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Idiosyncratic volatility vs. liquidity? Evidence from the US corporate bond market

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ABSTRACT

Our objective in this paper is to determine empirically the extent to which fixed-income investors are concerned about the relative effects of equity volatility and bond liquidity in the cross-section of corporate bond spreads. Our tests reveal that while both volatility and liquidity effects are significant, volatility, representing ex-ante credit shock, has the first-order impact, and liquidity represented by bond characteristics and price impact measure has the secondary impact on bond spreads. Conditional analysis further reveals that distressed bonds and distress regimes are both associated with significantly higher impact of volatility and liquidity shocks. However, the relative impact of these effects varies conditional on the underlying bond attributes and overall market conditions.

1. Introduction

Our objective in this paper is to study the relative impact of idiosyncratic volatility and liquidity on corporate yield spreads (i.e., excess of bond yields over equal maturity benchmark yields) cross-sectionally, and empirically disentangle both the effects. Overall we find that both volatility and liquidity matter separately for the cross-section of bond yields, with the relative importance of volatility and liquidity changing with firm-specific and economic conditions.

Idiosyncratic equity volatility refers to the firm-specific risk after controlling for systematic market risk factors, and *reflects* the residual stock volatility of a firm. In their influential paper, Campbell and Taksler (2003) show that idiosyncratic equity volatility has a significant role in explaining corporate

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bond spreads even after conditioning for ratings, bond and firm-specific characteristics and macroeconomic variables.[2,3] While idiosyncratic equity volatility captures ex-ante default risk, other studies reveal that credit risk determinants *alone* cannot adequately explain the levels or changes in the corporate bond spreads (e.g., Collin-Dufresne et al., 2001; Huang and Huang, 2003). If non-default sources of risk such as illiquidity matter in bond spreads, then by ignoring liquidity, structural models can overprice bonds, resulting in the so-called "credit puzzle" (Covitz and Downing, 2007; Driessen, 2005).[4]

While corporate debt constitutes a significant proportion of capital structure of firms, the underlying bond market remains highly illiquid.[5] Extant work documents the significant effect of illiquidity on bond prices (e.g., Longstaff et al., 2005; Driessen, 2005; and Chen et al., 2007).[6] If individual bond liquidity matters, and is not controlled for, then volatility effects on bond spreads as documented in Campbell and Taksler may be difficult to interpret.[7] While higher idiosyncratic equity volatility can imply higher ex-ante credit risk and bond spreads, it is not obvious from the Campbell and Taksler results whether higher spreads are attributable to higher equity volatility, lower bond liquidity, or both.

In this paper, we extend Campbell and Taksler (2003) by conditioning for underlying bond liquidity, and exploring the relative contribution of equity volatility and bond liquidity in the cross-sectional pricing of corporate bond spreads. We tease out the volatility impact from the liquidity effects, and examine whether idiosyncratic risk subsumes the information in liquidity in explaining corporate bond prices. We explore the roles of volatility and liquidity on *cross-sectional* bond prices unconditionally, as well as conditional on several underlying *distress features*. High-distress issues are defined as bonds with low ratings, low liquidity, or high underlying equity volatility. High-distress periods refer to low-growth or recessionary periods, and periods of high aggregate equity market volatility or low aggregate bond market liquidity in the economy.

We employ over 195,000 secondary trades of option-free corporate bonds issued by 818 firms over an 11-year period, 1994–2004. We measure idiosyncratic equity volatility as the variance of multifactor risk-adjusted residual returns, and quantify bond liquidity in terms of price impact of bond trades as well as several underlying bond characteristics.[8] Our work is unique in that it focuses on a large sample of corporate bonds over an extended period, uses an exhaustive list of volatility and liquidity variables, and provides a comprehensive study of the volatility and liquidity effects in cross-sectional bond pricing.[9]

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[2] An increase in idiosyncratic equity volatility increases the ex-ante probability of firm default, thereby depressing corporate bond prices and inflating bond spreads (Merton, 1974). Equivalently, a lower stock price causes higher volatility due to leverage (Black, 1976) and volatility feedback (Bekaert and Wu, 2000) effects, and implies higher default intensity and bond spreads (Das and Sundaram, 2007). In fact, the KMVMoody's model employs the distance-to-default (DTD), expressed as a function of firm-value volatility, to measure the implied credit risk of a firm.

[3] In Merton's model, the volatility that is relevant for option value and hence value of corporate debt is the total firm volatility that includes both idiosyncratic and systematic (or market-wide) volatility. However, as Campbell et al. (2001) point out, while idiosyncratic volatility has trended upwards since the mid-1970s, market-wide volatility has undergone temporary fluctuations but no definite trend increase. Hence, following Campbell and Taksler, (2003), we use idiosyncratic stock volatility as a proxy for total firm or asset volatility.

[4] Liquidity reflects the ability to trade large quantities of a security quickly (and at a price close to its value in frictionless markets) with minimal trading costs and little price impact.

[5] For example, Henderson et al. (2006) report that convertible and non-convertible debt together account for 83% (90%) of domestic (international) capital raised by firms during 1990–2001. Edwards et al. (2007) however reveal that the median corporate bond on the Trade Reporting and Compliance Engine (TRACE) system trades on only 48% of all days during 2003–2005 period.

[6] Lack of liquidity impacts bond spreads in many ways. Lack of liquidity imposes search costs, thereby inhibiting the frequency of trading and increasing the hedging risk for bond investors. As a result, investors demand an additional ex-ante liquidity risk premium and therefore higher bond spreads (Lo et al., 2004). Higher adverse selection and/or inventory control costs lead to wider bid-ask spreads, and hence higher required rates of return (Brennan and Subrahmanyam, 1996). Moreover, renegotiation during financial distress and hence underlying bond spreads can be influenced by the illiquidity in the distressed debt market (Ericsson and Renault, 2006).

[7] Campbell and Taksler (2003) employ an aggregate liquidity variable called TED spread, defined as 30-day Eurodollar yield *minus* Treasury yield, in lieu of individual bond liquidity measures; this makes it hard to decipher the individual contribution of *firm-specific* liquidity effects on bond spreads.

[8] Though bond volatility too can impact bond spreads, low trading frequency in corporate bonds precludes us from constructing a meaningful proxy for bond market volatility.

[9] For comparison, Longstaff et al. (2005) use data for 68 firms from 03/2001 to 10/2002, Driessen (2005) considers data for 104 firms from 02/1991 to 02/2000, and Chen et al. (2007) employ data for 4000 corporate bonds during 1995–2003.

We document two principal findings that remain unaltered under a battery of robustness tests. *First*, both equity volatility and bond liquidity effects are jointly important, but in terms of relative magnitude, equity volatility has the first-order impact, and bond liquidity has the secondary impact on cross-sectional pricing of bond spreads. *Second*, conditional cross-sectional tests reveal that, on an *absolute basis*, distressed bonds and distress regimes experience higher impacts of shocks to volatility as well as liquidity. Further, on a *relative basis*, volatility effects are dominant for distressed bonds and during high-distress regimes, while liquidity matters more for low-distress bonds and during low-distress regimes.

Our study extends the Campbell and Taksler study in many ways. Ignoring firm-specific bond liquidity can lead to model misspecification and, therefore, the Campbell and Taksler framework can imply biases in the ex-ante spreads required by bond investors. Moreover, debt issuers need to evaluate volatility as well as liquidity effects while pricing and timing their bond issues. Not including individual liquidity effects, as in the Campbell and Taksler framework, can bias the pricing and timing decisions of bond issuers. The Campbell and Taksler study is limited to the 1995–1999 period, when the market experienced very high growth induced by the high-tech bubble. By extending the sample to 2004 and including the very distinct post-bubble slowdown period, we hope to uncover the determinants of corporate bond spreads, and the differential impact of volatility and liquidity under different distress regimes.

Additionally, our paper extends the extant literature that explores the role of either equity volatility or bond liquidity on corporate bond spreads; while the earlier papers exclusively focus on *either* of these variables, we emphasize *joint focus* on both variables in bond pricing and evaluate their relative significance.[10] Taken together, our results imply that the idiosyncratic volatility effect does not subsume the liquidity effect in explaining bond prices, unlike the findings in equity markets (Spiegel and Wang, 2005). While volatility has a significant effect, liquidity still matters for the cross-sectional bond yields, and the strength of effects change conditional on the underlying portfolio, and overall market conditions. Our findings imply that the Campbell and Taksler framework, and more generally Merton (1974), can be augmented to include unconditional and conditional effects of both volatility and liquidity. Moreover, we emphasize that, since we do not explicitly measure exogenous shocks to either volatility or liquidity, our results are best interpreted as stylized facts, rather than any causal evidence.

Our work is further related to several recent papers that focus on disentangling credit and liquidity risks from yield spreads (e.g., Longstaff et al., 2005; Driessen, 2005; Covitz and Downing, 2007; Beber et al., 2009; and Schwartz, 2010).[11] Our work also represents an extension to bond markets of current work that examines the overlap in information content of volatility and liquidity risks in equity returns (e.g., Spiegel and Wang, 2005; Bali et al., 2005; and Boehme et al., 2006).[12]

The rest of the paper is structured as follows. Section 2 describes the data and variables. Section 3 presents univariate and bivariate portfolio results. Sections 4 and 5 report the results from unconditional and conditional Fama–MacBeth regressions for bond spreads. Section 6 concludes.

2. Data, variables, and descriptive statistics

We use a sample of corporate bonds that covers an 11-year period from 1994 through 2004, and comes from two complementary sources: the Mergent Fixed Investment Securities Database (FISD) issuance data and the National Association of Insurance Commissioners (NAIC) pricing database.[13]

[10] Previous equity volatility studies also include Cremers et al. (2008a,b), Alexander and Kaeck (2008), and Zhang et al. (2009). Extant corporate bond liquidity studies include Alexander et al. (2000), Baoet al. (2008), Bessembinder et al. (2006), Buraschia and Menini (2002), Chen et al. (2007), Edwards et al. (2007), Hong and Warga (2000), Houweling et al. (2005), Kalimipalli and Warga (2002), and Mahanti et al. (2008)

[11] Extant work also examines liquidity and credit risks embedded in the interest rate swap and credit default swap spreads (e.g., Liu et al., 2006; Tang and Yan, 2007; Das and Hanouna, 2009; Ericsson et al., 2009). Further, Berndt et al., (2007) extract a common risk factor from credit markets and investigate its contribution towards explaining average returns observed in bond, equity, and index option markets.

[12] Our paper also broadly ties into the existing literature on information spillovers between stocks and corporate bonds (e.g., Kwan, 1996; Hotchkiss and Ronnen, 2002; Downing et al., 2009; Gebhardt et al., 2005b; Duarte et al., 2005).

[13] The FISD includes detailed issue- and issuer-related information on all US debt securities maturing in 1990 or later. The NAIC database contains information on bond trades by all insurance companies (i.e., life insurance companies, property and casualty insurance companies, and health maintenance organizations). Based on the Flow of Funds Accounts published by the Federal Reserve, insurance companies hold about one third of all the outstanding corporate bonds in their portfolios, and hence account for a significant fraction of institutional corporate bond trades (Campbell and Taksler, 2003).

Table 1
Summary statistics. The table reports the number of observations (bond trades) and average yield spreads in percentage (first and second rows respectively) for different sub-samples of bonds based on industry, rating, maturity, and time period. FIN, IND, and UTL refer to Financial, Industrial, and Utility firms. ⩽BB indicates bonds with BB or lower ratings.

Number of observations and average bond spreads by industry, rating, maturity, and time period								
	By industry			By rating				
	FIN	IND	UTL	AA	A	BBB	⩽BB	Total
By maturity								
Long-term	5039	21,406	1720	2901	13,778	9616	1870	28,165
>15 years	0.97	1.28	1.37	0.58	0.81	1.49	4.03	1.23
Medium-term	23,062	29,624	5497	7514	30,295	16,642	3732	58,183
7–15 years	0.57	0.79	0.67	0.24	0.46	0.88	2.68	0.69
Short-term	44,607	53,603	11,527	12,056	56,422	32,338	8921	109,737
1–7 years	0.64	1.31	1.19	0.27	0.49	1.17	4.86	1.02
By time period								
1994–1999	42,091	61,503	12,336	14,414	58,585	36,203	6728	115,930
	0.49	0.64	0.46	0.22	0.38	0.73	2.09	0.57
2000–2004	30,617	43,130	6408	8057	41,910	22,393	7795	80,155
	0.85	1.89	2.19	0.45	0.73	1.81	6.00	1.52
Total	72,708	104,633	18,744	22,471	100,495	58,596	14,523	196,085
	0.64	1.16	1.05	0.30	0.53	1.14	4.19	0.96

Our final sample consists of 196,085 buy and sell bond transactions by insurance companies for 3047 straight bonds, issued by 818 publicly listed companies, and spanning 132 months from 1994 through 2004 (Appendix A details the sample selection).

Table 1 reports the number of bond trades and average yield spreads for different sub-samples based on industry, rating, maturity, and time period. A majority of the total of 196,085 transactions correspond to Industrial, short-term maturity, i.e., 1–7 years, and A-rated bonds during the first half of the sample period, i.e., 1994–1999. Industrials have the highest yield spreads, closely followed by Utilities; Financials have the lowest spreads. The second half of the sample, i.e., 2000–2004, which corresponds to the slowdown phase subsequent to the high-tech expansion period, is characterized by fewer bond trades and significantly higher yield spreads. In unreported results, we find that the industrials are mostly A- or BBB- rated, while Financials are largely A-rated and Utilities BBB-rated.

Fig. 1 plots the annual number of bond trades and average yield spreads. Bond trades gradually increase during the high-tech bubble period, 1994–1999, reaching a peak in 1999, and then decline substantially. We observe that A- and BBB- rated bonds, and Industrial and Financial issues account for the majority of the trades over the years; short-term maturity bonds dominate the second half of the sample. Bond spreads increase substantially after year 2000. Industrials earn the highest spreads for most years, but Utilities have carried maximum spreads since 2002. The yield spreads for non-investment grade bonds, i.e., rated BB and lower, have increased significantly since 2000. The U-shape in the term-structure of yield spreads is evident in the second half of the sample.

Based on an exhaustive survey of the extant literature, summarized in Section 2, we employ five alternative volatility measures, and 11 different liquidity measures, i.e., 10 liquidity proxies for bonds, and one for equity. Table 2 defines the volatility and liquidity variables used in our study.

The five equity volatility measures include daily *total* stock return volatility, reflecting both idiosyncratic and market news, and daily and monthly *idiosyncratic* volatility measures based on the Fama–French 3- and 4-factor models. We compute the total volatility, V, of a stock as the variance of equity returns over the 125-day period preceding a bond trade, adjusted for autocorrelation in daily returns using the approach proposed by French et al. (1987), and adopted by Goyal and Santa-Clara (2003):

$$V_{i,t} = \sum_{d=1}^{125} r_{i,t-d} + 2\sum_{d=2}^{125} r_{i,t-d} r_{i,t-d+1} \tag{1}$$

where t is the date of a specific bond trade and $r_{i,t}$ is the return of stock i on date t.

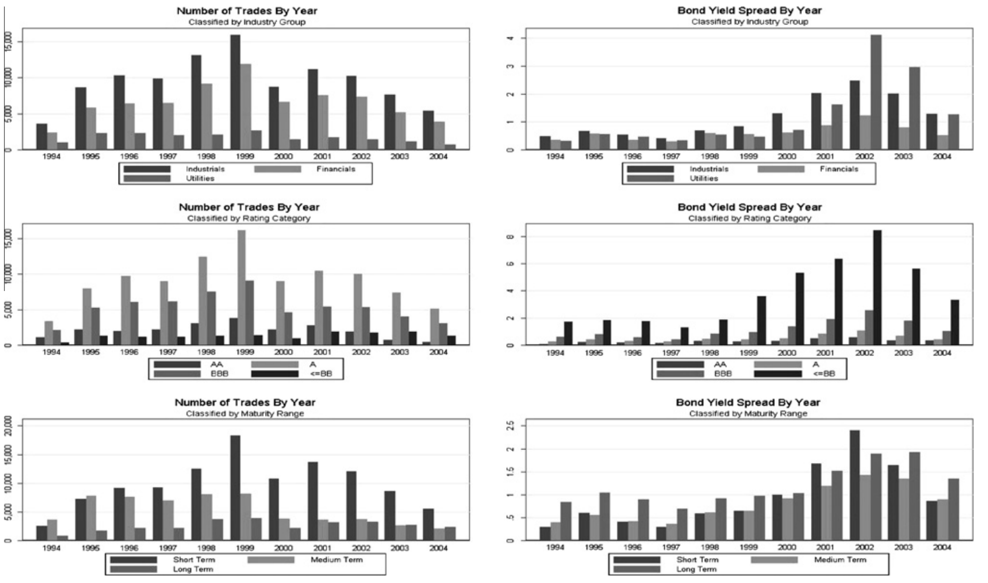

Fig. 1. Summary statistics by year. The figure plots the number of trades (left panel) and average yield spreads in percentage (right panel) by year for different industry groups, rating categories, and maturities for the sample period 1994–2004. Long-term bonds have maturities greater than 15 years, medium-term bonds have maturities between 7 and 15 years, and short-term bonds have maturities less than or equal to 7 years.

We compute the idiosyncratic volatility, *IV*, of any stock *i* as the variance of the residuals in the 3-factor or 4-factor Fama–French (1993) models applied to a 125-day or 6-month period preceding a bond trade:

$$IV_i = \text{variance}_{180\text{-day}}(\varepsilon_{i,t}) \text{ or variance}_{6\text{-month}}(\varepsilon_{i,t}) \tag{2}$$

where $\forall$ i and t, $\varepsilon_{i,t}$ is obtained as residuals from either of the following models:

$$\text{3-factor model}: r_{i,t} - r_{f,t} = \alpha_i + \beta_{i,MKT}(r_{MKT,t} - r_{f,t}) + \beta_{i,SMB}(SMB_t) + \beta_{i,HML}(HML_t) + \varepsilon_{i,t}$$
$$\text{4-factor model}: r_{i,t} - r_{f,t} = \alpha_i + \beta_{i,MKT}(r_{MKT,t} - r_{f,t}) + \beta_{i,SMB}(SMB_t) + \beta_{i,HML}(HML_t) + \beta_{i,MOM}(MOM_t) + \varepsilon_{i,t}$$

where t is the date of a bond trade, $r_{i,t}$ is the return of stock i on date t, $r_{MKT,t}$ and $r_{f,t}$ are the market CRSP value-weighted index and risk-free, 30-day Treasury Bill, returns on date t, SMB_t, HML_t and MOM_t are the returns on small minus big capitalization factor, high minus low book-to-market equity value factor and momentum factor respectively on date t, ε is the regression residual and variance denotes the 125-day or 6-month variance.[14] Daily and monthly return volatility variables are annualized by scaling with 252 and 12 respectively. All volatility variables are winsorized at the 1% level.

Based on the available data from NAIC and FISD, we employ ten different bond liquidity variables. They consist of six bond- and issuer-specific characteristics: offer amount, amount outstanding, age of the issue, time to maturity, coupon rate, and dummy for financial issues; two trade-based variables: trade size and annual trading frequency; and two bond price impact variables. All liquidity variables are winsorized at the 1% level. Trade size is computed as the actual dollar cost incurred for buy trades and amount received for sell trades; the dollar amounts exclude accrued interest, and hence reflect clean prices, but include commissions and fees. Trading frequency is the number of transactions in the year prior to a specific bond trade.

[14] Data on daily and monthly equity factors is obtained from the Wharton Research Data Services (WRDS).

Table 2
Variable definitions. The table defines the volatility and liquidity measures and bond market factors used in the paper.

Volatility measures (Data Sources: CRSP, WRDS)

1. Total 6-month return variance: Daily total stock return variance with autocorrelation adjustment (French et al., 1987) in the 6 months prior to the transaction date
2. Id. Volatility (3-factor, monthly): Idiosyncratic volatility computed as the variance of residuals from the application of Fama–French 3-factor model on 6 months of monthly stock returns prior to the transaction date
3. Id. Volatility (4-factor, monthly): Idiosyncratic volatility computed as the variance of residuals from the application of Fama–French 4-factor model on 6 months of monthly stock returns prior to the transaction date
4. Id. Volatility (3-factor, daily): Idiosyncratic volatility computed as the variance of residuals from the application of Fama–French 3-factor model on 125 days of daily stock returns prior to the transaction date
5. Id. Volatility (4-factor, daily): Idiosyncratic volatility computed as the variance of residuals from the application of Fama–French 4-factor model on 125 days of daily stock returns prior to the transaction date

All the volatility measures are reported on an annualized basis, i.e., scaled by 12 (252) for monthly (daily) data

Liquidity measures (Data Sources: FISD, NAIC, CRSP)

1. Issue or offer amount (in 000s of dollars)
2. Amount outstanding (in 000s of dollars)
3. Age of the issue (in years)
4. Time to maturity (in years)
5. Coupon rate (in %)
6. Dummy for financial issue (1 if the issuer is a financial firm, 0 otherwise)
7. Trade size (in 000s of dollars): based on NAIC variable "actual-cost" if it is a buy trade, and NAIC variable "consideration" if it is a sell trade
8. Annual trading frequency: number of transactions in 1 year prior to the transaction date
9. Bond liquidity index 1: bond price impact variable calculated based on the transaction prices of all trades in 1 year prior to the transaction date as: $10^8 \times (\sigma_{\text{prices}})/\text{total volume}$, where σ_{prices} is the standard deviation of transaction prices of all trades and total volume is the dollar volume of all trades in the 1-year window prior to the transaction date. Higher price impact values imply lower liquidity
10. Bond liquidity index 2: bond price impact variable calculated based on the transaction prices of all trades in 1-year window prior to the transaction date as: $10^8 \times \left(\frac{\text{maximum price}-\text{minimum price}}{\text{average price}}\right)\Big/\text{total volume}$, where maximum, minimum, and average prices denote the highest, lowest, and mean prices respectively based on all observed trades over the prior year, and total volume is defined as in variable 9 above. Higher price impact values imply lower liquidity
11. Equity liquidity: Inverse of Amihud (2002) equity impact measure computed over a 125-day window as inverse of $\sum_{k=1}^{125} 10^8 \times (|\text{returns}_{t-k}|/\$\ \text{trading volume}_{t-k})/125$ (excluding days of zero trading volume). It measures the inverse of the cumulative price impact of order flow. Higher price impact values imply higher liquidity

Bond market factors (Data Sources: DATASTREAM [1-3], NAIC [4])

1. Term-structure factor (TERM): 10-year swap rate minus 2-year swap rate
2. Default factor (DEF): Moody's BAA yield minus 10-year swap rate
3. Volatility factor: VIX index
4. Liquidity factor: equally-weighted average of bond liquidity index 1 values of all bonds each month

The computation of the bond price impact measure for corporate bonds is challenging given that bonds do not trade frequently, and hence returns on a daily basis may not be available during any given monthly time window. With sparse trading and large gaps between successive trades in the NAIC database, high frequency bond returns are hard to calculate.[15] Due to such low liquidity of corporate bonds, we employ a modified version of the Amihud (2002) measure. We use a long time window of 1 year to capture a reasonably large number of trades. We measure illiquidity as the impact of trading volume on *price volatility* over this 1-year window (Downing et al., 2005; Gady et al., 2007). Accordingly, we compute price impact as $(\sigma_{prices})/\text{total volume}$, referred to as the Liquidity Index 1, where σ_{prices} is the standard deviation of transaction prices of all trades, and total volume is the dollar volume of all trades in the 1-year window prior to the transaction date. Alternatively, we employ a range-based measure defined as: $\left(\frac{\text{maximum price}-\text{minimum price}}{\text{average price}}\right)\Big/\text{total volume}$, referred to as the Liquidity Index 2, where maximum, minimum and average prices denote the highest, lowest and mean prices respectively over the 1-year window of all trades. Both price impact measures determine the impact of trading volume on price

[15] The NAIC database only reports the prices underlying actual bond trades of insurance companies, and does not have any underlying quote data. This precludes us from using bid-ask spread measures of liquidity.

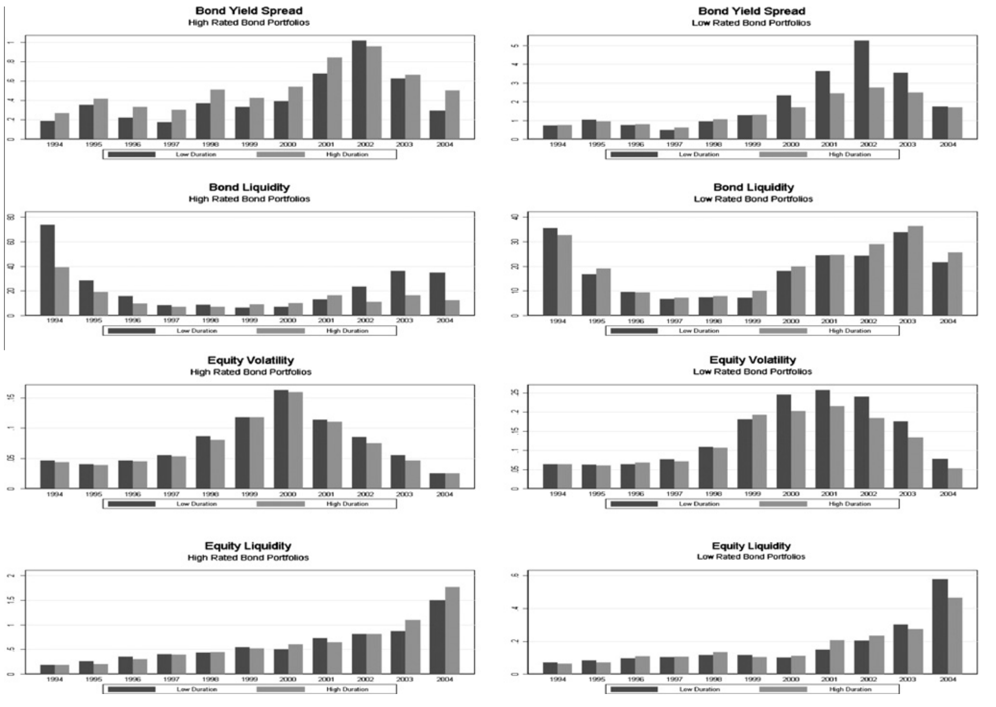

Fig. 2. Time series trends of bond spreads, bond and equity liquidity, and equity volatility. The figure plots average yearly bond spreads, bond liquidity (bond liquidity index 1), equity volatility (based on Fama–French 3-factor model applied to daily data) and equity liquidity (inverse of Amihud, 2002, measure) over the sample period 1994–2004. Left panel corresponds to high-rated bonds (rated AA or A); right panel presents low-rated bonds (rated BBB or below). Classification into high- and low-duration portfolios is based the median duration value of 8 years.

volatility. Larger values suggest that prices move by a large magnitude in response to a given trading volume and denote higher bond illiquidity. Our data shows that liquidity Indices 1 and 2 are strongly correlated with a correlation coefficient of 0.96.

We also employ an equity liquidity variable based on Amihud (2002), computed as the absolute percentage price change per dollar of trading volume, where trading volume is obtained as the dollar value of all equity trades over 125 days prior to the bond transaction date. We use the inverse of the Amihud measure to minimize the variability in this variable, and obtain a stable measure of price impact.[16]

Fig. 2 plots the trends of bond spreads and explanatory variables by year. In the second half of our sample, corresponding to the post high-tech bubble slow-growth period, we notice that while bond spreads, equity volatility and liquidity go up, bond liquidity drops. These trends are significantly pronounced for the low-rated bonds.

Previous literature (see Footnote 9) documents how different liquidity proxies are related to the bond liquidity and yield spreads. Higher bond liquidity, and hence lower bond spread, is associated with higher issue amount or amount outstanding, lower age, longer maturity, larger trade size, higher trading frequency, and smaller bond price impact variables. Financials have higher liquidity and hence

[16] To illustrate, for our full sample of 196,085 bond trades, the original Amihud measure has a mean of 132 and standard deviation of 10,914 (t-statistic = 5.35). On the other hand, the inverse of this measure has a mean of 0.41 and standard deviation of 0.63 (t-statistic = 291.65). This stark difference arises because the denominator (dollar trading volume) in the original Amihud measure is significantly more variable than the numerator (absolute returns). There is, however, no material impact on our results or conclusions if we use the original Amihud measure instead of its inverse.

lower bond spreads compared to Industrials and Utilities. Higher coupon normally implies a higher price or a lower yield. However, higher coupon also implies a larger tax burden and hence a higher required yield, though tax effects for swap-adjusted spreads will be minimal. Finally, higher equity liquidity is expected to have a positive impact on bond liquidity, and hence result in lower spreads.

Table 3 presents the summary statistics (Panels A and B) and correlations (Panels C–E) of all volatility and liquidity variables. Panel A shows that the idiosyncratic volatility is higher when measured at the daily versus the monthly frequency. Panel B reveals that, on average, the corporate bonds in our sample are about 3 years and 7 months old, have a term-to-maturity of about 8 years and 4 months, and carry a 7.3% coupon. Dollar amount outstanding and issued amount are largely similar, with a median value of $250 million. About 37% of all bonds traded are issued by Financials. Overall, each bond trades about 32 times per year, or once every eight trading days, and has an average trade size of $2.77 million. Panel C shows that all equity volatility variables are highly correlated. For a given frequency, 3- and 4-factor idiosyncratic volatilities are almost perfectly correlated. Daily idiosyncratic volatilities are strongly correlated to total volatility. Bond spreads bear large positive correlations with all measures of equity volatility. Panel D indicates that bond spreads are lower for bigger issues, younger bonds, Financials, larger trades, and more frequently traded bonds. Bonds with a higher price impact or lower liquidity carry higher spreads. Bonds with higher underlying equity liquidity have lower spreads. Overall, we find that bond spreads and bond liquidity are negatively related. Panel E reveals that bonds as well as stocks with lower liquidity tend to have higher underlying equity volatility, but the cross-correlations between different volatility and liquidity variables are very low and negligible.

In summary, we find that bond spreads are positively related to equity volatility, and negatively related to bond liquidity measures. Weak cross-correlations between equity volatility and bond liquidity variables imply near-orthogonality between those variables, and that they are unlikely to subsume each other in bond pricing.

3. Univariate and bivariate portfolio trends

We commence by exploring the unconditional relation between bond yield spreads and various liquidity and volatility variables. To this end, we form portfolios based on one-way and two-way sorts on different liquidity and volatility variables, and explore the impact of these variables on bond spreads.

3.1. Univariate sorts

We first construct univariate liquidity and volatility quintiles by sorting all bond trades based on values of different liquidity and volatility variables on bond transaction dates. We compute averages of bond spreads, bond characteristics, and liquidity and volatility measures for these portfolios.

When portfolios are formed using the bond liquidity index 1 (Panel A of Table 4), we find that low bond liquidity (or high liquidity index value) portfolios have higher bond spreads and equity volatilities, but lower rating and equity liquidity values. We thus find a strong and monotonic relationship between higher bond spreads, higher volatility, and lower liquidity. Panel B indicates that high equity volatility portfolios have higher bond spreads, lower ratings, and lower values of some bond liquidity variables, namely, trade size, coupon, and percentage of Financials. Though bond liquidity, measured as the price impact, is the lowest for the most volatile portfolio, there is no distinct monotonic trend indicating a large degree of orthogonality between bond liquidity and equity volatility.

All one-way ANOVA *F*-statistics reported in both panels are highly significant, thereby implying the rejection of the null hypothesis of equality of each variable across the portfolios. Bond portfolios based on any given criterion of liquidity or volatility are uniquely different from each other. Therefore, univariate portfolio analysis indicates that both equity volatility and bond liquidity have unconditional impact on bond spreads, i.e., bond spreads are positively related to equity volatility and negatively related to bond liquidity.[17]

[17] In unreported results, we find similar relations between bond spreads and other liquidity and volatility variables.

Table 3
Summary statistics and correlations. The table presents summary statistics and correlations for all volatility and liquidity measures used in the paper.

	Obs	Mean	Median	Std. dev.	Min	Max
Panel A: Summary statistics of all equity volatility measures						
Total 6-month return variance	163,304	0.15	0.10	0.18	0.01	2.53
Id. Volatility (3- factor, monthly)	162,278	0.06	0.04	0.09	0.00	1.37
Id. Volatility (4-factor, monthly)	162,278	0.06	0.03	0.09	0.00	1.19
Id. Volatility (3-factor, daily)	162,815	0.10	0.07	0.13	0.01	1.81
Id. Volatility (4-factor, daily)	162,815	0.10	0.07	0.13	0.01	1.79
Panel B: Summary statistics of all bond and equity liquidity measures						
Issued amount	196,085	388,616	250,000	401,132	25,000	2,750,000
Amount outstanding	195,689	385,936	250,000	402,305	4,826	2,750,000
Issue age	196,085	3.80	3.31	3.15	0.00	67.56
Time to maturity	196,085	8.67	6.27	8.53	1.01	98.60
Coupon amount	196,085	7.29	7.12	1.11	0.00	15.00
Dummy for financials	196,085	0.37	0.00	0.48	0.00	1
Trade size	196,063	2,772	1130	3.934	1	35,585
Annual trading frequency	196,063	32.46	18.00	42.41	1.00	381.00
Bond liquidity index 1	194,034	15.72	4.00	66.71	0.00	1246.36
Bond liquidity index 2	196,063	0.40	0.12	1.57	0.00	31.77
Equity liquidity	163,304	0.41	0.18	0.61	0.00	5.76
	Total 6-month return variance	Id. Volatility (3-factor, monthly)	Id. Volatility (4-factor, monthly)	Id. Volatility (3-factor, daily)	Id. Volatility (4-factor, daily)	Yield spread
Panel C: Correlations of all equity						
Total 6-month return variance	1.00					
Id. Volatility (3-factor, monthly)	0.66	1.00				
Id. Volatility (4-factor, monthly)	0.62	0.91	1.00			
Id. Volatility (3-factor, daily)	0.94	0.69	0.65	1.00		
Id. Volatility (4-factor, daily)	0.93	0.69	0.65	1.00	1.00	
Yield Spread	0.59	0.50	0.46	0.63	0.63	1.00

(*continued on next page*)

Table 3 (*continued*)

	Issued amount	Amount outstanding	Issue age	Time to maturity	Coupon amount	Dummy for financials	Trade size	Annual trading frequency	Bond liquidity index 1	Bond liquidity index 2	Equity liquidity	Yield spread
Panel D: Correlations of all bond and equity liquidity measures												
Issued amount	1.00											
Amount outstanding	1.00	1.00										
Issue age	−0.23	−0.24	1.00									
Time to maturity	−0.05	−0.05	−0.08	1.00								
Coupon amount	−0.19	−0.20	0.40	0.10	1.00							
Dummy for financials	0.23	0.23	−0.16	−0.13	−0.16	1.00						
Trade size	−0.01	−0.01	−0.04	0.13	0.05	−0.04	1.00					
Annual trading frequency	0.80	0.80	−0.37	−0.03	−0.25	0.22	0.00	1.00				
Bond liquidity index 1	−0.07	−0.08	0.09	0.00	0.04	−0.01	−0.07	−0.08	1.00			
Bond liquidity index 2	−0.07	−0.07	0.09	0.00	0.02	−0.01	−0.08	−0.07	0.96	1.00		
Equity liquidity	0.35	0.35	0.12	0.01	−0.14	0.16	−0.02	0.21	−0.04	−0.04	1.00	
Yield spread	−0.04	−0.04	0.11	0.01	0.13	−0.10	−0.05	−0.05	0.16	0.25	−0.12	1.00

	Total 6-month return variance	Id. Volatility (3-factor, monthly)	Id. Volatility (4-factor, monthly)	Id. Volatility (3-factor, daily)	Id. Volatility (4-factor, daily)
Panel E: Cross-correlations between all liquidity and volatility measures					
Issued amount	0.12	0.00	0.01	0.04	0.04
Amount outstanding	0.12	0.00	0.01	0.04	0.04
Issue age	0.01	0.05	0.04	0.02	0.02
Time to maturity	−0.04	−0.03	−0.03	−0.03	−0.03
Coupon amount	0.00	0.03	0.02	0.04	0.04
Dummy for financials	0.03	−0.10	−0.09	−0.09	−0.08
Trade size	−0.04	−0.04	−0.04	−0.04	−0.04
Annual trading frequency	0.12	0.03	0.04	0.05	0.05
Bond liquidity index 1	0.10	0.10	0.08	0.11	0.11
Bond liquidity index 2	0.19	0.19	0.16	0.20	0.20
Equity liquidity	−0.04	−0.10	−0.09	−0.10	−0.11

Table 4

Univariate portfolio results. The table presents average values of bond yield spreads, liquidity and volatility variables, and other bond characteristics for univariate portfolios based on bond liquidity index 1 and 3-factor daily idiosyncratic volatility. For each variable, quintiles are based on the sorted values of the measure, and observations are allocated to five portfolios depending on the value of the measure on the bond transaction date. Reported *F*-statistics correspond to one-way ANOVA tests for null hypothesis of equality of variable under consideration across portfolios.

Bond liquidity index 1	Rating value	Time to maturity	Duration	Yield	Yield spread	Total 6-month return variance	Id. Volatility (3-factor, monthly)	Id. Volatility (4-factor, monthly)	Id. Volatility (3-factor, daily)	Id. Volatility (4-factor, daily)
Panel A: Average bond characteristics and volatility measures for portfolios based on bond liquidity index 1										
Low	6.59	7.64	5.31	6.45	0.55	0.17	0.06	0.06	0.10	0.10
2	6.94	8.53	5.52	6.46	0.63	0.13	0.05	0.05	0.09	0.09
3	7.00	8.83	5.62	6.53	0.76	0.13	0.05	0.05	0.09	0.09
4	7.05	9.17	5.71	6.69	0.93	0.13	0.06	0.05	0.09	0.09
High	7.72	9.13	5.62	7.60	1.91	0.18	0.09	0.08	0.13	0.13
Total	7.06	8.66	5.55	6.74	0.95	0.15	0.06	0.06	0.10	0.10
F-stat	*1116.44*	*211.10*	*106.44*	*2134.42*	*3226.00*	*570.02*	*824.35*	*665.20*	*631.71*	*635.92*
Bond liquidity index 1	Issued amount	Amount outstanding	Issue age	Coupon amount	Dummy for financials	Trade size (exact)	Annual trading frequency	Bond liquidity index 1	Bond liquidity index 2	Equity liquidity
Average liquidity measures for portfolios based on bond liquidity index 1										
Low	736,597	735,977	1.72	6.86	0.46	3387	81.35	0.67	0.03	0.49
2	428,618	427,518	3.08	7.18	0.38	3204	34.89	1.96	0.07	0.45
3	323,976	321,909	4.15	7.33	0.36	3006	21.99	4.08	0.13	0.43
4	254,894	251,801	4.74	7.45	0.36	2557	15.35	8.77	0.26	0.38
High	211,225	206,330	5.24	7.59	0.30	1703	10.33	63.13	1.55	0.29
Total	391,115	388,490	3.79	7.28	0.37	2771	32.79	15.72	0.41	0.41
F-stat	*13,506.48*	*13,582.37*	*9346.18*	*2612.17*	*559.26*	*1161.33*	*27,786.11*	*7,119.43*	*7,442.28*	*508.97*
Id. Volatility (3-factor, daily)	Rating value	Time to maturity	Duration	Yield	Yield spread	Total 6-month return variance	Id. Volatility (3-factor, monthly)	Id. Volatility (4-factor, monthly)	Id. Volatility (3-factor, daily)	Id. Volatility (4-factor, daily)
Panel B: Average volatility bond characteristics and volatility measures for portfolios based on 3-factor daily idiosyncratic										
Low	6.39	8.68	5.82	6.18	0.43	0.04	0.02	0.02	0.02	0.02
2	6.65	9.25	5.92	6.48	0.55	0.07	0.03	0.03	0.04	0.04
3	6.88	9.12	5.75	6.53	0.65	0.10	0.04	0.04	0.07	0.07
4	7.20	9.22	5.76	6.78	0.83	0.16	0.07	0.07	0.11	0.11
High	8.16	8.22	5.22	7.94	2.07	0.36	0.15	0.14	0.26	0.26
Total	7.05	8.90	5.69	6.78	0.90	0.15	0.06	0.06	0.10	0.10
F-stat	*2732.62*	*89.36*	*285.17*	*3939.66*	*4569.55*	*26,634.61*	*14,586.84*	*14,097.81*	*28,998.52*	*29,100.10*

(*continued on next page*)

Table 4 (*continued*)

Id. Volatility (3-factor, daily)	Issued amount	Amount outstanding	Issue age	Coupon amount	Dummy for financials	Trade size	Annual trading frequency	Bond liquidity index 1	Bond liquidity index 2	Equity liquidity
Average liquidity measures for portfolios based on 3-factor daily idiosyncratic volatility										
Low	356,964	353,695	3.69	7.18	0.45	2730	28.32	17.12	0.40	0.55
2	355,815	354,034	3.45	7.34	0.39	2898	30.83	13.52	0.32	0.40
3	384,022	380,800	3.48	7.30	0.35	2883	32.09	12.60	0.30	0.40
4	436,700	434,237	3.59	7.30	0.30	2858	37.61	11.52	0.30	0.39
High	470,652	469,292	3.50	7.29	0.31	2554	44.32	18.80	0.58	0.31
Total	400,828	398,449	3.54	7.28	0.36	2785	34.63	14.71	0.38	0.41
F-stat	*495.62*	*501.80*	*33.09*	*94.98*	*547.21*	*44.13*	*677.56*	*80.29*	*218.71*	*677.35*

Table 5
Bivariate portfolio results. The table presents average yield spreads for bivariate portfolios based on nine liquidity variables and the 3-factor daily idiosyncratic volatility. Independent univariate quintiles are based on the sorted values of the liquidity and volatility variables and observations are allocated to 25 liquidity–volatility bivariate portfolios. The three two-way ANOVA *F*-statistics report the significance of the test of equality of spreads across univariate liquidity portfolios, univariate volatility portfolios, and bivariate liquidity–volatility portfolios respectively.

	Id. Volatility (3-factor, daily)					
	Low	2	3	4	High	All
Panel A: Issue age						
Low	0.40	0.44	0.51	0.63	1.01	0.59
2	0.36	0.46	0.59	0.77	1.68	0.80
3	0.39	0.51	0.63	0.90	2.59	0.99
4	0.43	0.56	0.71	0.89	2.44	0.97
High	0.60	0.85	0.85	0.98	2.88	1.26
All	0.43	0.55	0.65	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	615.48		*4617.70*		*2627.01*	
Panel B: Coupon amount						
Low	0.32	0.38	0.45	0.54	1.22	0.58
2	0.38	0.53	0.55	0.72	1.64	0.74
3	0.46	0.56	0.56	0.84	2.35	1.00
4	0.46	0.64	0.64	1.05	2.03	1.04
High	0.57	0.63	0.63	0.98	3.29	1.20
All	0.43	0.55	0.55	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	638.36		*4628.26*		*2639.73*	
Panel C: Trade size						
Low	0.43	0.56	0.66	0.94	2.92	1.14
2	0.40	0.53	0.66	0.87	2.52	1.04
3	0.40	0.52	0.62	0.79	1.87	0.82
4	0.45	0.55	0.66	0.81	1.61	0.81
High	0.47	0.57	0.65	0.74	1.16	0.71
All	0.43	0.55	0.65	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	245.91		*4502.83*		*2420.24*	
Panel D: Annual trading frequency						
Low	0.45	0.62	0.75	1.00	2.41	0.93
2	0.45	0.55	0.72	0.93	2.28	0.93
3	0.44	0.54	0.65	0.82	2.57	0.97
4	0.40	0.53	0.59	0.84	2.54	0.99
High	0.38	0.47	0.53	0.64	1.18	0.71
All	0.43	0.55	0.65	0.83	2.07	0.9.
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	413.69		*4881.08*		*2513.54*	
Panel E: Amount outstanding						
Low	0.42	0.60	0.74	0.93	2.32	0.93
2	0.45	0.51	0.64	0.86	2.64	1.00
3	0.40	0.52	0.65	0.93	2.07	0.86
4	0.46	0.53	0.62	0.79	2.35	1.01
High	0.39	0.49	0.50	0.62	1.24	0.72
All	0.42	0.54	0.64	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	283.33		*4793.16*		*2461.18*	
Panel F: Time to maturity						
Low	0.39	0.53	0.65	0.78	2.84	1.14
2	0.38	0.48	0.55	0.79	1.86	0.88
3	0.36	0.49	0.59	0.83	2.33	0.91

(*continued on next page*)

Table 5 (*continued*)

	Id. Volatility (3-factor, daily)					
	Low	2	3	4	High	All
4	0.37	0.47	0.56	0.73	1.07	0.61
High	0.64	0.76	0.87	0.99	2.09	1.03
All	0.43	0.55	0.65	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	316.43		*4490.23*		*2460.70*	
Panel G: Bond liquidity index 1						
Low	0.40	0.50	0.46	0.58	0.72	0.55
2	0.37	0.44	0.59	0.70	0.95	0.61
3	0.41	0.52	0.67	0.82	1.35	0.72
4	0.48	0.57	0.70	0.93	2.08	0.90
High	0.46	0.70	0.86	1.32	5.24	1.80
All	0.43	0.55	0.65	0.83	2.06	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	2876.10		*4922.14*		*3855.54*	
Panel H: Bond liquidity index 1						
Low	0.39	0.45	0.48	0.59	0.73	0.55
2	0.39	0.49	0.58	0.67	0.95	0.61
3	0.41	0.51	0.67	0.80	1.24	0.70
4	0.46	0.59	0.69	0.96	1.76	0.84
High	0.47	0.69	0.88	1.34	5.27	1.89
All	0.43	0.55	0.65	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	3223.97		*4836.23*		*4076.36*	
Panel I: Equity liquidity						
Low	0.54	0.76	0.92	1.30	3.79	1.68
2	0.40	0.54	0.67	0.82	2.20	0.93
3	0.40	0.52	0.60	0.80	1.55	0.77
4	0.40	0.45	0.58	0.72	1.17	0.65
High	0.42	0.51	0.49	0.51	0.62	0.51
All	0.43	0.55	0.65	0.83	2.07	0.90
	F-stat (liquidity)		*F-stat (volatility)*		*F-stat (model)*	
	1670.25		*4184.62*		*3213.10*	

3.2. Bivariate sorts

We then construct two-way sorted portfolios to simultaneously control for the effects of liquidity and volatility while examining their joint impact on bond spreads. We form quintiles of bond transactions based on the ranked values of each liquidity variable, and then *independently* form five more portfolios based on the sorted values of volatility measures. Allocation of observations to the two sets of independent quintiles yields 25 unique liquidity–volatility portfolios. Table 5 presents the trend of average bond spreads along bivariate portfolios corresponding to nine liquidity variables and the idiosyncratic volatility from the 3-factor daily returns model.[18]

Panel A reveals that bond spreads are the smallest for newly issued bonds and increase with issue age. Bond spreads also increase monotonically with volatility within each issue age portfolio. Thus, both issue age and idiosyncratic volatility are important in explaining the bond spreads. Similarly, Panels B–D show that, after controlling for volatility, bond spreads are negatively correlated with trade size and trading frequency; and spreads increase monotonically with higher coupons. There is always a strong monotonic positive correlation between yield spreads and volatility after controlling for the liquidity variables. Panels G and H reveal that, for a given volatility level, bond spreads are lower for higher liquidity portfolios, and the trends appear monotonic. Panel I shows that bond spreads and

[18] Though we report results corresponding to the 3-factor daily idiosyncratic volatility in this table and all subsequent tests, all our findings are robust to other idiosyncratic volatility measures.

equity liquidity are negatively correlated. In all three panels, yield spreads and equity volatility are strongly positively correlated. These trends imply that both bond and stock price impact variables, along with equity volatility, are important in explaining bond spreads.

Table 5 also reports the tests of significance of equality of bond spreads across (a) univariate liquidity portfolios, (b) univariate volatility portfolios, and (c) bivariate liquidity–volatility portfolios respectively. All the reported ANOVA *F*-statistics are highly significant, indicating that liquidity and volatility variables jointly impact bond spreads. In summary, bivariate portfolio analysis implies that both liquidity and volatility measures are critical to bond spreads, and idiosyncratic risk does not subsume the explanatory power of underlying liquidity.

4. Unconditional Fama–MacBeth cross-sectional regressions

We next perform cross-sectional regressions using Fama–MacBeth (1973) procedures with an objective to explore the relative impact of bond liquidity and equity volatility measures on bond spreads after conditioning for control variables. We term the cross-sectional regressions as unconditional tests since they are conducted using the full sample of all bond trades over the entire sample period. We follow Gebhardt et al. (2005a), who adapt Fama–MacBeth tests for cross-sectional bond pricing.

4.1. Fama–MacBeth regressions

We implement the Fama–MacBeth regressions based on the standard two-stage test approach. First, each month, we conduct regressions of bond yield spreads on corresponding bond characteristics, price impact measures, and volatility variables, in addition to bond factor betas as controls. We repeat such cross-sectional regressions for all 132 months in the sample. We report the time-series averages of slopes or coefficient values, associated *t*-statistics i.e. ratio of average slope to time-series standard error with Newey–West adjustment for serial correlation, and the adjusted R^2 values.

The two bond market factor betas we include are term structure and default factor betas (e.g., Gebhardt et al., 2005a; Houweling et al., 2005). The term structure variable (TERM) is obtained as the difference between 10-year and 2-year swap rates, and default factor (DEF) is computed as the difference between Moody's BAA yield and 10-year swap rate. Starting January 1995, using 18 bond portfolios formed each month based on classification of bonds into three industries, two ratings, and three duration categories, we obtain the bond factor betas on a rolling basis each month by regressing 24 months, or 12 months in case of 1995, of past portfolio spreads on the corresponding TERM and DEF factors. Portfolio betas are assigned to individual bonds constituting the portfolio in a given month.

Table 6 reports the results of Fama–MacBeth regressions for different combinations of variables. Regression 1 uses the bond liquidity index 1 and 3-factor daily idiosyncratic volatility as sole explanatory variables. Regression 2 augments the regression 1 with default and term betas. Regressions 3–5 employ different combinations of bond characteristics along with the bond liquidity index, volatility, and factor betas; all bond characteristics are not considered simultaneously because of possible multicollinearity issues.

All five sets of regressions reveal that default factor betas are always highly significant, but term factor betas are significant only in certain combinations. More importantly, equity volatility and bond liquidity are always significant. In particular, the coefficients and *t*-statistics associated with volatility and liquidity index remain largely unchanged whether considered standalone, jointly, or along with bond characteristics. Bond liquidity and equity volatility variables have their own individual, unique impact on bond spreads. Many bond characteristics, used as proxies for liquidity, remain significant.

Regressions 1a and 1b highlight that volatility has greater explanatory power than the liquidity index with the adjusted R^2 of 35% versus 4.85%. When conditioned for factor betas, the adjusted R^2 increases from 35% to 39.28%, comparing regression 2b–1b. However, adding liquidity characteristics to the volatility variable, going from regression 2b to 3d, increases the adjusted R^2 by just 6.03% from 39.28% to 45.31%. Finally, adding the liquidity index 1 to the above variables, i.e., contrasting

Table 6
Fama–MacBeth regressions with bond market factor betas. The table presents the results of two-stage Fama–MacBeth regressions augmented with bond market factor betas for individual bonds over the sample period 1995–2004. The bond market factor betas are computed each month as slopes in the regression of past 12–24 monthly spreads of 18 bond portfolios on term and default factors. Each month, cross-sectional regressions of bond spreads are carried out on issue-specific bond characteristics (char) and liquidity and volatility values. For each regression, the first row reports the coefficients as the time-series average of 120 monthly regression slopes and the second row presents *t*-statistics computed as the ratio of time-series average slope to the time-series standard error of monthly slopes with Newey–West adjustment for serial correlation. The liquidity index (liq indx) and volatility measure (vol meas) refer to bond liquidity Index 1 and 3-factor daily idiosyncratic volatility respectively.

	Bond characteristics						Liquidity and volatility measures		Bond factors		
Regression variables	Amount outstanding ($\times 10^{-6}$)	Issue age	Maturity	Coupon	Trade size ($\times 10^{-6}$)	Trade frequency ($\times 10^{-2}$)	Liquidity index	Volatility measure	Default beta	Term beta	Adjusted R^2 (%)
1											
(a) Liq Indx							0.007				4.85
							8.40				
(b) Vol Meas								9.46			34.99
								17.72			
(c) Liq Indx + Vol Meas							0.005	9.19			37.12
							7.28	*17.44*			
2											
(a) Liq Indx							0.007		0.71	0.41	16.43
							8.66		*7.36*	*3.44*	
(b) Vol Meas								8.68	0.37	0.08	39.28
								17.33	*6.76*	*1.23*	
(c) Liq Indx + Vol Meas							0.004	8.42	0.37	0.10	41.31
							7.57	*17.10*	*6.61*	*1.53*	
3											
(a) Char	−0.12		0.02	0.22	−0.03				0.69	0.34	19.25
	−6.46		*12.53*	*12.56*	*−9.25*				*6.89*	*2.76*	
(b) Char + Liq Indx	−0.05		0.02	0.20	−0.02		0.006		0.68	0.36	22.88
	−2.24		*11.96*	*11.67*	*8.39*		*8.15*		*6.93*	*2.94*	
(c) Char + Liq Indx + Vol Meas	−0.12		0.01	0.14	−0.01		0.004	8.18	0.34	0.05	46.91
	−6.31		*7.31*	*13.72*	*−5.29*		*7.12*	*17.36*	*6.34*	0.80	
(d) Char + Vol Meas	−0.17		0.01	0.15	−0.01			8.42	0.34	0.04	45.31
	−8.31		*7.62*	*14.93*				*17.53*	6.61	0.56	
4											
(a) Char	−0.23	0.00	0.02		−0.03				0.75	0.38	16.31
	−10.60	*−0.83*	*14.48*		*−9.08*				*7.34*	*3.01*	

(b) Char + Liq Indx	−0.17	−0.01	0.02		−0.02		0.007		0.74	0.39	20.31
	−7.67	*−3.26*	*13.96*		*−8.06*		*8.35*		*7.38*	*3.21*	
(c) Char + Liq Indx + Vol Meas	−0.18	0.00	0.01		−0.01		0.004	8.39	0.37	0.07	45.13
	−9.01	*−0.24*	*9.20*		*−4.44*		*7.35*	*17.47*	*6.75*	*1.09*	
(d) Char + Vol Meas	−0.22	0.01	0.01		−0.01			8.66	0.38	0.06	43.36
	−10.65	*1.79*	*9.70*		*−5.86*			*17.69*	*7.02*	*0.80*	
5											
(a) Char			0.02	0.22	−0.03	−0.10			0.69	0.34	19.34
			12.36	*12.94*	*−9.27*	*−4.3*			*6.91*	*2.73*	
(b) Char + Liq Indx			0.01	0.21	−0.02	0	0.006		0.68	0.35	22.98
			11.91	*12.07*	*−8.32*	*0.18*	*8.19*		*6.97*	*2.91*	
(c) Char + Liq Indx + Vol Meas			0.01	0.15	−0.01	−0.09	0.004	8.17	0.34	0.05	46.66
			7.07	*13.91*	*−5.28*	*−3.66*	*7.18*	*17.21*	*6.31*	*0.83*	
(d) Char + Vol Meas			0.01	0.16	−0.01	−0.15		8.41	0.35	0.04	45.07
			7.35	*14.96*	*−6.64*	*−6.04*		*17.38*	*6.56*	*0.58*	

regression 3c with 3d, we find that the adjusted R^2 increases further by 1.60%, from 45.31% to 46.91%. Thus, volatility has the maximum impact on R^2, followed by bond characteristics and the liquidity index. These results imply that, in terms of the overall explanatory power, equity volatility has the first-order impact, and liquidity, represented by bond characteristics and bond price impact, has the second-order effect on bond spreads.

Similar results obtain when we compare regression 2 to regressions 4 and 5 involving other combinations of bond characteristics. For example, in regression 4, adding bond characteristics to volatility, going from regression 2b to 4d, increases the adjusted R^2 by 4.08%. Adding the liquidity index as well (i.e., comparing regression 4c with 4d), we notice that the adjusted R^2 increases further by 1.77%.

Analogous conclusions bear out from the shock analysis conducted using regression coefficients and standard deviations of variables, from Panels A and B in Table 3. We find that 1σ positive shock to volatility results in the widening of bond spreads by 108–111 bps, i.e., 8.17×0.13 in regression 5c to 8.39×0.13 in regression 4c. However, 1σ shock to liquidity index, resulting in lower liquidity, causes higher spreads of about 26 bps, 0.004×66.71 in regressions 3c, 4c, or 5c. Similar 1σ shocks to amount outstanding, coupon, and maturity result in higher spreads of about 8, 16, and 8 bps respectively.

In summary, volatility and liquidity index retain largely unchanged coefficients and significant *t*-statistics across different regressions. Both volatility and liquidity matter in determining corporate bond spreads; idiosyncratic risk does not subsume the information in underlying liquidity. Based on the explanatory power and shock analysis, *equity volatility* has the *first-order* impact, and *liquidity* has the *second-order* effect on bond spreads.

4.2. Robustness tests

We examine the robustness of our results under various controls.[19] All our earlier findings remain robust, and conclusions remain unaltered when we (a) include ratings and durations as characteristics instead of corresponding factor betas, (b) control for equity liquidity, (c) consider aggregate stock market volatility or bond market liquidity factor betas, (d) use bond portfolios instead of individual bonds, (e) orthogonalize liquidity and volatility measures, (f) run Fama–MacBeth regressions by half-year instead of monthly basis, (g) use the liquidity index 2 in lieu of the liquidity index 1, and (h) substitute the 3-factor daily idiosyncratic volatility with other volatility measures.

5. Conditional Fama–MacBeth cross-sectional regressions

Next, we carry out Fama–MacBeth cross-sectional regressions over sub-samples by conditioning for (a) underlying bond- and issuer-specific characteristics such as rating, equity volatility, bond liquidity, and industry classification, and (b) overall market conditions such as time-period to capture regime effects, aggregate equity market volatility, and aggregate bond market liquidity. The objective is to discern how the interaction between equity volatility and bond liquidity is altered while explaining bond spreads when underlying issue and firm characteristics and/or market conditions change. However, since we do not explicitly capture the exogenous shocks to either idiosyncratic volatility or liquidity, our results are best interpreted as stylized facts, rather than any causal evidence.

5.1. High- and low- rating categories

We first examine how the impact of volatility and liquidity differs between high-rated, rated AA or A, and low-rated, BBB or below, bond issues.

Equity volatility alone explains 38.45% of the variation in spreads for low-rated bonds and 4.50% for high-rated bonds, as revealed in regression 1b of Panels A and B in Table 7. After controlling for default and term structure factor betas in regression 2b, volatility still retains the dominant explanatory power for low-rated bonds, but not so for high-rated bonds. On the other hand, liquidity variables,

[19] We do not discuss the details or report the results; they will be made available upon request.

Table 7

Conditional Fama–MacBeth regressions based on rating groups. The table presents the results of Fama–MacBeth regressions for individual bonds sorted into two ratings portfolios over the period 1995–2004. High (low) ratings refer to ratings AA or A (BBB or below). Each month, cross-sectional regressions of bond spreads are carried out on bond characteristics (char) and liquidity and volatility values. For each regression, the first row reports the coefficients as the time-series average of 120 monthly regression slopes and the second row presents *t*-statistics computed as the ratio of time-series average slope to the standard error of monthly slopes with Newey–West correction. The liquidity index (liq indx) and volatility measure (vol meas) refer to bond liquidity Index 1 and 3-factor daily idiosyncratic volatility respectively.

	Bond characteristics				Liquidity and volatility measures		Bond factors		
Regression variables	Amount outstanding ($\times 10^{-6}$)	Maturity	Coupon	Trade size ($\times 10^{-6}$)	Liquidity index	Volatility measure	Default beta	Term beta	Adjusted R^2 (%)
Panel A: Low-rated (BBB and BB) bonds									
1									
(a) Liq Indx					0.015				10.48
					9.10				
(b) Vol Meas						9.60			38.45
						11.98			
(c) Liq Indx + Vol Meas					0.009	8.98			42.45
					6.92	*11.67*			
2									
(a) Liq Indx					0.015		0.27	0.30	14.41
					9.67		*1.81*	*1.76*	
(b) Vol Meas						9.57	0.09	0.12	40.43
						12.15	*1.15*	*1.29*	
(c) Liq Indx + Vol Meas					0.009	8.96	0.08	0.14	44.30
					7.06	*11.85*	*0.99*	*1.50*	
3									
(a) Char	−0.24	0.01	0.33	−0.07			0.41	0.33	12.35
	−2.44	*4.13*	*7.41*	*−6.43*			*2.35*	*1.60*	
(b) Char + Liq Indx	0.19	0.01	0.28	−0.05	0.014		0.38	0.36	20.52
	2.13	*2.23*	*6.45*	*−5.91*	*9.17*		*2.20*	*1.83*	
(c) Char + Liq Indx + Vol Meas	−0.35	0.00	Q.11	−0.03	0.008	8.81	0.12	0.15	49.64
	−2.95	*0.58*	*9.19*	*−4.88*	*6.27*	*11.93*	*1.54*	*1.45*	
(d) Char + Vol Meas	−0.57	0.01	0.24	−0.04		9.34	0.14	0.14	46.76
	−4.04	*1.07*	*10.03*	*−5.43*		*12.04*	*1.80*	*1.40*	
Panel B: High-rated (AA and A) bonds									
1									
(a) Liq Indx					0.001				1.06
					5.31				
(b) Vol Meas						2.02			4.50

(*continued on next page*)

Table 7 (*continued*)

Regression variables	Bond characteristics				Liquidity and volatility measures		Bond factors		Adjusted R^2 (%)
	Amount outstanding ($\times 10^{-6}$)	Maturity	Coupon	Trade size ($\times 10^{-6}$)	Liquidity index	Volatility measure	Default beta	Term beta	
						6.57			
(c) Liq Indx + Vol Meas					0.001	2.03			5.85
					4.32	6.64			
2									
(a) Liq Indx					0.001		0.05	−0.77	3.71
					5.32		0.62	−0.72	
(b) Vol Meas						2.05	0.09	−0.14	7.22
						6.56	0.97	−1.99	
(c) Liq Indx + Vol Meas					0.001	2.04	0.09	−0.15	8.57
					4.34	*6.58*	*0.93*	*−2.02*	
3									
(a) Char	−0.06	0.01	0.07	0.00			0.07	−0.08	13.41
	−4.42	*12.88*	*10.02*	*−1.35*			*0.97*	*−1.19*	
(b) Char + Liq Indx	−0.05	0.01	0.07	0.00	0.001		0.06	−0.09	14.36
	−3.58	*12.84*	*9.67*	*−0.76*	*4.98*		*0.86*	*−1.19*	
(c) Char + Liq Indx + Vol Meas	−0.06	0.01	0.06	0.00	0.001	1.96	0.08	−0.19	20.16
	−4.19	*12.22*	*9.47*	*1.46*	*4.07*	*6.50*	*0.91*	*−2.45*	
(d) Char + Vol Meas	−0.07	0.01	0.06	0.00		1.97	0.09	−0.19	18.95
	−5.05	*12.23*	*9.87*	*0.77*		*6.57*	*0.96*	*−2.49*	

i.e., bond characteristics and the price-impact index, together account for 9.21% of bond spreads for low-rated bonds, comparing regressions 2b and 3c in Panel A, and 12.94% for high-rated bonds, comparing regressions 2b and 3c in Panel B. Thus, volatility has higher significance for distressed bonds, while the impact of liquidity is stronger for high credit issues.[20]

Table 8 summarizes the absolute and relative contributions of volatility and liquidity effects. We see that, based on the total adjusted R^2 in regression 3c, volatility accounts for 77.46% of the total explanatory power for low-rated portfolios, and only 22.32% for high-rated bonds; similar numbers for liquidity are 18.55% for low-rated issues and 64.19% for high-rated bonds. Analogous findings emerge from the shock analysis: 1σ shocks to volatility and liquidity in regression 3c increase bond spreads respectively by 171 and 54 bps for low-rated bonds, and 13 and 20 bps for high-rated issues. In *absolute* terms, both volatility and liquidity shocks matter more for low-rated issues, as seen in columns 6 and 7; on a *relative* basis, however, columns 8 and 9 show that volatility shocks are more prominent for low-rated issues, while liquidity shocks have a greater impact on high-rated bonds.

5.2. Additional tests

We further repeat conditional analysis for sub-samples based on several variables: issue-specific attributes like equity volatility, bond liquidity and industry, and overall market conditions such as time-period, VIX, and aggregate bond market liquidity. We form two portfolios based on the annual median values of each underlying variable or, based on industry, classify bonds into Financials vs. Industrials and Utilities, and then conduct cross-sectional regressions for each sub-sample. Table 8 tabulates the results. Columns 6 and 7, Table 8, reveal that, in absolute terms, effects of both volatility and liquidity shocks are more prominent for high-volatility bonds; however columns 8 and 9 indicate that, on a relative basis, volatility shocks matter more for high-volatility issues, while liquidity shocks are more evident for low-volatility issues. In terms of their relative contribution to the overall explanatory power, as columns 4 and 5 show, there is a similar segmentation in volatility and liquidity effects.

When we form portfolios based on bond liquidity, we find that while high-liquidity index issues experience higher absolute effects of both shocks, the relative impact of equity volatility matters more for low-liquidity bonds, while liquidity variables are more relevant for high-liquidity bonds. We also examine the relative impact of volatility and liquidity by industry classification. Financial issues possess better credit ratings and higher liquidity than other issues. In contrast, Industrials and Utilities are relatively high-yield issues. Volatility is more prominent for Industrial and Utility bonds, and liquidity variables have greater impact on Financial issues.

We run the Fama–MacBeth regressions separately for 1995–1999, high-growth, and 2000–2004, low-growth, sub-periods. The low-growth period is characterized by higher absolute impact of volatility and liquidity shocks on spreads; while the relative effect of volatility shock is higher in the low-growth period, the liquidity shock has a stronger effect in high-growth years. We also observe that liquidity variables have higher incremental power during low-VIX regime, while volatility matters more during high-VIX periods. Similarly, while low bond market liquidity regimes experience higher absolute shock impact, volatility matters substantially more during low market liquidity periods, and liquidity is more relevant during high aggregate liquidity years.

To summarize, the conditional analysis reveals that, on an *absolute* basis, distressed bonds (i.e., issues with low ratings, high equity volatility or low bond liquidity, and Industrials and Utilities) as well as distress regimes (i.e., recessionary years, periods of high equity volatility or low bond liquidity) experience a greater impact of shocks to both volatility and liquidity on corporate bond prices. However, on a *relative* basis, idiosyncratic volatility effects are considerably more prominent for distressed bonds and during high-distress regimes, whereas the liquidity variables have comparatively higher information content for low-distress bonds and during low-distress regimes.

[20] These results are consistent with Longstaff et al. (2005); Driessen (2005), who document strong liquidity effects for high-rated bonds.

Table 8

Summary of conditional Fama–MacBeth regressions. The table presents the summary of Fama–MacBeth regressions corresponding to different bond portfolios based on cross-sectional attributes and market conditions over the period 1995–2004.

- Columns 1 and 2 refer to the incremental contribution of volatility (based on regression 1b) and liquidity variables (based on regressions 3c vs. 2b) to adjusted R^2 for different sub-samples
- Column 3 presents the corresponding total adjusted R^2 of regression 3c
- Columns 4 and 5 capture the relative contributions of volatility and liquidity as a proportion of total adjusted R^2, and are obtained as (column 1)/(column 3) and (column 2)/(column 3) values
- Columns 6 and 7 denote the effect of 1 σ shock to volatility and liquidity on bond spreads, in basis points, in regression 3c
- Columns 8 and 9 measure the relative effect of 1 σ shocks to volatility and liquidity as a proportion of the total effect on bond spreads, and are obtained as (column 6)/(column 6 + column 7) and (column 7)/(column 6 + column 7) values

Besides the overall portfolio, we consider four sub-samples based on different portfolio characteristics:

- High (low) ratings refer to bonds with ratings AA or A (BBB or below)
- Low (high) idiosyncratic volatility issues refer to bonds whose underlying stock idiosyncratic volatility values are below (above) the corresponding annual median values
- Low (high) bond liquidity issues refer to bonds whose liquidity index 1 values are above (below) the corresponding annual median index values
- Industrials and Utilities, and Financials

In addition, we consider three sub-samples based on market conditions:

- High-growth (1994–1999) period and Low-growth (or recessionary) (2000–2004) period
- Low (high) VIX regime refers to months when VIX values are below (above) the full-period median value
- Low (high) market liquidity regime refers to months when aggregate liquidity (obtained as equally-weighted average of liquidity index 1 measure for all bonds) is above (below) the full-sample median value

In columns 4, 5, 8, and 9, we further italicize the specific sub-sample where a given variable has the maximum contribution

	Absolute contribution to adjusted R^2			Relative contribution to adjusted R^2		Absolute impact on spread due to (in bps) 1σ shock		Relative impact on spread due to 1σ shock	
	Volatility 1 (%)	Liquidity 2 (%)	Total 3 (%)	Volatility 4 (%) (1)/(3)	Liquidity 5 (%) (2)/(3)	Volatility 6	Liquidity 7	Volatility 8 (%) (6)/(6 + 7)	Liquidity 9 (%) (7)/(6 + 7)
From Table 6 All bonds	34.99	7.63	46.91	74.59	16.27	109	42	72.01	27.99%
Sub-samples based on cross-sectional attributes									
From Table 7 Low-rated	38.45	9.21	49.64	*77.46*	18.55	171	54	*75.80*	24.20
High-rated	4.50	12.94	20.16	22.32	*64.19*	13	20	39.77	*60.23*
From Table A-2 High idiosyncratic volatility	36.35	8.87	50.92	*71.39*	17.42	144	64	*69.19*	30.81
Low idiosyncratic volatility	1.76	12.63	23.09	7.62	*54.70*	10	26	28.80	*71.20*
Unreported Table Low bond liquidity	40.96	6.26	51.76	*79.13*	12.09	150	53	*73.75*	26.25
High bond liquidity	11.18	11.10	30.80	36.30	*36.04*	32	21	60.67	*39.33*
Unreported Table Industrials and Utilities	34.53	8.71	48.29	*71.51*	18.04	124	46	*72.93*	27.07
Financials	18.18	10.54	40.88	44.47	*25.78*	46	43	51.72	*48.28*
Sub-samples based on market conditions									
From Table A-3 Low-growth period (2000–2004)	47.38	4.30	55.42	*85.49*	7.76	203	50	*80.20*	19.80

High-growth period (1995–1999)	22.60	10.95	38.40	58.85	*28.52*	46	34	57.71	*42.29*
From Table A-4 High VIX	39.24	6.29	50.07	*78.37*	12.56	120	39	*75.38*	24.62
Low VIX	30.74	8.96	43.75	70.26	*20.48*	76	42	64.47	*35.53*
Unreported Table Low bond market liquidity	43.53	5.76	52.68	*82.63*	10.93	181	43	*80.85*	19.15
High bond market liquidity	26.45	9.49	41.14	64.29	*23.07*	59	33	63.83	*36.17*

6. Summary and conclusions

The primary objective of this paper is to explore the relative importance of equity volatility and bond liquidity in the Campbell and Taksler (2003) framework. We extend Campbell and Taksler by (a) conditioning for underlying bond liquidity, (b) evaluating the interaction between idiosyncratic equity volatility and bond liquidity in determining corporate bond spreads, and (c) exploring how such interactions are altered when underlying bond and firm characteristics vary, or when market conditions change. This paper contributes to the literature by providing a better understanding of the relative importance of equity volatility and bond liquidity in the cross-sectional pricing of corporate debt.

Our analysis shows that the cross-section of corporate bond spreads depends on both volatility and liquidity, with their relative importance depending on underlying firm and economic conditions. Unconditional Fama–MacBeth regressions reveal that while both volatility and liquidity effects are important in evaluating bond spreads, equity volatility has the first-order impact, and bond liquidity, represented by bond characteristics and bond price impact measures, has the second-order effect on bond spreads. Conditional cross-sectional regressions implemented on sub-samples based on relative distress features, however, reveal very distinct *absolute* and *relative* significance of the two effects.

Our findings imply that bond pricing models can deliver improved pricing and hedging performance by incorporating the relative significance of equity volatility and bond liquidity effects for different distress portfolios and regimes. Our results also indicate a need for regime-switching models for bond spreads that can better incorporate the differential effects of volatility and liquidity across distress regimes (e.g., Watanabe and Watanabe, 2008; and Acharya et al., 2010). Further, our findings reveal that, unlike the results for equity markets documented by Spiegel and Wang (2005), idiosyncratic risk does not subsume bond liquidity in explaining bond spreads. This implies that corporate bond markets are inherently more illiquid compared to equity markets, thereby rendering it much harder to diversify illiquidity.

Finally, our findings on the relative strengths of volatility and liquidity effects can have several practical implications. They can, for example, guide (a) fixed-income traders to better formulate their investment and hedging strategies, (b) debt issuers to better time their debt issuance in order to minimize the cost of borrowing, and (c) policy makers to better address the impact of volatility and liquidity shocks on credit markets.

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Appendix A. Bond sample selection

From the NAIC database, we first collect transaction information such as trade date, market value of transaction, par amount of traded bonds, and accrued interest on the US corporate bond trades between 1994 and 2004. The NAIC bond trades are then merged with various bond attributes such as issuance date, maturity, coupon, and other issue- and issuer-specific variables from the FISD. Based on 6-digit CUSIP numbers, the corporate bonds are matched to the stock price data in the Center for Research in Security Prices (CRSP) database. Bond ratings and amount outstanding on the transaction date of each bond trade are extracted from the Ratings and Amount History tables in the FISD. For bond ratings, we use the Standard & Poor's (S&P) rating value if it exists; otherwise we use Moody's rating data. On the bond transaction dates, we compute yield-to-maturity and Macaulay duration based on reported buy or sell prices, and other related variables. We obtain yield spreads for each bond transaction using matching maturity swap rates as a benchmark (Houweling et al., 2005). Daily swap rates for 15 different maturities, ranging between 1 and 30 years, are obtained from DATASTREAM. Each bond trade is matched to a corresponding swap rate based on linear interpolation of the two closest neighboring maturity swap yields. Since the tax treatment of swaps is similar to that of corporate bonds, bond spreads based on a swap benchmark have little tax component in them (Longstaff et al., 2005).

We impose several screening criteria on the bond sample. From the NAIC database, we exclude bond trades characterized by any of the following: (a) erroneous trade dates and incorrect third-party vendor names; (b) underlying maturity is less than 1 year on transaction date; (c) missing transaction prices or transaction prices are extreme, i.e. transaction price below \$100 or above \$10,000, where \$1000 is the par value; (d) variables needed to compute yield-to-maturity are missing or are erroneous; (e) yield-to-maturity cannot be computed due to non-convergence of the pricing formula, or computed yield is greater than 100% or less than 1%; and (f) variables needed to compute the Macaulay duration are missing or the Macaulay duration cannot be computed.

Based on the FISD variables, we further exclude the following bond issues: bonds with callable, redeemable, putable, exchangeable, convertible, sinking fund, enhancement, or asset-backed features; perpetual and variable rate bonds; medium-term notes; Yankee, Canadian, and foreign currency issues; Rule 144a issues; TIPS, Treasuries, Munis, Treasury coupon- and principal-strips; and agency-type bonds. We also drop bond issues that are unrated, or have either missing or extreme bond ratings, i.e. below C grade, or belonging to AAA or Aaa ratings.[21] Finally, we drop all bond trade observations that (a) do not have any matching stocks in the CRSP database, or (b) have insufficient stock returns data in the 6 months prior to the bond transaction date, and hence equity volatilities cannot be computed. All computed bond measures such as yield-to-maturity, yield spread, and duration are winsorized at the 1% level. The final matched dataset consists of issuance- and transaction-related information on the fixed-rate, US dollar-denominated, domestic, straight corporate bond trades by all insurance companies for publicly traded firms.

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