0.79	0.81	0.88	0.91	0.97	1.05	1.08		
β_{TERM}	0.83	0.83	0.81	0.84	0.86	0.92	0.94	0.96	0.99	0.99		
β_L	−0.02	0.15	0.31	0.48	0.67	0.80	1.06	1.43	2.03	2.78		
Rating	5.33	5.40	5.38	5.37	5.46	5.78	6.07	6.50	6.84	7.49		
Return	0.07	0.08	0.19	0.21	0.24	0.24	0.25	0.32	0.34	0.41	0.34	2.81
Size (M)	1894	1956	2019	2102	2026	1649	1377	937	706	530		
Coupon	6.51	6.50	6.50	6.54	6.60	6.69	6.77	6.84	6.92	7.01		
Panel B: Amihud bond market liquidity measure												
β_{DEF}	0.64	0.65	0.68	0.72	0.75	0.81	0.84	0.87	0.88	0.90		
β_{TERM}	0.73	0.74	0.76	0.80	0.82	0.86	0.88	0.90	0.88	0.85		
β_L	−0.03	0.01	0.03	0.07	0.12	0.19	0.27	0.38	0.60	0.84		
Rating	5.01	4.96	5.24	5.41	5.67	5.93	6.18	6.51	7.04	7.66		
Return	0.09	0.11	0.21	0.22	0.22	0.24	0.27	0.28	0.30	0.38	0.29	2.33
Size (M)	2368	2485	2153	1860	1609	1256	1126	1026	790	528		
Coupon	6.43	6.45	6.54	6.55	6.63	6.69	6.78	6.84	6.91	7.06		

across all rating groups is 0.17% per month with a *t*-statistic of 2.68.

Overall, our results show that liquidity betas of both the Pastor-Stambaugh and Amihud factors are able to explain the cross-sectional variation in corporate bond returns. Returns for bonds with high sensitivities to liquidity exceed returns for bonds with low sensitivities by about 4% annually. Moreover, there is evidence of a significant positive relation between average corporate bond returns and liquidity betas that is independent of the rating effect. Results suggest that liquidity risk is important for corporate bond pricing.

6. Additional tests

The analysis above shows the importance of liquidity risk in bond pricing. In this section, we conduct additional tests for robustness.

6.1. The extended Acharya-Pedersen model

Acharya and Pedersen (2005) propose an equilibrium asset pricing model with liquidity risk. The model is essentially a liquidity-adjusted capital asset pricing model that includes both expected liquidity and covariances of an asset's return and liquidity with market return and liquidity. An advantage of this model is that it provides a unified framework to jointly test the effects of liquidity risk and the level of liquidity. For comparative purposes, we test this model using individual bond returns.

We employ the extended Acharya-Pedersen model with the Fama-French *SMB* and *HML*, as well as term and default factors in empirical tests. The testing procedure is the same as in Section 3. The results (omitted for brevity) indicate that it is somewhat difficult to get reliable estimates of the fully extended Acharya-Pedersen model due to a fairly large number of betas involved and severe collinearity among the betas representing different forms of liquidity risk in the cross-sectional test. Notwithstanding this difficulty, all results consistently show that only the covariance of bond returns and aggregate bond liquidity is significantly priced. Results render further evidence that liquidity risk matters over and above the effects of other risk factors, the level of liquidity, and bond characteristics.

6.2. Multivariate portfolio sorts

The univariate portfolio sorts presented earlier show a positive relation between liquidity beta and expected corporate bond returns. However, univariate relations could be confounded by the correlation between liquidity risk and other risk variables. By controlling for the effects of other risk variables, multivariate independent portfolio sorts should provide clearer evidence for the relation between liquidity risk and expected corporate bond returns. In this subsection, we investigate the role of liquidity beta relative to betas of other risk factors in explaining the cross-sectional variation of bond returns using multivariate portfolio sorts.

Corporate bonds are sorted each month independently into four default beta portfolios and four term beta portfolios. This creates 16 portfolios in the intersection of default and term betas. Each of these portfolios is further sorted into four portfolios based on liquidity beta. This portfolio formation process generates the variation in liquidity beta independent of the variation in default and term betas. Betas are again estimated over rolling five-year periods for each corporate bond.

Table 9
Liquidity-beta portfolio sorts by rating.

Bonds in each rating category are sorted into four portfolios each month by the pre-ranking Pastor-Stambaugh and Amihud liquidity betas in Panels A and B, respectively. Liquidity betas are estimated jointly with other betas using the Pastor-Stambaugh and Amihud bond market liquidity measures. The sample period is from January 1994 to March 2009. Betas are estimated over rolling five-year periods for each corporate bond, and average monthly excess returns (in percentage) are calculated for each ex post portfolio. Differences in average excess returns (Diff) between the high and low portfolios and the corresponding *t*-statistics are reported for each rating category.

Rating	Liquidity beta portfolios					
	Low	2	3	High	Diff	*t*
Panel A: Pastor-Stambaugh bond liquidity measure						
Aaa	0.0934	0.1075	0.1262	0.2575	0.1641	2.43
Aa1	0.1387	0.1658	0.2620	0.3105	0.1719	1.65
Aa2	0.1327	0.2025	0.2709	0.3085	0.1758	2.51
Aa3	0.1305	0.2480	0.2156	0.3062	0.1757	2.47
A1	0.1360	0.2495	0.2350	0.3291	0.1931	3.07
A2	0.1475	0.2104	0.2288	0.3288	0.1813	2.71
A3	0.1753	0.2197	0.2655	0.3382	0.1629	2.13
Baa1	0.1532	0.2305	0.2138	0.2769	0.1238	1.84
Baa2	0.1818	0.2502	0.2067	0.3170	0.1352	1.90
Baa3	0.1995	0.2679	0.2938	0.3884	0.1889	2.83
Ba1	0.2065	0.2462	0.3316	0.4656	0.2592	2.51
Ba2	0.2312	0.2924	0.2741	0.4303	0.1991	2.12
Ba3	0.2653	0.3429	0.3815	0.4971	0.2318	2.39
B1	0.2850	0.3426	0.4207	0.4381	0.1531	1.28
B2	0.2524	0.3860	0.4598	0.5597	0.3073	2.59
B3 and below	0.3701	0.4376	0.5154	0.6027	0.2326	1.86
Average	0.1917	0.2565	0.2929	0.3903	0.1986	3.07
Panel B: Amihud bond liquidity measure						
Aaa	0.1066	0.1305	0.1704	0.1984	0.0918	1.33
Aa1	0.1532	0.2131	0.2183	0.3235	0.1703	1.50
Aa2	0.1595	0.1757	0.2382	0.3094	0.1499	2.21
Aa3	0.1670	0.1896	0.1993	0.3222	0.1552	2.78
A1	0.1633	0.2243	0.2196	0.3648	0.2015	2.95
A2	0.1560	0.1925	0.2411	0.3115	0.1555	2.28
A3	0.1792	0.2197	0.2701	0.2929	0.1137	1.61
Baa1	0.1732	0.2373	0.2203	0.2742	0.1010	2.41
Baa2	0.1832	0.2100	0.2568	0.2901	0.1069	2.18
Baa3	0.1961	0.2506	0.2768	0.3992	0.2031	1.90
Ba1	0.2318	0.3415	0.2982	0.4076	0.1757	1.82
Ba2	0.2284	0.2470	0.3312	0.4224	0.1940	2.31
Ba3	0.2985	0.3810	0.3741	0.4320	0.1335	2.17
B1	0.3715	0.3378	0.3376	0.4796	0.1081	1.83
B2	0.3769	0.3313	0.3957	0.5330	0.1562	2.26
B3 and below	0.4018	0.4044	0.5212	0.5668	0.1650	2.22
Average	0.2091	0.2507	0.2858	0.3817	0.1726	2.68

Table 10 reports the relation between excess returns and liquidity betas when controlling for the effects of default and term betas. The left side shows the results associated with the Pastor-Stambaugh bond market liquidity measure. Results show a strong positive relation between average returns and liquidity betas independent of default and term beta effects. The high-low liquidity beta spreads are all positive. Out of 16 *t*-statistics, 12 are significant at least at the 5% level and three at the 10% level. The average high-low spread is 0.19% per month with an average *t*-statistic of 3.98. The right side of Table 10 reports portfolio sorts using the Amihud bond liquidity measure. Results show a similar pattern. Out of the 16 groups, 11 have *t*-statistics that are significant at least at the 5% level and four at the 10% level. The average spread is 0.16% per month with an average *t*-statistic of 3.13.

Summarizing, results of multivariate portfolio sorts provide further assurance for the importance of liquidity risk in corporate bond pricing. Controlling for the effects of default and term betas, liquidity beta has a significantly positive relation with average bond returns. Evidence shows that the liquidity risk factor is priced and results are robust to the choice of liquidity measures.

6.3. *Tests using the Sadka liquidity factor*

Sadka (2006) decomposes equity-based liquidity into variable and fixed components and finds that the permanent variable component is priced in stock returns. To complete our analysis, we investigate whether the Sadka factor is important for corporate bond pricing. Following Sadka (2006), we focus on the tests using the permanent variable and transitory fixed components of equity-based liquidity. The Sadka equity-based liquidity factor components are available in the database of Wharton Research Data Services through 2005. We

Table 10
Multivariate portfolios sorts.
The sample period is from January 1994 to March 2009. Betas are estimated over rolling five-year periods for each bond. Bonds are independently sorted each month into four default beta portfolios and four term beta portfolios, and 16 portfolios are created at the intersection of default and term betas. Each of these portfolios is further sorted into four portfolios by liquidity betas. Average excess returns (in percentage) of each ex post portfolio are reported along with differences in average excess returns between the high and low liquidity-beta portfolios (Diff) for each default and term beta combination and the corresponding *t*-statistics for these return differences. The results using the Pastor-Stambaugh and Amihud bond market liquidity measures are shown on the left and right sides, respectively.

Characteristic portfolio		β_L											
		Pastor-Stambaugh bond liquidity measure						Amihud bond liquidity measure					
β_{DEF}	β_{TERM}	1	2	3	4	Diff	*t* (diff)	1	2	3	4	Diff	*t* (diff)
1	1	0.1231	0.1401	0.2729	0.3347	0.2116	4.31	0.1247	0.1842	0.2853	0.3293	0.2046	3.65
1	2	0.1314	0.1903	0.3072	0.2933	0.1619	1.72	0.1518	0.2152	0.2656	0.2919	0.1401	2.13
1	3	0.1618	0.2261	0.3308	0.3946	0.2328	2.35	0.2222	0.2351	0.3381	0.3704	0.1482	1.86
1	4	0.1987	0.2781	0.2459	0.3793	0.1806	0.84	0.2332	0.1864	0.2403	0.3857	0.1525	2.03
2	1	0.1661	0.1632	0.3229	0.3664	0.2003	4.15	0.1664	0.2160	0.2706	0.3066	0.1402	1.21
2	2	0.1577	0.1466	0.2130	0.3330	0.1753	3.64	0.1555	0.1500	0.2571	0.2676	0.1121	2.51
2	3	0.1631	0.2303	0.2740	0.2916	0.1285	1.82	0.1904	0.2091	0.2569	0.3177	0.1273	2.49
2	4	0.1780	0.1728	0.2804	0.4017	0.2238	2.25	0.1842	0.2114	0.3071	0.3306	0.1464	1.79
3	1	0.1731	0.2988	0.2484	0.3409	0.1678	1.79	0.1990	0.1714	0.3122	0.2797	0.0807	1.90
3	2	0.1662	0.1833	0.2264	0.2769	0.1108	1.97	0.1655	0.2214	0.2169	0.2545	0.0890	2.02
3	3	0.1599	0.1989	0.2557	0.2905	0.1306	2.16	0.1690	0.1870	0.2693	0.2929	0.1239	1.99
3	4	0.1468	0.2027	0.2711	0.3047	0.1579	2.57	0.1903	0.1735	0.3005	0.2969	0.1066	1.97
4	1	0.1752	0.2750	0.3008	0.4170	0.2418	2.92	0.2167	0.1910	0.3268	0.3700	0.1533	2.08
4	2	0.1846	0.2504	0.2281	0.3801	0.1955	2.85	0.1715	0.2428	0.3314	0.3576	0.1861	1.68
4	3	0.1771	0.1724	0.2859	0.3571	0.1800	2.47	0.1752	0.2062	0.2558	0.3099	0.1348	2.95
4	4	0.1759	0.2570	0.2441	0.3917	0.2158	2.43	0.1719	0.1893	0.2576	0.3984	0.2265	2.57
Average		0.1618	0.2106	0.2694	0.3469	0.1851	3.98	0.1675	0.1986	0.2791	0.3316	0.1641	3.13

estimate liquidity betas associated with the Sadka factor and perform cross-sectional tests using the same procedure as in other regression tests for the factor model.

The bottom two rows of Table 3 show the results of cross-sectional tests using the Sadka factor components as the liquidity variables. For the model excluding characteristic variables, the beta (β_{L1}) of the Sadka permanent variable liquidity component (*SPV*) is significant at the 1% level and the beta (β_{L2}) of the transitory fixed component (*STF*) is significant at the 5% level. Including the bond characteristic variables lowers the significance of both coefficients modestly. When we use the excess return adjusted for expected liquidity cost as the dependent variable, results change slightly. The bottom two rows of Table 4 show results for cross-sectional regressions using the Sadka liquidity components. The permanent variable liquidity component is significant at the 5% level, but the transitory fixed component is insignificant. Including the bond characteristic variables lowers the significance of the *SPV* beta slightly but raises the significance of the *STF* beta to the 10% level.

For cross-sectional regressions of rating portfolios, the *SPV* beta (β_{L1}) is significant at the 10% level, but the *STF* beta (β_{L2}) is not (see Row 2 from the bottom of Table 6). Adding bond characteristics lowers significance of the former slightly but improves the latter to the 10% level. Finally, Panel E of Table 7 reports results for cross-sectional regressions of individual bonds within each rating group using the Sadka factor. Results show that on average *SPV* beta is significant at the 10% level, but *STF* beta is not. Eight out of 16 rating groups have *SPV* betas significant at least at the 5% level, and another two groups have *SPV* betas significant at the 10% level. Overall, some evidence exists that the information-based liquidity risk factor (*SPV*) is important for corporate bond pricing.

7. Conclusions

In this paper, we provide evidence on the role of liquidity risk in the pricing of corporate bonds using a long-span data sample that combines two important transaction data sets for corporate bonds. Our paper represents the first extension of the work of Pastor and Stambaugh (2003) and Acharya and Pedersen (2005) to the corporate bond market. The paper considers market-wide liquidity as an additional state variable in the corporate bond pricing model and investigates whether liquidity risk is priced in bond returns. We use both the Pastor-Stambaugh and Amihud measures and other variants as proxies for the liquidity factor and examine robustness of test results to these liquidity measures. Moreover, we include bond-specific characteristics in the empirical model to capture the potential effects of the liquidity and default information embedded in these variables.

We employ both regression and portfolio-based test methodologies to examine whether liquidity risk explains cross-sectional variations in expected corporate bond returns. Our results consistently show that liquidity risk is priced in the corporate bond market. We find a positive and economically significant relation between expected corporate bond returns and liquidity risk even after controlling for the effects of default and term betas, stock market risk factors, bond characteristics, the level of liquidity, and ratings. This relation is robust to different model specifications and the choice of liquidity measures. Liquidity risk spread accounts for a significant portion of corporate bond risk premium. Results strongly suggest that liquidity risk is an important determinant of expected corporate bond returns.

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