Prices and Volatilities in the Corporate Bond Market

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Abstract

We document a strong positive cross-sectional relation between corporate bond yield spreads and bond return volatilities. As corporate bond prices are generally attributable to both credit risk and illiquidity as discussed in Huang and Huang (2012), we apply a decomposition methodology to quantify the relative contributions of credit and illiquidity. Overall, our credit and illiquidity proxies can explain almost three quarters of the yield spread-bond volatility relation with credit and illiquidity contributing in a 70:30 ratio. Furthermore, we find that the credit portion of the yield spread-bond volatility relation is important even after controlling for equity volatility. The relation between yield spreads and volatilities is robust to different sample periods, including the financial crisis. We also find the ratio to be smaller for the investment-grade subsample, consistent with credit risk being relatively more important for understanding the yield spread-volatility relation in speculative-grade bonds.

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1 Introduction

From both a theoretical and empirical perspective, the relation between equity returns and volatility has been extensively studied. As early as Markowitz (1952), standard asset pricing theory has assumed that investors face a trade-off between expected returns and variances in their portfolios. Later work (Campbell (1993, 1996)) shows that in a multiperiod setting, investors should hedge against increasing market volatility, as high aggregate volatility states coincide with a decline in investment opportunities. At the firm-level, Merton (1987) predicts higher expected returns for firms with greater idiosyncratic volatility due to imperfect diversification. In the equity market, the empirical evidence is mixed. Ang, Hodrick, Xing, and Zhang (2006) find a negative price of risk for aggregate volatility, but also find that high idiosyncratic volatility stocks have lower returns.

In this paper, our primary focus is on the relation between corporate bond prices and bond-level return volatilities, a natural and simple measure of the risk of corporate bonds. The current literature has recognized the theoretical implications of volatility on bond prices, but has focused on equity volatilities.[1] The theoretical relevance of equity volatility in bond prices is as a proxy for asset volatility in structural models of default. Bond volatility, however, is directly relevant to bond investors even in a simple mean-variance framework and provides a direct metric of risk. In addition, it potentially provides significant information about risk above and beyond equity volatility. We document that bond return volatility on its own can explain 35.4% of the cross-sectional variation in observed yield spreads. Furthermore, a one standard deviation increase in bond return volatility is associated with an increase in yield spreads of 1.34%.[2] In comparison, the average A yield spread in our sample is 1.14% and the average Baa yield spread is 1.90%. When we include equity volatility as a control, bond volatility continues to be economically and statistically significant, showing

[1]Campbell and Taksler (2003) find that equity volatility is as important for explaining yield spreads as ratings.

[2]This result contrasts the equity literature, where there is a negative relation between returns and volatilities.

that bond volatility is able to capture components of risk that are distinct from equity volatility. Furthermore, we find that a small number of characteristics can explain a large part of the variation in corporate bond prices. When bond volatility is combined with only equity volatility, ratings, book-to-market, and the γ measure from Bao, Pan, and Wang (2011), almost 63% of the cross-sectional variation in yield spreads is explained.

Though our primary focus on yield spreads follows much of the corporate bond literature, it contrasts the equity literature, which focuses on expected returns. Instead, yields are promised returns and effectively a normalized (inverse) measure of prices. The link between the two comes from the fact that prices reflect expected future cash flows discounted at expected rates of return.[3] Because expected future cash flows partially reflect (idiosyncratic) firm-specific default information and bond volatility has both an idiosyncratic and a systematic component, there is potentially greater scope for bond volatility to explain prices than expected returns. Thus, we also calculate the relation between expected bond returns and bond volatility, finding a significant, but smaller relation than between yield spreads and bond volatility. Bond volatility explains 19.18% of the cross-sectional variation in expected excess returns and a one standard deviation increase is associated with an 89 basis point difference in expected returns.

Beyond establishing that bond volatility is a useful characteristic for explaining the cross-section of yield spreads, we establish and quantify the reasons for the yield spread-bond volatility relation by applying the Hou and Loh (2013) decomposition methodology.[4] The methodology allows for a multistage analysis where the coefficient on the yield spread-bond volatility regression is decomposed into parts explained by a series of candidate variables. Furthermore, the methodology allows for a quantification of the percentage of the coefficient due to different candidate variables. In particular, Huang and Huang (2012) note that the

[3] See Huang and Shi (2013) for a detailed discussion of the use of yield spreads versus returns.

[4] A recent debate in the asset-pricing literature is about the sources of the negative cross-sectional relation between equity returns and idiosyncratic volatility. The Hou and Loh (2013) methodology is uniquely suited to provide direct empirical evidence of the reasons that a characteristic or factor is related to prices and to also *quantify* the contribution of different explanations.

price-risk relation in corporate bonds can be understood through the lens of both credit risk and illiquidity. By using a decomposition, we are able to quantify the relative contributions of credit risk and illiquidity to the yield spread-bond volatility relation.[5]

We apply the Hou and Loh (2013) methodology, using a series of illiquidity and credit proxies as candidate variables in explaining the yield spread-bond volatility relation. As proxies for illiquidity, we consider the γ measure from Bao, Pan, and Wang (2011), the Amihud (2002) measure, the implied round-trip cost (IRC) measure from Feldhutter (2012), the volatilities of the Amihud and IRC measures, and zero trading days. For credit quality, we consider two types of variables, accounting-based and market-based. Accounting-based variables include Moody's ratings, whose inputs are largely accounting variables, book leverage, interest coverage, free cash flow-to-debt, and EBITDA-to-sales. As market-based variables, we consider equity book-to-market and distance-to-default.[6] We find that the credit proxies together can explain 50.59% of the relation between yield spreads and volatility, but the illiquidity proxies are also important, explaining 20.99%.

In addition to providing a better understanding of the relative contributions of credit risk and illiquidity in corporate bond pricing, our decomposition also provides commentary on the different variables used in the literature. The four illiquidity proxies advocated by Dick-Nielsen, Feldhutter, and Lando (2012), the Amihud measure, IRC, and their volatilities, together explain 10.19% of the yield spread-bond volatility relation, a similar magnitude to the 10.12% explained by the γ measure from Bao, Pan, and Wang (2011). For credit risk, our results suggest that ratings are a good summary variable for accounting-based credit quality, but adding even simple market-based measures provides significant additional explanatory power. In particular, book-to-market is a powerful credit risk proxy, contributing 18.01% to

[5] Empirical results such as Chen, Lesmond, and Wei (2007), Bao, Pan, and Wang (2011), and Dick-Nielsen, Feldhutter, and Lando (2012) have established the relation between yield spreads and illiquidity. Bao and Pan (2013) find that high empirical bond volatility is associated with both poorer credit quality and lower liquidity, suggesting that bond volatility may be a useful summary variable in capturing both major components of risk in the corporate bond market.

[6] Book-to-market has been used extensively by Fama and French (1993) and Asness and Frazzini (2011) among others and distance-to-default has been used by Hillegeist, Keating, Cram, and Lundstedt (2004) and Campbell, Hilscher, and Szilagyi (2008) among others.

the yield spread-bond volatility relation.

To provide a comparison to our bond volatility results, we consider equity volatility as an alternative measure of return volatility. We first confirm the positive relation between yield spreads and equity volatility that has been documented in the prior literature.[7] We then decompose the relation between yield spreads and equity volatility into credit quality and bond illiquidity components, finding that credit quality has nearly nine times the explanatory power of bond illiquidity. Unlike bond volatility, equity volatility is only indirectly related to bond illiquidity, explaining the relatively small marginal contribution of bond illiquidity.

As both the yield spread-bond volatility and yield spread-equity volatility relations have credit risk as an important driver, we examine whether bond volatility provides additional credit information above and beyond equity volatility or if the importance of bond volatility even after controlling for equity volatility is solely due to capturing illiquidity. We first orthogonalize bond volatility to equity volatility and decompose the coefficient from a regression of yield spreads on orthogonalized bond volatilities. Illiquidity and credit are approximately equal contributors. Importantly, there is still an important credit component. Thus, while part of the yield spread-bond volatility relation is due to credit risk that is also captured by equity volatility, bond volatility contains some information about credit risk above and beyond equity volatility.

We also consider the price-bond volatility relation in a number of sample cuts. We find that both credit quality and illiquidity retain their importance before, during, and after the financial crisis. During the financial crisis, the importance of book-to-market, a market-based credit variable, more than doubles, before returning to pre-crisis levels. Turning to maturity, we find that the relative contribution of illiquidity to explaining the yield spread-volatility relation is stronger for shorter maturity bonds. Furthermore, we find that fundamental credit quality is more important in explaining speculative-grade bonds than investment-grade bonds. This result is consistent with the Huang and Huang (2012) conclusion that

[7] See Campbell and Taksler (2003), Cremers, Driessen, Maenhout, and Weinbaum (2008), and Rossi (2013).

credit fundamentals can explain a greater proportion of speculative-grade yield spreads. Finally, we also find that our conclusions are robust to using portfolios, which mitigates the problem of variables measured with noise.

Our paper is most closely related to the literature on the price-risk trade-off in the corporate bond market. Collin-Dufresne, Goldstein, and Martin (2001) find that time series changes in yield spreads are difficult to explain with fundamentals, finding R^2 values in the range of 20%. Studies of yield spreads in the cross-section have found significantly more positive results, with larger explanatory power by variables such as equity volatility, option-implied volatility, and illiquidity proxies.[8] The R^2 values found in these studies are typically in the range of 50% after controlling for many variables, suggesting that while a significant proportion of cross-sectional variation can be explained, there is still significant residual variation that remains for the literature to understand.

In recent years, researchers have largely turned to explaining spreads either through a new credit risk mechanism or through illiquidity. However, the literature has largely ignored quantifying the relative contributions of credit quality and illiquidity in explaining spreads.[9] One notable exception is He and Milbradt (2013), who use a structural model and calibrations to quantify credit and illiquidity components. Our study instead documents a variable, bond return volatility, that has significant explanatory power for the cross-section of yield spreads and quantifies the relative contributions of credit and illiquidity in a purely reduced form framework.

The rest of the paper is organized as follows. In Section 2, we describe our data and methodology. Section 3 documents the relation between yield spreads and bond volatility. Section 4 decomposes the yield spread-bond volatility relation into credit and illiquidity components. Section 5 considers equity volatility and the additional information that bond

[8]See Campbell and Taksler (2003), Bao (2009), Ericsson, Jacobs, and Oviedo (2009), and Zhang, Zhou, and Zhu (2009) among others.

[9]Papers on bond illiquidity typically document that illiquidity variables have a marginal contribution even after controlling for credit quality, but typically make little attempt to quantify the relative contributions to explaining the variation in yield spreads. Papers that look to match credit spreads through new credit risk mechanisms often focus on the level of the Baa-Aaa spread.

volatility provides. In Section 6, we consider a number of sample cuts and portfolio analysis, and Section 7 concludes.

2 Data and Decomposition Methodology

2.1 Data sources

The primary data source for our study is bond pricing data from FINRA's TRACE (Transaction Reporting and Compliance Engine). FINRA, a self-regulatory organization, is responsible for the collection and reporting of over-the-counter corporate bond trades. Previously, FINRA disseminated data in phases, starting on July 1, 2002 with Phase I requiring dissemination of investment-grade securities of $1 billion in face value or greater. Over the course of Phase II and Phase III implementation, reporting was expanded to cover approximately 99% of all public transactions.

Recently, FINRA publicly released an enhanced version of TRACE with a larger cross-section. Furthermore, the enhanced version of TRACE no longer top-codes the par value traded at $1 million for speculative-grade bonds and $5 million for investment-grade bonds. However, this data is reported with an 18 month lag. Thus, we use the enhanced version of TRACE to June 2011 and standard TRACE from July 2011 to December 2012.[10]

We obtain bond characteristics and ratings from Mergent FISD. Industry classifications and equity volatility are determined from CRSP. We use Compustat to calculate a number of accounting ratios. All Compustat-related variables are lagged three months to account for reporting delays in SEC filings. Finally, we use the Constant Maturity Treasury (CMT) series from the U.S. Treasury to determine Treasury yields.

[10]Our analysis is largely cross-sectional as variables are cross-sectionally de-meaned. Hence, the effect of using top-coded data for a subsample should have little effect on our results.

2.2 Sample description

Our initial sample is all corporate bonds that are traded in TRACE, but we impose a number of standard corrections and filters. We keep bonds with at least half a year to maturity and standard coupon intervals (including zero coupon bonds). Bonds issued by financial firms, defined as having a SIC code starting with 6, are dropped as the pricing of such bonds may be different than industrials, particularly in how prices are related to leverage. Bonds with conversion, put, or fixed-price call options are dropped.[11] Bonds without equity information are also dropped as we use CRSP information to determine industry classification. Finally, bonds without a rating are dropped.

Table 1 summarizes the corporate bonds in our sample.[12] The average yield spread in our sample is 2.14%.[13] We have 6,085 bonds in our sample and 194,863 bond-month observations. The average maturity of bonds is 8.62 years, the average face value is $559.18 million. We code Moody's ratings (*Moody_rating*) as 1 for Aaa and 21 for C, with intermediate ratings coded appropriately, and find a mean of 8.39, corresponding to a rating slightly worse than Baa1. These numbers are similar to the broader Mergent FISD reported in Bao and Pan (2013). The average volatility of bond returns calculated using value-weighted bond prices (*Bond_vol*) is 7.86%.[14] Specifically, we take the volume-weighted average of bond prices on the 21st of the month or later and calculate returns as

$$r_{i,t} = \ln\left(\frac{P_{i,t} + AI_{i,t} + C_{i,t}}{P_{i,t-1} + AI_{i,t-1}}\right),$$

where $P_{i,t}$ is the clean price, $AI_{i,t}$ is the accrued interest, and $C_{i,t}$ is the coupon paid (if

[11]We retain bonds with only make whole call options as Powers and Tsyplakov (2008) find that these options have little effect on the yield of a bond.

[12]As bond volatility is a crucial variable in our analysis, we drop all observations for which bond volatility cannot be calculated.

[13]Yield spreads are calculated using the yield based on the volume-weighted average price for all trades on the 21st or later minus a comparable Treasury yield interpolated from the Constant Maturity Treasury series. Results using yields based on the last trade of the month are not materially different.

[14]Using value-weighted prices to calculate returns is important as using month-end prices to calculate volatilities would lead to a mechanical relation between volatility and bid-ask spreads.

any). Bond volatility is then calculated as the annualized volatility of returns over the last 12 months if at least 10 returns are available over the last 12 months.

The average fraction of bond zero-trading days (*Bond_zero*), calculated as business days without trading divided by days when the market, is open is 58.74%. Following Dick-Nielsen, Feldhutter, and Lando (2012), we calculate the *Amihud* and the implied round-trip cost (*IRC*) measures along with their standard deviations as illiquidity proxies. The Amihud measure is calculated by first calculating a daily average price impact measure,

$$\frac{1}{N_t}\sum_{i=1}^{N_t}\frac{|r_i|}{Volume_i},$$

where N_t is the number of trades in a day, r_i is the return of trade i, and $Volume_i$ is the face value of trade i in $mm. A monthly *Amihud* measure is calculated by taking the median over the course of a month. The *IRC* measure is calculated by first taking all cases where the same volume of a bond is traded during a business day and calculating

$$\frac{P_{max}-P_{min}}{P_{max}},$$

and taking the mean over a month. The average *Amihud* and *Amihud_vol* are 0.0115 and 0.0148, respectively, and the average *IRC* and *IRC_vol* are 0.0022 and 0.0025, respectively. We follow Bao, Pan, and Wang (2011) and define γ as

$$\gamma = -Cov(\Delta p_t, \Delta p_{t-1}),$$

the negative covariance of the log price changes in two consecutive periods. The mean and median of γ are 1.51 and 0.46, respectively.

In Table 2, we report summary statistics for the firms corresponding to our corporate bond sample. There are 669 unique firms in our sample. The average of book leverage (*Leverage*), defined as total liabilities divided by total assets, is 0.69, and the median is similar at 0.68. As a measure of operational efficiency, we use *EBITDA/Sales*, defined using Compustat data as OIADP/AT. It has a mean of 0.22. *Interest_coverage* is defined as (OIADP+XINT)/XINT following Blume, Lim, and MacKinlay (1998) and has a mean of 7.31. On average, the free cash flow-to-debt (*FCF/Debt*) and volatility of equity returns (*Equity_vol*) are 0.12 and 27.81%, respectively.

To calculate book-to-market (*Book_to_market*), we follow Asness and Frazzini (2011) and assume that book equity (CEQ) is known three months after the fiscal year end. Market equity is calculated using the most recent equity prices available by taking market equity from Compustat (CSHO×PRCC_F) and adjusting by equity returns without dividends to account for changes in market equity. In our sample, *Book_to_market* has a mean of 0.55. To calculate distance-to-default (*Distance_to_default*), we follow Campbell, Hilscher, and Szilagyi (2008) in jointly solving

$$E = VN(d_1) - Ke^{-rT}N(d_2),$$

and

$$\sigma_E = N(d_1)\frac{V}{E}\sigma_v,$$

for V and σ_v and defining distance-to-default as

$$Distance\_to\_default = \frac{\ln\left(\frac{V}{K}\right) + 0.06 + r_f - \frac{1}{2}\sigma_v^2}{\sigma_v}.$$

The mean *Distance_to_default* in our sample is 8.52.

2.3 Decomposition methodology

We use a coefficient decomposition methodology developed in Hou and Loh (2013) to first quantify the relation between yield spreads and bond volatilities and then to explain this relation through credit quality and illiquidity variables. The main assumption behind the methodology is that bond volatility is a function of a set of candidate variables. Variation in the candidate variables drives part of the variation in bond volatilities, which in turn drives variation in yield spreads. Thus, the methodology is designed to allow the yield spread-bond volatility relation to be attributed to the set of candidate variables. We first estimate panel regressions of bond yield spreads on bond return volatilities:

$$Yield\_spread_{i,t}^{dm} = \rho^{dm} Bond\_vol_{i,t}^{dm} + \epsilon_{i,t}^{dm}. \tag{1}$$

We use cross-sectionally demeaned variables indicated by the superscript dm in order to focus on the cross-sectional relation between yield spreads and bond volatility. $Yield\_spread_{i,t}^{dm}$ denotes the yield spread of a bond and $Bond\_vol_{i,t}^{dm}$ is its return volatility. ρ^{dm} measures the cross-sectional relation between yield spreads and bond volatility. In our baseline regressions, the estimated ρ^{dm} is 0.202 with a t-value of 9.66 (see Table 3). This positive relation between yield spreads and bond volatility is robust when we control for a number of illiquidity and credit risk measures.

Next, we regress $Bond\_vol_{i,t}^{dm}$ on a candidate explanatory variable ($Candidate_{i,t}^{dm}$):

$$Bond\_vol_{i,t}^{dm} = \delta^{dm} Candidate_{i,t}^{dm} + \mu_{i,t}^{dm}. \tag{2}$$

This regression allows us to assess the cross-sectional relation between bond volatility and the candidate variable using demeaned variables. As noted by Hou and Loh (2013), any candidate variable that can potentially explain the relation between yield spreads and bond volatilities should be correlated with bond volatilities.[15] We then use the regression coefficient estimates to decompose $Bond\_vol_{i,t}^{dm}$ into two orthogonal components: (1) $\delta^{dm} Candidate_{i,t}^{dm}$ is the component of $Bond\_vol_{i,t}^{dm}$ that is related to the candidate variable, and (2) $\mu_{i,t}^{dm}$ is the

[15] A high correlation with bond volatility does not guarantee that the candidate variable can explain a large fraction of the yield spread-bond volatility relation because the part of bond volatility that is related to the candidate variable may not be the part that is responsible for the relation between yield spread and bond volatility. See Hou and Loh (2013) for more detailed discussion.

residual component that is unrelated to the candidate variable.

Finally, we use the linearity of covariance to decompose ρ^{dm} estimated from Equation (1) into two components given by:

$$\begin{aligned}
\rho^{dm} &= \frac{Cov(Yield_spread^{dm}_{i,t}, Bond_vol^{dm}_{i,t})}{Var(Bond_vol^{dm}_{i,t})} \\
&= \frac{Cov(Yield_spread^{dm}_{i,t}, \delta^{dm} Candidate^{dm}_{i,t} + \mu^{dm}_{i,t})}{Var(Bond_vol^{dm}_{i,t})} \\
&= \frac{Cov(Yield_spread^{dm}_{i,t}, \delta^{dm} Candidate^{dm}_{i,t})}{Var(Bond_vol^{dm}_{i,t})} + \frac{Cov(Yield_spread^{dm}_{i,t}, \mu^{dm}_{i,t})}{Var(Bond_vol^{dm}_{i,t})} \\
&= \rho^{C,dm} + \rho^{R,dm},
\end{aligned} \tag{3}$$

where $\rho^{C,dm}$ divided by ρ^{dm} measures the fraction of the relation between yield spreads and bond volatility explained by the candidate variable, and $\rho^{R,dm}$ divided by ρ^{dm} measures the fraction of the relation unexplained by the candidate variable. Due to the potentially persistent nature of yield spreads and the potential for underestimating standard errors using conventional methods, we determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011).[16]

3 Yield Spreads and Bond Return Volatilities

In this section, we document the relation between yield spreads and bond return volatilities and control for a number of prominent illiquidity and credit risk measures. We include *Amihud*, *Amihud_vol*, *IRC*, and *IRC_vol*, the four illiquidity variables advocated by Dick-Nielsen, Feldhutter, and Lando (2012), γ, a robust illiquidity measure from Bao, Pan, and Wang (2011), and *Bond_zero*, a traditional measure of illiquidity used in the bond literature and adapted from the international equity literature. Our credit variables include accounting variables (*Leverage*, *Interest_coverage*, *FCF/Debt*, and *EBITDA/Sales*), Moody's ratings (which

[16]See Appendix B for a more detailed discussion.

are largely based on accounting variables), and market-based measures (*Book_to_market* and *Distance_to_default*).

In Table 3, we present the estimation results of regressions of bond yield spread on *Bond_vol* and illiquidity and credit risk measures using 78,948 bond-month observations.[17] The relation between bond yield spread and *Bond_vol* is positive and both statistically and economically significant. The estimated coefficient on *Bond_vol* is 0.202, and the t-value is 9.66. A one standard deviation increase in *Bond_vol* is associated with an increase of 1.34 percentage points in bond yield spreads, which is 63% of the overall mean of yield spread in our sample. Based on the adjusted R^2, bond return volatilities can explain 35.4% of the cross-sectional variation in bond yield spreads. The pricing-relevant information in bond volatilities goes beyond the information contained in equity volatilities as bond volatility remains statistically and economically significant even after controlling for equity volatility.

When we control for illiquidity measures one at a time, we find that the coefficient of *Bond_vol* remains significantly positive at the 1% confidence level with a t-value ranging from 9.30 to 10.46 and an adjusted R^2 ranging from 0.354 to 0.392. The illiquidity measures are largely positive and strongly significant, consistent with previous literature. The one exception is *Bond_zero*,which has an insignificant relation with yield spreads.[18] Controlling for all six illiquidity measures, we continue to find a strong and robust relation between yield spreads and bond return volatilities. After we include credit controls, bond return volatility continues to be significant, with a minimum t-stat of 7.49 across all of our specifications. *Moody_rating* and *Book_to_market* are the two particularly powerful credit proxies in explaining the cross-section of yield spreads. When included alone with bond return volatility, the variables increase the adjusted R^2 to 52.8% and 47.8%, respectively. Our evidence suggests that while ratings are a powerful variable in explaining yield spreads, market-based informa-

[17]The number of observations is 78,948 for every regression in Table 3 because we require bond volatility, illiquidity measures, and credit risk measures to be available for all regressions. The results are robust if we require only variables in each regression to be available.

[18]This contrasts the emerging equity literature where zero returns are a good proxy for illiquidity and predict future returns. See Bekaert, Harvey, and Lundblad (2007).

tion as simple as a *Book_to_market* ratio provides significant additional explanatory power.[19] Furthermore, we find that a linear model including *Bond_vol*, *Equity_vol*, γ, *Moody_rating*, and *Book_to_market* can explain close to 63% of the variation in yield spreads, suggesting that a linear model with five characteristics can explain a significant amount of the cross-sectional variation in corporate bond prices.

Though much of the corporate bond literature focuses on yield spreads rather than expected returns, we also consider the relation between expected bond returns and bond volatility. The disconnect between yields and expected returns comes from the fact that yields are *promised* returns. The gap between the two arises from the fact that expected returns may be much lower than promised returns if a bond issuer has a large probability of default. Alternatively, yields can be thought of as a normalized measure of corporate bond prices. Prices are functions of both the expected returns and the expected cash flows. By using yields rather than expected returns, we are able to capture both components of prices. As bond volatility potentially contains information about both default rates (which affect expected cash flows) and expected returns, the yield spread-bond volatility relation should be stronger than the expected return-bond volatility relation. Indeed, we find that while there is a statistically and economically significant relation between expected excess returns and bond volatility, this relation is smaller than the yield spread-bond volatility relation. In particular, the coefficient on *Bond_vol* is 0.134 when expected returns are the dependent variable, compared to 0.202 when yield spreads are the dependent variable.[20]

4 Decomposing the Price-Risk Relation

Bond volatility is a consequence of both the credit risk of the underlying bond issuer and of the illiquidity of the underlying bond. Bonds with high credit risk have greater exposure to

[19]This result is also consistent with Bao and Hou (2013), who find that book-to-market has power to explain corporate bond-equity comovement within ratings.

[20]For details of this analysis, including the construction of expected returns, see Appendix A.

shocks in underlying firm value,[21] leading to larger return volatilities. Greater illiquidity is also associated with larger return volatilities as shown in Bao and Pan (2013). In this section, we apply the methodology described in Section 2.3 to decompose the yield spread-bond volatility relation into credit risk and illiquidity components. Importantly, the methodology not only shows that both credit risk and illiquidity are important determinants of this relation but also allows us to quantify their relative contributions.

4.1 Illiquidity measures

Table 4 reports the results of the decomposition of the yield spread-bond volatility relation using illiquidity measures. To illustrate the methodology of the decomposition, we discuss the univariate results using γ as an example. In Stage 1, we regress bond yield spreads on bond return volatilities, finding a coefficient of 0.2204,[22] with a p-value of 0.000. The 5th and 95th percentile of the bootstrap estimates are 0.158 and 0.314, respectively, and the adjusted R^2 is 37.46% with the 5th and 95th percentiles of 33.15% and 43.90%, respectively.

In Stage 2, we add γ to the first stage panel regression. The estimated coefficient on γ is 0.0015 with a p-value of 0.000. An increase in γ of 1.067, which is roughly the interquartile range in the sample for this regression, is associated with an increase in yield spreads of approximately 16 basis points. These numbers are consistent with Bao, Pan, and Wang (2011) who find that γ captures an illiquidity effect and thus yield spreads are positively related to γ. Even controlling for γ, the estimated coefficient of *Bond_vol* is still positive and statistically significant (=0.1869, p-value=0.000) and that the adjusted R^2 of the regression is 43.81%. In Stage 3, we estimate the relation between *Bond_vol* and γ in a cross-sectional regression of *Bond_vol* on contemporaneous γ. The estimated coefficient of γ is 0.0054 with a p-value of 0.000 and an adjusted R^2 of 11.99%.

[21] See Bao and Hou (2013) for further discussion.

[22] This coefficient is different from that of Table 3 because we require available only Yield_spread, Bond_vol, and γ in this regression while we require available Yield_spread, Bond_vol and all six illiquidity measures in Table 3. For the same reason, the number of observations in this regression is 136,230 while the number of observations in Table 3 is 78,948.

Finally, in Stage 4, we decompose the Stage 1 coefficient of *Bond_vol* into two components: one related to γ ($\rho^{\gamma,dm}$) and the other related to the residual ($\rho^{R,dm}$). The coefficient of $\rho^{\gamma,dm}$ is 0.0559 with a p-value of 0.000. The coefficient of ρ^R is 0.1645 with a p-value of 0.000. The sum of $\rho^{\gamma,dm}$ and $\rho^{R,dm}$ equals to the Stage 1 coefficient of *Bond_vol*, 0.2204, by construction. Therefore, the relative contribution of γ in explaining the yield spread-bond volatility relation is 25.36% ($=\rho^{\gamma,dm}/\rho$=0.0559/0.2204, with a p-value of 0.000 and the 5th and 95th percentiles of 20.03% and 29.18%, respectively), and the relative contribution of residual is 74.64%, with a p-value of 0.000 and 5th and 95th percentiles of 70.82% and 79.97%, respectively). This analysis shows that γ can explain a substantial fraction of the yield spread-bond volatility relation. This analysis is consistent with both Bao, Pan, and Wang (2011) who show that γ is an important determinant of corporate bond yield spreads and Bao and Pan (2013) who find that illiquidity is an important determinant of bond return volatility.[23]

Applying the same decomposition methodology, we examine the other five illiquidity measures (*Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, and *Bond_zero*), finding results that are qualitatively similar to γ with the exception of *Bond_zero*, which is related to neither yield spreads, nor bond volatility. In Panel B, we consider a multivariate decomposition allowing us to both gauge the aggregate explanatory power of the illiquidity variables and to determine whether the explanatory power of illiquidity can be captured largely by a single proxy. While the first stage analysis is still a regression of yield spreads on bond volatilities, bond volatilities are now assumed to be a function of all six illiquidity measures. With the exception of *Bond_zero*, all of the illiquidity variables are positively related to *Bond_vol* in a multivariate regression framework, consistent with *Bond_vol* capturing some component of illiquidity.

In Stage 4 of the multivariate analysis, we are able to attribute the yield spread-bond volatility relation to the set of variables, finding that in aggregate, the six illiquidity proxies can explain almost 40% of the relation. More than half of the relation is attributable to the γ measure from Bao, Pan, and Wang (2011). The four primary measures from Dick-Nielsen,

[23]Importantly, ρ^{γ} is only significant if γ can explain *Bond_vol* and the part of γ that can explain *Bond_vol* is also correlated with yield spreads.

Feldhutter, and Lando (2012) contribute an additional 18%, with the implied round-trip cost measure from Feldhutter (2012) providing the largest contribution at 8.40%. Overall, our results suggest that different illiquidity measures explain different components of the yield spread-bond volatility relation. It is clear, however, that illiquidity is an important component of this relation.

4.2 Credit risk measures

Table 5 reports the decomposition results using credit risk measures. Panel A illustrates the results of univariate analysis, and Panel B shows the results of multivariate analysis. In Panel A, the adjusted R^2s of Stage 3 show that *Moody_rating* is strongly related to *Bond_vol* (adjusted R^2=18.69%) while the other four credit risk measures (i.e., *Leverage*, *Interest_coverage*, *FCF/Debt*, and *EBITDA/Sales*) are relatively weakly related to *Bond_vol* with adjusted R^2 values of around 2%. The results of Stage 4 show that *Moody_rating* explains 42.74% of the yield spread-bond volatility relation. This fraction is far larger than the fraction explained by any of the four accounting-based measures, all of which explain less than 8%. Compared to the univariate analysis of illiquidity measures in Table 4, we find that *Moody_rating* not only dominates other credit risk measures but also explains a higher fraction of the yield spread-bond volatility relation than any of the illiquidity measures.[24] The two market-based credit measures, *Distance_to_default* and *Book_to_market*, are also able to explain a large proportion of the yield spread-volatility relation at 15.49% and 27.82%, respectively. This suggests that measures based on aggregating market information are potentially useful.

Panel B presents the multivariate analysis that uses seven credit risk measures. The fraction explained by *Moody_rating* drops to 35.23%. In unreported results, we find that this modest drop is related to the including of *Book_to_market* as the inclusion of only accounting-based credit risk measures has no material effect on *Moody_rating*. The fraction explained

[24]The illiquidity measures, however, are more important than the other four accounting-based credit risk measures in explaining the yield spread-bond volatility relation.

by the four accounting-based measures account for an economically insignificant total of -0.99% of the yield spread-bond return volatility relation. *Book_to_market* retains most of its economic significance in the multivariate analysis, dropping from 27.82% to 23.52%, while the contribution of *Distance_to_default* becomes small and negative. Overall, the total contribution of credit variables is approximately 54%. Furthermore, our analysis shows that while *Moody_rating* is a good proxy for accounting-based credit risk, adding a market-based variable such as *Book_to_market* can significantly improve our understanding of the yield spread-bond volatility relation.

To directly compare all illiquidity measures and credit risk measures, we conduct a decomposition that uses both illiquidity and credit risk measures and report the results in Table 6. Consistent with the multivariate analysis in Panel B of Tables 4 and 5, we find that *Moody_rating* continues to be a leading variable in explaining the yield spread-bond volatility relation: the fraction explained is 37.63%. *Book_to_market* contributes another 18.01% as the top two credit variables provide virtually all of the credit contribution. On the illiquidity side, γ provides 10.12%, while the four illiquidity variables advocated by Dick-Nielsen, Feldhutter, and Lando (2012) provide 10.19% in aggregate. Thus, while γ is the strongest illiquidity variable in explaining the yield spread-bond volatility relation, other illiquidity variables continue to contribute. The residual term explains only 28.42% of the yield spread-bond volatility relation, suggesting that our set of illiquidity and credit proxies is able to capture most of the yield spread-bond volatility relation.

The multivariate analysis allows us to quantify the relative contribution of illiquidity and credit risk in explaining the yield spread-bond volatility relation. The total fraction explained by all illiquidity measures is 20.99%, and the total fraction explained by all credit risk measures is 50.59%. These results suggests that both credit risk and illiquidity variables are important and that credit risk measures are relatively more important than illiquidity measures: credit risk and illiquidity measures contribute to the relation in approximately a 70:30 ratio.

5 Comparing Measures of Volatility

To better understand the explanatory power of volatility for yield spreads, we consider equity volatility as an alternative volatility measure. In addition, we consider the additional explanatory power that bond volatility has above and beyond equity volatility.

5.1 Alternative volatility measure: Equity Volatility

Previous literature, starting with Campbell and Taksler (2003), finds a significant relation between equity volatility and credit spreads. From the perspective that equity volatility is a market-based measure that incorporates both a firm's leverage and its underlying asset volatility, this relation reflects the fact that equity volatility is a good summary statistic of a firm's credit quality. This credit spread-equity volatility relation has been shown to be robust for corporate bonds by Cremers, Driessen, Maenhout, and Weinbaum (2008) and Rossi (2013) and for CDS by Ericsson, Jacobs, and Oviedo (2009) and Zhang, Zhou, and Zhu (2009). Furthermore, many studies of the illiquidity of corporate bonds (e.g. Bao, Pan, and Wang (2011)) have used equity volatility as a credit control and have found a significant positive relation between yield spreads and equity volatility.

Here, we consider equity volatility as an alternative measure of return volatility both because it has been shown to be an important determinant of yield spreads and because it provides a simple sanity check of our decomposition. Unlike bond volatility, there is no direct relation between equity volatility and illiquidity. Indirectly, the two variables may be related because firms with poorer credit quality tend to have higher equity volatility and their bonds tend to be less liquid. Thus, we would expect the vast majority of the yield spread-equity volatility relation to be explained by credit variables rather than illiquidity proxies.

In Table 7, we report the results of the decomposition of the yield spread-equity volatility relation. Consistent with the previous literature, we find a positive and significant relation between yield spreads and equity volatility. Over 30% of the cross-sectional variation in yield spreads can be explained by equity volatility alone. Stage 3 of the decomposition shows that equity volatility has significant relations with most of the candidate variables, including a positive relation with proxies for illiquidity. However, the most economically significant variables are *Moody_rating* and *Book_to_market*, the strongest credit proxies in our previous analysis along with *Distance_to_default*. A one notch decrease in credit quality (an increase in our variable of 1 as better ratings are coded as lower numbers) is associated with an increase in equity volatility of 1.34 percentage points. An increase in *Book_to_market* of 0.41, roughly the interquartile range in the sample for this regression, is associated with an increase in equity volatility of 3.5 percentage points while an increase in *Distance_to_default* of 4.63 is associated with a decline in equity volatility of approximately 8.1 percentage points.

Finally, in Stage 4, we attribute the yield spread-equity volatility relation to our series of credit quality and illiquidity variables, finding that *Moody_rating*, *Book_to_market*, and *Distance_to_default* each contribute approximately to 26% of the yield spread-equity volatility relation, accounting for virtually all the explanatory power of our variables. In contrast to the yield spread-bond volatility relation where the relative credit-to-illiquidity contribution ratio is 70:30, the ratio here is closer to 90:10, suggesting that the relation between yield spreads and equity volatility documented in the literature is largely attributable to credit risk.

5.2 Marginal contribution of bond volatility

Thus far, our analysis on the relation between yield spreads and volatility has focused on univariate regressions. The yield spread-bond volatility relation is driven by both credit risk and illiquidity while the yield spread-equity volatility relation is driven almost solely by credit risk. While yield spreads are related to bond volatility even after controlling for equity volatility, a natural question is whether this marginal contribution is due solely to the additional information it contains about illiquidity. If not, is the credit component economically significant? Answering this question requires a decomposition of the bond volatility coefficient in a regression of

$$Yield\_spread_{i,t}^{dm} = \rho_1^{dm} Bond\_vol_{i,t}^{dm} + \rho_2^{dm} Equity\_vol_{i,t}^{dm} + \epsilon_{i,t}^{dm},$$

where the goal is to decompose ρ_1^{dm}. Though the Hou and Loh (2013) methodology is designed to decompose coefficients in univariate regressions, it is easily adaptable to this setting by first running a regression to orthogonalize bond volatility to equity volatility

$$Bond\_vol_{i,t}^{dm} = \theta^{dm} Equity\_vol_{i,t}^{dm} + \nu_{i,t}^{dm}.$$

The Hou and Loh (2013) decomposition can then be used on the following univariate regression

$$Yield\_spread_{i,t}^{dm} = \rho_1^{dm} \nu_{i,t}^{dm} + \zeta_{i,t}^{dm}.$$

Results of the decomposition of the yield spread-orthogonalized bond volatility relation are presented in Table 8. First, we find that yield spreads are both economically and statistically related to orthogonalized bond volatility. An increase in orthogonalized bond volatility of 5 percentage points is associated with a 71.75 basis point increase in yield spreads. This result is consistent with the fact that equity volatility has an economically small relation with illiquidity. Thus, partialling out equity has a minimal effect on the part of yield spread-bond volatility relation that is due to illiquidity. The effect on the credit part of the relation, however, is an empirical question.

We find that 33.79% of the yield spread-orthogonalized bond volatility relation is explained by illiquidity and 34.86% is due to credit.[25] This nearly 50:50 ratio contrasts with

[25] The total contribution of credit variables is largely from *Moody_rating*, *Book_to_market*, and *Distance_to_default*, which contribute 44.69%, 23.71%, and -39.49%, respectively. The extremely negative contribution of distance-to-default is due to how ratings, book-to-market, and distance-to-default are correlated. Re-running the analysis with *Distance_to_default* dropped, we find the contributions of *Moody_rating* and *Book_to_market* to be 17.77% and 12.57%, respectively. The total contribution of credit variables is 29.17%.

the 70:30 credit-to-illiquidity ratio in the yield spread-bond volatility relation. The magnitude of the coefficient explained by illiquidity is 0.0485 as compared to 0.0424 for the yield spread-bond volatility relation. Overall, our results suggest that while controlling for equity volatility weakens the part of the yield spread-bond volatility relation due to credit (and does not materially affect the part due to illiquidity), bond volatility still adds additional pricing-relevant credit information above and beyond equity volatility.

6 Subsample and Portfolio Analysis

6.1 Subprime crisis

From Bao, Pan, and Wang (2011), Dick-Nielsen, Feldhutter, and Lando (2012), and Friewald, Jankowitsch, and Subrahmanyam (2012), it is well-known that both corporate bond market liquidity and credit quality deteriorated and yield spreads spiked during the subprime mortgage crisis. Though these papers attribute a substantial part of the spike in yield spreads to the contemporaneous spike in illiquidity, the effect on the yield spread-bond volatility relation is less clear. While illiquidity tends to be correlated with return volatility, the relation may become weaker in periods of persistent illiquidity. Feldhutter (2012) argues that there were persistent price pressures during the crisis. Thus, whether the yield spread-bond volatility relation changed in the crisis remains an empirical question. To address this issue, we split our sample into three periods, with pre-crisis defined as the period up to March 2007, the crisis period as April 2007 to June 2009, and the post-crisis period as July 2009 onwards.

Table 9 presents the decomposition results with multivariate analysis. The general conclusions are the same across periods as for the full sample. Yield spreads and bond return volatilities are significantly related across periods and the most important variables in explaining this relation are *Moody_rating* and *Book_to_market*. Among the illiquidity variables, γ is the most important, though it does not drive out the other illiquidity variables. The relative contributions of credit and illiquidity are roughly 70:30 in all periods, though the ratio is somewhat higher during the subprime crisis.

One notable difference across periods is the spike in importance of *Book_to_market*. Prior to and after the subprime crisis, the contributions of *Book_to_market* are 13.84% and 9.33%. During the crisis, the contribution of *Book_to_market* spikes to 30.31%. This suggests that during periods of high credit risk, it is particularly important to account for market-based credit risk proxies.

6.2 Time-to-maturity

Dick-Nielsen, Feldhutter, and Lando (2012) find that the liquidity component – the difference in bond yields between a bond with average liquidity and a very liquid bond – increases with the maturity. Thus, we classify the bonds into short- (less than 2 years), medium- (2-5 years), and long-term maturity (5-30 years) and use the value-weighted bond volatility to examine the relative contributions of illiquidity and credit risk in explaining the yield spread-bond volatility relation.

In Table 10, we present decomposition results for each of the three maturity groups. γ continues to be the strongest illiquidity variable in explaining the yield spread-bond volatility relation while *Moody_rating* and *Book_to_market* provide the strongest explanatory power among the credit variables. We also find that the relative contribution of credit-to-illiquidity increases from 68:32 for short maturities to 83:17 for long maturities. Much of this additional contribution for credit comes from the additional importance of ratings in explaining the yield spread-bond volatility relation.

6.3 Investment grade bonds

As noted by Huang and Huang (2012), a larger proportion of yield spreads is due to fundamental credit risk for bonds with poorer ratings. As a further test, we classify the bonds into investment- and speculative-grade bonds based on Moody's ratings. Bonds with a rating of at least Baa3 are classified as investment-grade bonds, while the bonds with ratings lower than Baa3 are classified as speculative-grade bonds. Table 11 shows the multivariate decomposition results. With explanatory power of 13.30%, 9.98%, and 11.90%, respectively, *Moody_rating*, *Book_to_market*, and γ are still the three most important variables for investment bonds. Among the illiquidity variables, the four Dick-Nielsen, Feldhutter, and Lando (2012) variables provide another 16.21% in explanatory power. For the credit variables, only *Moody_rating* and *Book_to_market* provide both economically and statistically significant explanatory power for the yield spread-bond volatility relation. The total contribution of the six illiquidity measures is 28.22%, and the total contribution of the seven credit risk measures is 26.27%, leaving 45.51% unexplained by illiquidity and credit risk measures.

When we move to the speculative bonds, γ is still an important variable with a contribution of 10.22%, similar in magnitude to the investment grade subsample. In contrast, both *Moody_rating* and *Book_to_market* become much more economically significant than in the investment grade subsample, increasing from 13.30% to 26.82% and 9.98% to 18.49%, respectively. The total contribution of illiquidity and credit are 22.60% and 50.76%, respectively. Our results are consistent with Huang and Huang (2012), who argue that the relative importance of credit risk in bond pricing increases as credit quality decreases.

6.4 Portfolios sorted by bond volatility

Though the primary focus of our paper is to understand the cross-section of yield spreads at the bond-level, individual variables can be measured with errors, particularly because bond volatility and some candidate variables are generated regressors. To examine the robustness of our results to measurement error, we conduct a robustness check by sorting bonds into portfolios by individual bond volatility and then averaging yield spreads, bond volatilities, and candidate variables at the portfolio level. If the variables are not measured accurately at the individual bond level, using portfolio averages can potentially improve the precision of the estimates because errors could offset each other within a portfolio.

Each month, we sort individual bonds into 100 portfolios by bond volatility and calculate the weighted average of each variable within each portfolio using the amount outstanding as the weight.[26] We then conduct decomposition analysis using the portfolio-level variables and report the results in Table 12. In Stage 1, the portfolio average bond volatility is positively and significantly related to the portfolio yield spread. A one standard deviation increase in the portfolio average bond volatility (7.34%) is associated with an increase of 1.65% in the portfolio bond yield spread, which is comparable to the mean portfolio bond yield spread, 2.10%. Portfolio average bond volatilities alone can explain 54.22% of the cross-sectional variation in portfolio bond yield spreads, which is higher than the individual bond-level analysis (R^2=35.4%), indicating that the relation between yield spread and bond volatility is stronger when both variables are more accurately measured.

The results of Stage 2 show that after controlling for portfolio candidate variables, the portfolio average bond volatility is still positively related to the portfolio yield spread, and the magnitude of the coefficient on portfolio average bond volatility is smaller than that in Stage 1. The drop in the coefficient on portfolio average bond volatility is larger than the drop in the coefficient on individual bond volatility when controlling for candidate variables in Table 6, which suggests that the candidate variables can better capture the relation between yield spread and bond volatility when measured more accurately at the portfolio level.

Stage 3 of the portfolio analysis shows that *Amihud_vol*, *IRC*, and γ are positively related to bond volatility among the six illiquidity variables, and *Moody_rating*, *Leverage*, *EBITDA/Sales*, and *Book_to_market* are positively related to bond volatility among the seven credit quality variables. These results are consistent with those from the individual-bond analysis. The R^2 in the regression is close to 70%, indicating that bond volatility is very much a variable that aggregates credit risk and illiquidity information.

The decomposition results in Stage 4 show that the total fraction of the relation between

[26] We choose 100 portfolios because this number of portfolios can offer a good trade-off between loss of information and measurement errors in the sense that it allows us both to retain the information in the variables, especially in the cross-section, and to examine how measurement errors affect our results. We also use equal-weighted portfolios, and the results are similar.

yield spread and bond volatility explained by both illiquidity and credit quality variables is 95.81%, suggesting that the candidate variables can explain most of the relation at the portfolio level. Illiquidity variables can explain 31.22% of the relation, and credit quality variables can explain 64.59% of the relation. The credit-to-illiquidity ratio (67:33) is marginally lower than the 70:30 for individual bonds.

In sum, the results in Table 12 confirm that our primary results are robust to using portfolios sorted by bond volatility and to the concern of measurement error at the individual bond level.

7 Conclusion

We document a strong positive relation between corporate bond yield spreads and corporate bond return volatility in the cross-section. In particular, a one standard deviation increase in bond volatility is associated with a 1.34 percentage point increase in the yield spread. Furthermore, the relation between yield spreads and bond volatilities is robust to the inclusion of equity volatility, a variable that has been shown in the literature to have significant explanatory power for yield spreads. Our results highlight a negative relation between risk (as measured by volatilities) and prices, in contrast to the equity literature where an anomalously positive relation between prices and volatilities has been extensively documented.

As the yield spread-bond volatility relation can be due to either credit risk or illiquidity, we use a methodology developed by Hou and Loh (2013) to decompose the magnitude of this relation. Using six proxies for illiquidity, including those advocated in the recent bond illiquidity literature, and seven credit risk proxies, we find that our proxies can explain close to 72% of the yield spread-bond volatility relation. Importantly, this methodology also allows us to quantify the relative contributions of credit and illiquidity to the magnitude of the yield spread-bond volatility relation at 70:30.

To better understand the yield spread-bond volatility relation, we also explore the yield spread-equity volatility relation in more detail. Based on structural models of default, bond and equity volatility are both related to a firm's underlying asset volatility. As asset volatility is an important determinant of credit quality, this implies that both bond and equity volatility may be measures of a firm's credit quality. We verify the positive relation between yield spreads and equity volatilities and document that the relation is largely due to credit risk, with illiquidity providing a negligible contribution. Furthermore, we document that the relation between yield spreads and bond volatility still contains a credit component even after controlling for equity volatility. This implies that bond volatility is important both because of its illiquidity component and its additional credit information.

Finally, we perform a series of additional tests on subsamples to test the strength of the price-volatility relation for different periods of time and different bond characteristics. Our results are similar during the pre-crisis, crisis, and post-crisis periods, with bond volatility continuing to have a strong relation with yield spreads and credit and illiquidity explaining this relation in an approximately 70:30 ratio. The relation between yield spreads and bond volatility tends to be stronger at short to medium maturities and for speculative grade bonds. Overall, our results suggest that bond volatility is a good metric for the risk of corporate bonds and their associated prices because bond volatility contains elements of the two most critical determinants of corporate bond pricing, credit and illiquidity.

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Appendix

A Expected Returns

As described in Hou, van Dijk, and Zhang (2012), ex post realized equity returns are a noisy measure of ex ante expected returns. This issue is potentially even more problematic in studying corporate bonds, where the sample is shorter and returns are more skewed. Thus, in the spirit of Campello, Chen, and Zhang (2008) and Bongaerts, de Jong, and Driessen (2011), we calculate default-adjusted yields as measures of ex ante expected returns. Suppose that a firm has a default intensity of λ and a default arrival time that follows an exponential distribution.[27] Denote the required rate of return to be r_D and the recovery rate to be R. The price of a corporate bond issued by the firm with maturity T is

$$\begin{aligned} B &= \underbrace{\sum_{t=1}^{2T} e^{-0.5t(r_D+\lambda)}\frac{c}{2}}_{\text{Coupons}} + \underbrace{e^{-T(r_D+\lambda)}}_{\text{Face value}} + \underbrace{\sum_{t=1}^{2T} Re^{-0.5tr_D}\left(e^{-0.5(t-1)\lambda} - e^{-0.5t\lambda}\right)}_{\text{Recovery}} \\ &= \frac{c}{2}\left(\frac{1-e^{-T(r_D+\lambda)}}{e^{0.5(r_D+\lambda)}-1}\right) + e^{-T(r_D+\lambda)} + R\left(e^{0.5\lambda}-1\right)\left(\frac{1-e^{-T(r_D+\lambda)}}{e^{0.5(r_D+\lambda)}-1}\right) \\ &= \left(R\left(e^{0.5\lambda}-1\right)+\frac{c}{2}\right)\left(\frac{1-e^{-T(r_D+\lambda)}}{e^{0.5(r_D+\lambda)}-1}\right) + e^{-T(r_D+\lambda)} \end{aligned} \tag{4}$$

Thus, the price of a bond paying a semi-annual coupon of $\frac{c}{2}$ with a recovery of R is the same as a bond paying a semi-annual coupon of $R(e^{0.5\lambda}-1)+\frac{c}{2}$ with a recovery of 0. It can also be shown that the yield of a bond with a zero recovery is

$$y^* = r_D + \lambda \tag{5}$$

For the bond with non-zero recovery, the yield is less than y^* due to the fact that the coupon is smaller than for the zero recovery bond. However, we can write down the relation between bond price and yield as

$$B = \tilde{c}\left(\frac{1-e^{-Ty}}{e^{0.5y}-1}\right) + e^{-Ty}, \tag{6}$$

and calculate the sensitivity of the coupon rate to the yield as $\frac{\partial\tilde{c}}{\partial y}$, where $\tilde{c}$ is the semi-annual coupon rate. The yield on the zero recovery bond can then be linearly approximated by

$$y^* = y + R(e^{0.5\lambda}-1)/\frac{\partial\tilde{c}}{\partial y}, \tag{7}$$

where y is the yield on the non-zero recovery bond. To test the robustness of our methodology, we also compute expected returns following Bongaerts, de Jong, and Driessen (2011). The main assumption in their methodology is to collapse a coupon-paying bond into a zero

[27] We estimate λ by fitting to historical Moody's default rates by rating.

coupon bond whereas we explicitly account for coupons, but use a first-order approximation for the relation between yields and coupons. Though the simplifying assumptions used in the two methodologies are different, we find that their outputs are very highly correlated. While it is common in the equity literature to subtract off the risk-free rate from expected returns, we continue to subtract off the yield of a Treasury bond with similar maturity. We do this for two reasons. First, this makes the results here more easily compared with our main results. Second, subtracting off the risk-free rate makes our results susceptible to being driven by term structure effects.

In Table A.1, we present decomposition results that correspond to Table 6 in the paper. We find that the relation between bond volatility and expected excess returns is economically and statistically significant. Both the coefficient and R^2 are smaller than when yield spreads are used, reflecting the fact that yield capture both expected returns and expected cash flows. Since bond volatility is related to both, its relation to yield spreads is stronger than its relation to expected excess returns. We also find that the relative contribution of credit-to-illiquidity in explaining the expected excess return-bond volatility relation is 55:45.

Table A.1: Multivariate Analysis of the Relation between Expected Bond Return and Bond Volatility

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress expected return on bond volatility	Bond_vol	0.1339	(0.000)	[0.084, 0.199]
		Adjusted R2	19.18%		[14.21%, 27.25%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.0668	(0.000)	[0.047, 0.106]
		Amihud	0.0391	(0.120)	[-0.012, 0.094]
		Amihud_vol	0.0227	(0.180)	[-0.017, 0.047]
		IRC	0.7380	(0.000)	[0.325, 1.219]
		IRC_vol	-0.4163	(0.007)	[-0.611, -0.077]
		γ	0.0013	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0013	(0.058)	[-0.003, 0.000]
		Moody_rating	0.0002	(0.290)	[-0.000, 0.001]
		Leverage	0.0256	(0.018)	[0.002, 0.042]
		Interest_coverage	-0.0000	(0.352)	[-0.000, 0.000]
		FCF/Debt	0.0111	(0.000)	[0.007, 0.013]
		EBITDA/Sales	0.0024	(0.087)	[-0.000, 0.004]
		Distance_to_default	0.0005	(0.152)	[-0.000, 0.001]
		Book_to_market	0.0234	(0.000)	[0.007, 0.033]
		Adjusted R2	38.65%		[28.18%, 47.49%]
3	Regress on candidate variables	Amihud	0.0254	(0.376)	[-0.114, 0.184]
		Amihud_vol	0.3177	(0.000)	[0.237, 0.387]
		IRC	2.8333	(0.000)	[1.423, 3.773]
		IRC_vol	1.1315	(0.001)	[0.457, 1.719]
		γ	0.0035	(0.000)	[0.002, 0.008]
		Bond_zero	-0.0269	(0.001)	[-0.033, -0.019]
		Moody_rating	0.0074	(0.000)	[0.005, 0.010]
		Leverage	0.0606	(0.000)	[0.034, 0.084]
		Interest_coverage	0.0007	(0.000)	[0.000, 0.001]
		FCF/Debt	-0.0035	(0.477)	[-0.014, 0.011]
		EBITDA/Sales	0.0284	(0.000)	[0.019, 0.037]
		Distance_to_default	0.0010	(0.018)	[0.000, 0.002]
		Book_to_market	0.0356	(0.000)	[0.024, 0.046]
		Adjusted R2	32.16%		[29.25%, 36.16%]
4	Decompose first-stage Coefficient	Amihud	0.0003	(0.376)	[-0.001, 0.003]
		Amihud percentage	0.19%	(0.376)	[-0.71%, 2.16%]
		Amihud_vol	0.0049	(0.000)	[0.003, 0.008]

Amihud_vol percentage	3.64%	(0.000)	[2.81%, 4.96%]
IRC	0.0067	(0.000)	[0.003, 0.013]
IRC percentage	5.04%	(0.000)	[2.60%, 7.62%]
IRC_vol	0.0026	(0.001)	[0.001, 0.005]
IRC_vol percentage	1.94%	(0.001)	[0.85%, 3.09%]
γ	0.0184	(0.000)	[0.010, 0.028]
γ percentage	13.77%	(0.000)	[10.73%, 16.43%]
Bond_zero	0.0006	(0.119)	[-0.000, 0.002]
Bond_zero percentage	0.47%	(0.119)	[-0.13%, 1.70%]
Moody_rating	0.0321	(0.000)	[0.019, 0.046]
Moody_rating percentage	23.93%	(0.000)	[17.48%, 31.01%]
Leverage	0.0033	(0.001)	[0.001, 0.006]
Leverage percentage	2.43%	(0.001)	[1.07%, 3.49%]
Interest_coverage	-0.0051	(0.001)	[-0.008, -0.004]
Interest_coverage percentage	-3.79%	(0.001)	[-5.66%, -3.00%]
FCF/Debt	0.0002	(0.476)	[-0.001, 0.001]
FCF/Debt percentage	0.13%	(0.476)	[-0.41%, 0.65%]
EBITDA/Sales	-0.0010	(0.007)	[-0.002, -0.000]
EBITDA/Sales percentage	-0.72%	(0.007)	[-1.04%, -0.28%]
Distance_to_default	-0.0039	(0.019)	[-0.006, -0.001]
Distance_to_default percentage	-2.88%	(0.019)	[-4.72%, -0.74%]
Book_to_market	0.0295	(0.000)	[0.011, 0.052]
Book_to_market percentage	22.01%	(0.000)	[12.24%, 26.91%]
Residual	0.0453	(0.000)	[3.17%, 6.84%]
Residual Percentage	33.84%	(0.000)	[27.976%, 45.367%]
Total	0.1339	(0.000)	[0.084, 0.199]
Percentage	100%		
Number of obs	78,948		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and bond volatility into a number of components each related to a candidate variable. Stage 1 is a regression of monthly $Return\_spread_{i,t}$ on $Bond\_vol_{i,t}$, where *Return_spread* is the expected return for a bond minus the relevant end-of-month Treasury yield for the bond. *Bond_vol* is volatility of monthly bond returns using value-weighted bond prices as in Bao and Pan (2013) and data from the previous 12 months. Stage 2 adds candidate variables to the regression. Stage 3 regresses $Bond\_vol_{i,t}$ on the candidate variables to decompose $Bond\_vol_{i,t}$ into a residual component and components related to each of the candidate variables. In Stage 4, the coefficient ρ_t^{dm} from Stage 1 is decomposed into components each related to the candidate variable and a residual component. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures are *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures are *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

B Bootstrapping

Goncalves (2011) provides a bootstrap method – the panel moving blocks bootstrap (MBB) – for panel data linear regression models with individual fixed effects. This resampling method is robust to time-serial and cross-sectional dependence. In the following, we describe the application of panel MBB to our decomposition analysis.

We consider the following panel linear regression model ($i =, 1, 2..., n; t = 1, 2, ...T$)

$$y_{it} = \alpha_i + x_{it}^{'}\beta + \varepsilon_{it} \tag{8}$$

where y_{it}, α_i, and ε_{it} are scalars, and x_{it} and β are $p \times 1$ vectors.

(1) For any t, let $Z_{t,n} = \left(z_{1t}^{'}, ..., z_{nt}^{'},\right)$ denote $n\left(p+1\right) \times 1$ vector containing n cross sectional observations on z_{it}, where $\varepsilon_{it} = \left(y_{it}, x_{it}^{'}\right)$ is a $1 \times (p+1)$ vector.

(2) Let l denote the length of blocks and $B_{t,l} = \{Z_{t,n}, ..., Z_{t+l-1,n}\}$ be the block of consecutive observations starting at observation t.

(3) Resampling $k = \frac{T}{l}$ blocks randomly with replacement from the set of $T - l + 1$ overlapping blocks $\{B_{1,l}, \quad , B_{T-l+1,l}\}$.

(4) Let $I_1, ..., I_k,$ be i.i.d. random variables uniformly distributed on $\{0, ..., T-l\}$, the pseudo-data $\left\{Z_{t,n}^{*}, t = 1, ..., T\right\}$ is the result of arranging the elements of the k resampled blocks $B_{I_1+1,l}, \quad , B_{I_k+1,l}$ in a sequence.

(5) Using $\left\{Z_{t,n}^{*}, t = 1, ..., T\right\}$ to estimate the regression (1) and then calculating estimator $\overset{\wedge}{\beta}_{nT}^{*}$.

We set the length of blocks, l, to be 6-month, and use the alternatives of 12 and 24 months for robustness checks. We use 1000 bootstrap iterations. In each iteration, we randomly pick with replacement several blocks of consecutive cross sections from actual sample to form a new sample. We then estimate panel regressions using this new sample and estimate the p-value and 5th and 95th percentiles of the bootstrap estimates. We resample the whole cross sections to deal with the cross-firm correlation of coefficients. We use blocks of consecutive cross-sections to preserve the serial dependence of the data. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero.

C Decomposition Using Fama-MacBeth Regressions

To check the robustness of our decomposition method based on panel regressions, we use cross-sectional Fama-MacBeth regression to decompose the relation between bond yield spread and bond volatility. The decomposition using only one candidate variable is as follows. For each month t, we regress the cross section of bond yield spread on contemporaneous bond return volatility:

$$Yield\_spread_{i,t} = \alpha_t + \rho_t Bond\_vol_{i,t} + \epsilon_{i,t}. \tag{9}$$

$Yield\_spread_{i,t}$ denotes the yield spread of bond, and $Bond\_vol_{i,t}$ is bond return volatility. ρ_t measures the cross-sectional relation between bond yield spread and bond return volatility in month t.

Next, we regress $Bond\_vol_{i,t}$ on a candidate explanatory variable ($Candidate_{i,t}$):

$$Bond\_vol_{i,t} = a_t + \delta_t Candidate_{i,t} + \mu_{i,t}. \tag{10}$$

We then use the regression coefficient estimates to decompose $Bond\_vol_{i,t}$ into two orthogonal components: (1) $\delta_t Candidate_t$ is the component of $Bond\_vol_{i,t}$ that is related to the candidate variable, and (2) $a_t+\mu_{i,t}$ is the residual component that is unrelated to the candidate variable.

Finally, we use the linearity of covariance to decompose ρ_t estimated from Equation (9) into two components given by:

$$\begin{aligned}\rho_t &= \frac{Cov(Yield\_spread_{i,t}, Bond\_vol_{i,t})}{Var(Bond\_vol_{i,t})} \\ &= \frac{Cov(Yield\_spread_{i,t}, \delta Candidate_{i,t} + a_t + \mu_{i,t})}{Var(Bond\_vol_{i,t})} \\ &= \frac{Cov(Yield\_spread_{i,t}, \delta Candidate_{i,t})}{Var(Bond\_vol_{i,t})} + \frac{Cov(Yield\_spread_{i,t}, a_t + \mu_{i,t})}{Var(Bond\_vol_{i,t})} \\ &= \rho_t^C + \rho_t^R.\end{aligned} \tag{11}$$

The time series average of ρ_t^C divided by ρ_t measures the fraction of the relation between bond yield spread and bond return volatility explained by the candidate variable, and ρ_t^R divided by ρ_t measures the fraction of the relation unexplained by candidate variable. Using the time series errors of ρ_t^C and ρ_t^R, we can determine the statistical significance of the candidate component and the residual component. We conduct the decomposition using the above method and present the results in Table B.1. The results are similar to those of the decomposition using panel regressions (see Table 6).

Table B.1: Multivariate Fama-MacBeth Decomposition Using Both Illiquidity and Credit Proxies As Candidate Variables

Stage	Description	Variable	Coefficient	t-stat	p-value
1	Regress yield spread on bond volatility	Constant	0.0023	(2.96)	[0.004]
		Bond_vol	0.2453	(13.79)	[0.000]
		Adjusted R2	48.57%		
2	Add candidate variable to first-stage regressions	Constant	-0.0356	(-5.06)	[0.000]
		Bond_vol	0.1126	(13.88)	[0.000]
		Amihud	0.0469	(4.25)	[0.000]
		Amihud_vol	0.0256	(7.44)	[0.000]
		IRC	0.4292	(6.74)	[0.000]
		IRC_vol	-0.0686	(-1.69)	[0.094]
		γ	0.0009	(6.04)	[0.000]
		Bond_zero	-0.0050	(-9.53)	[0.000]
		Moody_rating	0.0031	(7.58)	[0.000]
		Leverage	0.0215	(4.12)	[0.000]
		Interest_coverage	0.0003	(4.79)	[0.000]
		FCF/Debt	0.0037	(3.58)	[0.001]
		EBITDA/Sales	-0.0039	(-3.87)	[0.000]
		Distance_to_default	0.0001	(0.90)	[0.368]
		Book_to_market	0.0099	(5.75)	[0.000]
		Adjusted R2	80.20%		
3	Regress on candidate variable	Constant	-0.0304	(-2.86)	[0.005]
		Amihud	0.0694	(1.05)	[0.294]
		Amihud_vol	0.2758	(9.07)	[0.000]
		IRC	1.5333	(3.73)	[0.000]
		IRC_vol	1.2174	(3.93)	[0.000]
		γ	0.0093	(10.47)	[0.000]
		Bond_zero	-0.0277	(-8.86)	[0.000]

		Moody_rating	0.0060	(5.58)	[0.000]
		Leverage	0.0425	(4.13)	[0.000]
		Interest_coverage	0.0008	(4.49)	[0.000]
		FCF/Debt	-0.0057	(-0.74)	[0.462]
		EBITDA/Sales	0.0275	(4.89)	[0.000]
		Distance_to_default	-0.0008	(-2.02)	[0.045]
		Book_to_market	0.0217	(6.77)	[0.000]
		Adjusted R2	42.27%		
4	Decompose first-stage coefficient	Amihud	0.0035	(2.14)	[0.034]
			1.41%		
		Amihud_vol	0.0092	(6.46)	[0.000]
			3.76%		
		IRC	0.0084	(4.30)	[0.000]
			3.41%		
		IRC_vol	0.0059	(3.95)	[0.000]
			2.40%		
		γ	0.0387	(10.66)	[0.000]
			15.80%		
		Bond_zero	0.0033	(3.98)	[0.000]
			1.33%		
		Moody_rating	0.0859	(9.77)	[0.000]
			35.01%		
		Leverage	0.0102	(3.66)	[0.000]
			4.16%		
		Interest_coverage	-0.0122	(-4.25)	[0.000]
			-4.97%		
		FCF/Debt	0.0009	(0.98)	[0.329]
			0.38%		
		EBITDA/Sales	-0.0033	(-4.86)	[0.000]
			-1.36%		
		Distance_to_default	0.0021	(0.54)	[0.591]
			0.87%		
		Book_to_market	0.0293	(3.52)	[0.001]
			11.96%		
		Residual	0.0634	(13.65)	[0.000]
		Percentage	25.87%		
		Total	0.2453	(13.79)	[0.000]
			100%		
		Number of obs	78,948		

We use cross-sectional Fama-MacBeth regressions to decompose the relation between yield spreads and bond volatility into a residual component and a number of components each related to a candidate variable. Stage 1 is a regression of monthly $Yield\_spread_{i,t}$ on $Bond\_vol_{i,t}$, where *Yield_spread* is the yield based on the last price for a bond in the month minus the relevant end-of-month Treasury yield for the bond. *Bond_vol* is volatility of monthly bond returns using value-weighted bond prices as in Bao and Pan (2013) and data from the previous 12 months. Stage 2 adds candidate variables to the regression. Stage 3 regresses $Bond\_vol_{i,t}$ on the candidate variables to decompose $Bond\_vol_{i,t}$ into a residual component and components related to each of the candidate variables. In Stage 4, the coefficient ρ_t^{dm} from Stage 1 is decomposed into components each related to the candidate variable and a residual component. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures are *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures are *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. The numbers in the Coefficient column is the time series average of coefficient estimates. The numbers in parentheses are t-values, and the numbers in square-brackets are p-values. The t-values and p-values are based on the time series of the estimated coefficients.

Tables

Table 1: Bond Summary Statistics

	Mean	SD	5%	25%	Med.	75%	95%
Bond-months	194,863						
Bonds	6,085						
Yield_spread	2.14	2.82	0.38	0.82	1.42	2.47	6.08
Bond_vol	7.86	8.21	1.27	3.30	5.67	9.34	22.03
Maturity	8.62	8.37	0.96	2.71	5.50	9.17	27.29
Amount	559.18	475.69	38.49	250.00	450.00	700.00	1,500.00
Moody_rating	8.39	3.36	3.00	6.00	8.00	10.00	15.00
Bond_zero	58.74	26.36	9.52	40.00	63.64	80.95	95.00
Amihud	1.15	1.80	0.03	0.18	0.50	1.29	4.59
Amihud_vol	1.48	1.88	0.05	0.35	0.86	1.90	5.03
IRC	0.22	0.30	0.00	0.04	0.12	0.29	0.80
IRC_vol	0.25	0.30	0.00	0.05	0.15	0.33	0.81
γ	1.51	4.92	0.01	0.13	0.46	1.37	5.68

Summary statistics for the bonds in our sample. Observations are reported at the bond-month level. *Bonds* is the number of distinct bonds. *Yield_spread* is the yield based on the average price for a bond in the month using trades from the 21st of the month or later minus the relevant end-of-month Treasury yield for the bond. *Bond_vol* is volatility of monthly bond returns using value-weighted bond prices as in Bao and Pan (2013) and data from the previous 12 months. *Yield_spread* and *Bond_vol* are expressed in %. *Maturity* is a bond's time to maturity in years. *Amount* is a bond's amount outstanding in $mm of face value. *Moody_rating* is a numerical translation of Moody's rating, where 1=Aaa and 21=C. *Bond_zero*, *Amihud*, *Amihud_vol*, *IRC*, and *IRC_vol* are defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012). *Bond_zero* is expressed in %. *Amihud*, *Amihud_vol*, *IRC*, and *IRC_vol* are scaled by 100 as compared with Dick-Nielsen, Feldhutter, and Lando (2012). γ is the negative covariance between the change in log prices in two consecutive periods based on Bao, Pan, and Wang (2011). See Table 13 for variable descriptions.

Table 2: Firm Summary Statistics

	Mean	SD	5%	25%	Med.	75%	95%
Bond-months	194,863						
Firms	669						
Assets	93.03	162.62	5.15	15.25	30.25	69.86	479.92
Sales	43.50	54.84	3.13	9.15	18.42	51.32	176.90
Leverage	0.69	0.16	0.44	0.58	0.68	0.80	0.97
EBITDA/Sales	0.22	0.13	0.05	0.13	0.21	0.31	0.45
Interest_coverage	7.31	7.78	1.40	3.17	4.85	8.43	21.57
FCF/Debt	0.12	0.13	-0.06	0.04	0.10	0.18	0.33
Eq_vol	27.81	16.90	10.68	16.85	23.78	33.52	58.67
Distance_to_default	8.52	4.41	2.49	5.01	7.88	11.48	16.79
Book_to_market	0.55	0.41	0.12	0.29	0.47	0.69	1.21

Summary statistics for the firms with bonds in our sample. Observations are reported at the bond-month level. *Assets* is Compustat data item AT measured in \$billion. *Sales* is Compustat data item SALE measured in \$billion. *Leverage* is using Compustat data defined as total liabilities divided by total assets (LT/AT). *EBITDA/Sales* is defined as earnings before interest divided by sales. We follow Blume, Lim, and MacKinlay (1998) to define *Interest_coverage* as operating income after depreciation plus interest and related expense divided by Interest and Related Expense ((OIADP+XINT)/XINT). The ratio is set to 100 if it is greater than 100 or if firm has 0 or negative interest expense. *FCF/Debt* is defined as free cash flow divided by total liabilities. Free cash flow is defined using Compustat data as EBITDA minus change in current assets (ACT) plus change in current liabilities (LCT) minus capital expenditures (CAPX). *Equity_vol* is 100 times the volatility of equity returns using the data from the previous 12 months. *Distance_to_default* and *Book_to_market* are calculated as in Bao and Hou (2013). See Table 13 for variable descriptions.

Table 3: Regressions of Bond Yield Spreads on Bond Volatility, Illiquidity, and Credit Risk Measures

Bond_vol	Eq_vol	Amihud	Amihud_vol	IRC	IRC_vol	γ	Bond_zero	Moody_rating	Leverage	Interest_coverage	$\frac{FCF}{Debt}$	$\frac{EBITDA}{Sales}$	Distance_to_default	Book_to_market	N	adj. R^2
0.202															78948	0.354
(9.66)																
0.144	0.0498														78896	0.435
(7.94)	(8.17)															
0.197		0.147													78948	0.361
(9.37)		(4.41)														
0.194			0.135												78948	0.363
(9.32)			(6.26)													
0.190				1.132											78948	0.367
(9.34)				(7.70)												
0.194					0.705										78948	0.361
(9.30)					(7.59)											
0.182						0.00147									79003	0.392
(10.46)						(3.51)										
0.202							-0.000377								78948	0.354
(9.65)							(-0.23)									
0.170		0.00901	0.0376	1.519	-0.630	0.00139	-0.00467								78948	0.405
(9.92)		(0.26)	(2.40)	(4.19)	(-2.71)	(3.27)	(-3.22)									
0.133								0.00331							78948	0.528
(7.49)								(16.09)								
0.195									0.0249						78948	0.374
(9.57)									(5.18)							
0.191										-0.000475					78948	0.385
(9.25)										(-8.49)						
0.196											-0.0207				78948	0.366
(9.60)											(-6.02)					
0.201												-0.0180			78948	0.365
(9.66)												(-3.90)				
0.176													-0.00157		78948	0.419
(8.48)													(-13.27)			
0.160														0.0224	78948	0.478
(12.09)														(5.65)		
0.103								0.00307	0.0349	0.000291	0.00798	-0.00261	0.000592	0.0232	78948	0.626
(10.70)								(13.92)	(4.57)	(4.45)	(3.11)	(-0.84)	(2.54)	(4.61)		
0.0847		0.0286	0.0273	0.723	-0.273	0.00101	-0.00395	0.00304	0.0331	0.000277	0.00717	-0.00167	0.000576	0.0215	78948	0.651
(9.82)		(1.15)	(2.15)	(2.86)	(-1.69)	(3.30)	(-4.02)	(14.02)	(4.77)	(4.54)	(3.10)	(-0.59)	(2.74)	(4.86)		

All regressions are panel regressions using bond-month observations. The dependent variable is the volume-weighted bond yield spread, and the independent variables include *Bond_vol*, illiquidity measures, and credit risk measures. We cross-sectionally demean all variables to focus on the cross-sectional effect. All variables are used in decimals. All regressions use standard errors clustered by firm and month. We present each regression in every two rows. Numbers in parentheses are t-values. See Table 13 for variable descriptions.

Table 4: Decomposition Results Using Illiquidity Proxies As Candidate Variables

Panel A: Univariate analysis

Stage	Description	Variable	(1) Amihud	(2) Amihud_vol	(3) IRC	(4) IRC_vol	(5) γ	(6) Bond_zero
1	Regress yield	Bond_vol	0.2218	0.2296	0.2224	0.2311	0.2204	0.2161
	spread on		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	value-weighted		[0.157, 0.302]	[0.160, 0.324]	[0.159, 0.307]	[0.163, 0.331]	[0.158, 0.314]	[0.153, 0.288]
	bond volatility	Adjusted R2	36.84%	38.24%	37.26%	39.36%	37.46%	35.70%
			[32.23%, 42.90%]	[33.47%, 45.01%]	[32.26%, 42.72%]	[34.08%, 46.21%]	[33.15%, 43.90%]	[31.41%, 40.70%]
2	Add candidate	Bond_vol	0.2136	0.2142	0.2122	0.2206	0.1869	0.2160
	variable to		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	first-stage		[0.151, 0.292]	[0.151, 0.303]	[0.151, 0.296]	[0.153, 0.318]	[0.139, 0.270]	[0.152, 0.288]
	regressions	Candidate	0.1610	0.2222	0.9676	0.9338	0.0015	-0.0021
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
			[0.111, 0.187]	[0.150, 0.263]	[0.727, 1.154]	[0.661, 1.244]	[0.001, 0.002]	[-0.003, -0.001]
		Adjusted R2	37.92%	40.09%	38.32%	40.23%	43.81%	35.75%
			[33.31%, 44.23%]	[35.65%, 46.54%]	[33.54%, 44.01%]	[35.42%, 47.36%]	[39.49%, 48.07%]	[31.46%, 40.82%]
3	Regress bond	Candidate	0.8774	1.2280	6.5342	7.6399	0.0054	-0.0029
	volatility on		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.358)
	candidate variable		[0.695, 1.049]	[0.968, 1.484]	[4.958, 7.683]	[5.890, 9.332]	[0.004, 0.012]	[-0.009, 0.006]
		Adjusted R2	4.45%	8.54%	6.89%	8.63%	11.99%	0.01%
			[3.63%, 6.09%]	[6.93%, 11.18%]	[5.09%, 8.72%]	[6.75%, 11.23%]	[9.20%, 16.82%]	[-0.00%, 0.12%]
4	Decompose Stage 1	Candidate	0.0177	0.0337	0.0248	0.0296	0.0559	0.0001
	Coefficient		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.349)
			[0.011, 0.029]	[0.020, 0.054]	[0.015, 0.037]	[0.019, 0.048]	[0.035, 0.086]	[-0.000, 0.001]
		Percentage	7.96%	14.69%	11.17%	12.80%	25.36%	0.05%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.349)
			[6.56%, 10.14%]	[12.41%, 17.38%]	[9.27%, 13.25%]	[11.32%, 15.29%]	[20.03%, 29.18%]	[-0.05%, 0.29%]
		Residual	0.2041	0.1959	0.1976	0.2015	0.1645	0.2160
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[14.55%, 27.59%]	[14.01%, 27.11%]	[14.25%, 27.20%]	[14.21%, 28.33%]	[12.23%, 23.09%]	[15.24%, 28.78%]
		Percentage	92.04%	85.31%	88.83%	87.20%	74.64%	99.95%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[89.864%, 93.437%]	[82.619%, 87.587%]	[86.749%, 90.729%]	[84.708%, 88.684%]	[70.824%, 79.971%]	[99.706%, 100.046%]
		Total	0.2218	0.2296	0.2224	0.2311	0.2204	0.2161
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.157, 0.302]	[0.160, 0.324]	[0.159, 0.307]	[0.163, 0.331]	[0.158, 0.314]	[0.153, 0.288]
			100%	100%	100%	100%	100%	100%
		Number of obs	150923	120272	150125	113378	136230	180075

Panel B: Multivariate analysis

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.2311	(0.000)	[0.166, 0.328]
		Adjusted R2	40.18%		[35.36%, 47.61%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.1780	(0.000)	[0.133, 0.259]
		Amihud	0.0535	(0.057)	[-0.001, 0.096]
		Amihud_vol	0.1029	(0.001)	[0.048, 0.153]
		IRC	1.3132	(0.000)	[0.955, 1.656]
		IRC_vol	-0.5740	(0.001)	[-0.745, -0.289]
		γ	0.0018	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0063	(0.001)	[-0.008, -0.004]
		Adjusted R2	49.28%		[45.11%, 53.95%]
3	Regress on candidate variables	Amihud	0.1364	(0.023)	[0.026, 0.286]
		Amihud_vol	0.5233	(0.000)	[0.389, 0.644]
		IRC	5.0473	(0.000)	[2.578, 6.453]
		IRC_vol	1.0139	(0.049)	[0.016, 2.139]
		γ	0.0049	(0.000)	[0.003, 0.012]
		Bond_zero	-0.0322	(0.001)	[-0.039, -0.022]
		Adjusted R2	21.13%		[16.97%, 27.39%]
4	Decompose first-stage Coefficient	Amihud	0.0029	(0.023)	[0.001, 0.008]
		Amihud percentage	1.25%	(0.023)	[0.24%, 3.11%]
		Amihud_vol	0.0155	(0.000)	[0.008, 0.027]
		Amihud_vol percentage	6.70%	(0.000)	[4.84%, 8.62%]
		IRC	0.0194	(0.000)	[0.008, 0.036]
		IRC percentage	8.40%	(0.000)	[4.31%, 12.13%]
		IRC_vol	0.0040	(0.049)	[0.000, 0.008]
		IRC_vol percentage	1.74%	(0.049)	[0.03%, 3.34%]
		γ	0.0478	(0.000)	[0.028, 0.071]
		γ percentage	20.69%	(0.000)	[14.39%, 25.07%]
		Bond_zero	0.0011	(0.003)	[0.000, 0.002]
		Bond_zero percentage	0.47%	(0.003)	[0.11%, 1.11%]
		Residual	0.1404	(0.000)	[10.79%, 19.12%]
		Residual Percentage	60.75%	(0.000)	[55.851%, 67.845%]
		Total	0.2311	(0.000)	[0.166, 0.328]
		Percentage	100%		
		Number of obs	94,178		

In Panel A, we use panel regressions with cross-sectionally demeaned variables to decompose the relation between volume-weighted yield spreads and bond volatility into a component related to an illiquidity candidate variable and a residual component. Stage 1 is a regression of monthly $Yield\_spread_{i,t}$ on contemporaneous $Bond\_vol_{i,t}$ ($Yield\_spread^{dm}_{i,t} = \rho^{dm} Bond\_vol^{dm}_{i,t} + \epsilon^{dm}_{i,t}$). Stage 2 adds a candidate variable ($Candidate_{i,t}$) to the regression. Stage 3 regresses $Bond\_vol_{i,t}$ on the candidate variable ($Bond\_vol^{dm}_{i,t} = \delta^{dm} Candidate^{dm}_{i,t} + \mu^{dm}_{i,t}$) to decompose $Bond\_vol_{i,t}$ into two components $\delta^{dm} Candidate^{dm}_{it}$ and μ^{dm}_{it}. In Stage 4, the coefficient ρ^{dm} from Stage 1 is decomposed into two orthogonal components as follows:

$$\rho^{dm} = \frac{Cov(Yield\_spread_{it}^{dm}, Bond\_vol_{it}^{dm})}{Var(Bond\_vol_{it}^{dm})} = \frac{Cov(Yield\_spread_{it}^{dm}, \delta^{dm} Candidate_{it}^{dm})}{Candidate_{it}^{dm}} + \frac{Cov(Yield\_spread_{it}^{dm}, \mu_{it}^{dm})}{Candidate_{it}^{dm}} = \rho^{C,dm} + \rho^{R,dm}.$$

$\rho^{C,dm}$ divided by ρ^{dm} measures the fraction of the relation between bond yield spread and bond return volatility explained by the candidate variable, and $\rho^{R,dm}$ divided by ρ^{dm} measures the fraction of the relation unexplained by candidate variable. In Panel B, we decompose the relation between yield spreads and bond volatility into a number of components each related to an illiquidity measure and a residual component. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 5: Decomposition Results Using Credit Proxies As Candidate Variables

Panel A: Univariate analysis

Stage	Description	Variable	(1) Moody_rating	(2) Leverage	(3) Interest_coverage	(4) FCF/Debt	(5) EBITDA/Sales	(6) Distance_to_default	(7) Book_to_market
1	Regress yield spread on value-weighted bond volatility	Bond_vol	0.2146	0.2146	0.2149	0.1937	0.2147	0.2148	0.2054
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.153, 0.288]	[0.154, 0.293]	[0.153, 0.288]	[0.150, 0.257]	[0.156, 0.294]	[0.151, 0.285]	[0.147, 0.284]
		Adjusted R2	34.88%	34.88%	34.92%	33.01%	34.89%	34.61%	31.79%
			[30.43%, 39.39%]	[30.75%, 39.59%]	[30.23%, 39.15%]	[28.27%, 39.01%]	[30.44%, 39.60%]	[30.31%, 38.95%]	[28.10%, 35.34%]
2	Add candidate variable to first-stage regressions	Bond_vol	0.1511	0.2040	0.2051	0.1902	0.2092	0.1923	0.1623
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.095, 0.215]	[0.144, 0.281]	[0.143, 0.276]	[0.147, 0.253]	[0.152, 0.288]	[0.129, 0.258]	[0.124, 0.220]
		Candidate	0.0031	0.0305	-0.0006	-0.0154	-0.0273	-0.0017	0.0232
			(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
			[0.003, 0.004]	[0.025, 0.037]	[-0.001, -0.000]	[-0.019, -0.014]	[-0.034, -0.022]	[-0.002, -0.002]	[0.017, 0.028]
		Adjusted R2	48.15%	38.30%	37.70%	33.79%	36.87%	40.95%	46.56%
			[43.41%, 62.25%]	[33.88%, 45.04%]	[33.39%, 43.50%]	[29.21%, 40.34%]	[32.40%, 42.03%]	[36.18%, 52.19%]	[41.13%, 50.74%]
3	Regress bond volatility on candidate variable	Candidate	0.0090	0.0700	-0.0014	-0.0594	-0.0564	-0.0043	0.0466
			(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
			[0.006, 0.012]	[0.042, 0.097]	[-0.002, -0.001]	[-0.077, -0.040]	[-0.084, -0.031]	[-0.006, -0.003]	[0.036, 0.055]
		Adjusted R2	18.69%	2.45%	2.54%	1.34%	1.14%	5.63%	8.65%
			[15.71%, 21.80%]	[1.49%, 3.42%]	[1.99%, 3.33%]	[0.68%, 2.07%]	[0.57%, 1.82%]	[4.27%, 7.60%]	[5.37%, 11.34%]
4	Decompose Stage 1 Coefficient	Candidate	0.0917	0.0156	0.0150	0.0060	0.0079	0.0333	0.0571
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.074, 0.117]	[0.011, 0.022]	[0.012, 0.021]	[0.004, 0.010]	[0.005, 0.012]	[0.025, 0.050]	[0.029, 0.089]
		Percentage	42.74%	7.28%	6.98%	3.10%	3.67%	15.49%	27.82%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[38.11%, 50.59%]	[5.43%, 10.07%]	[6.10%, 9.14%]	[2.08%, 4.50%]	[2.47%, 5.22%]	[12.34%, 22.30%]	[19.17%, 32.50%]
		Residual	0.1229	0.1990	0.1999	0.1877	0.2068	0.1815	0.1482
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[7.73%, 17.47%]	[14.13%, 27.42%]	[13.94%, 26.83%]	[14.45%, 24.91%]	[15.00%, 28.40%]	[12.22%, 24.17%]	[11.63%, 19.74%]
		Percentage	57.26%	92.72%	93.02%	96.90%	96.33%	84.51%	72.18%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[49.408%, 61.891%]	[89.929%, 94.572%]	[90.857%, 93.898%]	[95.503%, 97.920%]	[94.777%, 97.530%]	[77.703%, 87.662%]	[67.498%, 80.825%]
		Total	0.2146	0.2146	0.2149	0.1937	0.2147	0.2148	0.2054
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.153, 0.288]	[0.154, 0.293]	[0.153, 0.288]	[0.150, 0.257]	[0.156, 0.294]	[0.151, 0.285]	[0.147, 0.284]
			100%	100%	100%	100%	100%	100%	100%
		Number of obs	194863	194860	193826	167374	194412	194144	187839

Panel B: Multivariate analysis

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.1824	(0.000)	[0.139, 0.236]
		Adjusted R2	30.02%		[25.97%, 34.83%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.1008	(0.000)	[0.077, 0.134]
		Moody_rating	0.0029	(0.000)	[0.003, 0.004]
		Leverage	0.0295	(0.000)	[0.012, 0.044]
		Interest_coverage	0.0003	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0090	(0.000)	[0.004, 0.012]
		EBITDA/Sales	-0.0029	(0.005)	[-0.004, -0.001]
		Distance_to_default	0.0004	(0.126)	[-0.000, 0.001]
		Book_to_market	0.0230	(0.000)	[0.008, 0.032]
		Adjusted R2	59.39%		[54.77%, 68.70%]
3	Regress on candidate variables	Moody_rating	0.0068	(0.000)	[0.005, 0.009]
		Leverage	0.0552	(0.000)	[0.032, 0.070]
		Interest_coverage	0.0007	(0.000)	[0.000, 0.001]
		FCF/Debt	0.0026	(0.301)	[-0.009, 0.016]
		EBITDA/Sales	0.0117	(0.014)	[0.003, 0.020]
		Distance_to_default	0.0008	(0.027)	[0.000, 0.001]
		Book_to_market	0.0427	(0.000)	[0.029, 0.050]
		Adjusted R2	17.33%		[12.89%, 20.25%]
4	Decompose first-stage Coefficient	Moody_rating	0.0643	(0.000)	[0.056, 0.075]
		Moody_rating percentage	35.23%	(0.000)	[30.43%, 42.50%]
		Leverage	0.0070	(0.000)	[0.005, 0.009]
		Leverage percentage	3.85%	(0.000)	[2.90%, 4.69%]
		Interest_coverage	-0.0074	(0.001)	[-0.011, -0.006]
		Interest_coverage percentage	-4.08%	(0.001)	[-5.31%, -3.40%]
		FCF/Debt	-0.0003	(0.302)	[-0.001, 0.001]
		FCF/Debt percentage	-0.14%	(0.302)	[-0.80%, 0.65%]
		EBITDA/Sales	-0.0011	(0.015)	[-0.003, -0.000]
		EBITDA/Sales percentage	-0.62%	(0.015)	[-1.26%, -0.16%]
		Distance_to_default	-0.0063	(0.028)	[-0.009, -0.001]
		Distance_to_default percentage	-3.44%	(0.028)	[-5.07%, -0.57%]
		Book_to_market	0.0429	(0.000)	[0.018, 0.067]
		Book_to_market percentage	23.52%	(0.000)	[11.98%, 30.37%]
		Residual	0.0833	(0.000)	[6.39%, 11.15%]
		Residual Percentage	45.68%	(0.000)	[39.992%, 54.231%]
		Total	0.1824	(0.000)	[0.139, 0.236]
		Percentage	100%		
		Number of obs	161075		

In Panel A, we use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and bond volatility into a component related to a credit risk candidate variable and a residual component. Stage 1 is a regression of monthly $Yield\_spread_{i,t}$ on contemporaneous $Bond\_vol_{i,t}$. Stage 2 adds a candidate variable to the regression. Stage

3 regresses $Bond\_vol_{i,t}$ on the candidate variable to decompose $Bond\_vol_{i,t}$ into a component related to the candidate variable and a residual component. In Stage 4, the Stage 1 coefficient of regressing bond yield spread on bond volatility is decomposed into two orthogonal components, one related to the candidate variable and a residual component. In Panel B, we decompose the relation between yield spreads and bond volatility into a number of components each related to a credit risk measure and a residual component. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 6: Multivariate Analysis Using Both Illiquidity and Credit Proxies As Candidate Variables

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.2022	(0.000)	[0.157, 0.268]
		Adjusted R2	35.36%		[31.10%, 43.03%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.0847	(0.000)	[0.064, 0.122]
		Amihud	0.0286	(0.150)	[-0.010, 0.073]
		Amihud_vol	0.0273	(0.084)	[-0.003, 0.048]
		IRC	0.7227	(0.000)	[0.378, 1.111]
		IRC_vol	-0.2732	(0.018)	[-0.441, -0.037]
		γ	0.0010	(0.000)	[0.001, 0.001]
		Bond_zero	-0.0040	(0.001)	[-0.005, -0.003]
		Moody_rating	0.0030	(0.000)	[0.003, 0.004]
		Leverage	0.0331	(0.000)	[0.015, 0.045]
		Interest_coverage	0.0003	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0072	(0.000)	[0.004, 0.009]
		EBITDA/Sales	-0.0017	(0.034)	[-0.004, -0.000]
		Distance_to_default	0.0006	(0.009)	[0.000, 0.001]
		Book_to_market	0.0215	(0.000)	[0.009, 0.028]
		Adjusted R2	65.06%		[61.51%, 75.16%]
3	Regress on candidate variables	Amihud	0.0254	(0.353)	[-0.124, 0.174]
		Amihud_vol	0.3177	(0.000)	[0.238, 0.397]
		IRC	2.8333	(0.000)	[1.385, 3.745]
		IRC_vol	1.1315	(0.007)	[0.410, 1.845]
		γ	0.0035	(0.000)	[0.002, 0.008]
		Bond_zero	-0.0269	(0.001)	[-0.033, -0.019]
		Moody_rating	0.0074	(0.000)	[0.005, 0.010]
		Leverage	0.0606	(0.000)	[0.034, 0.084]
		Interest_coverage	0.0007	(0.000)	[0.000, 0.001]
		FCF/Debt	-0.0035	(0.434)	[-0.015, 0.011]
		EBITDA/Sales	0.0284	(0.000)	[0.019, 0.037]
		Distance_to_default	0.0010	(0.027)	[0.000, 0.002]
		Book_to_market	0.0356	(0.000)	[0.025, 0.046]
		Adjusted R2	32.16%		[29.28%, 35.77%]
4	Decompose first-stage Coefficient	Amihud	0.0003	(0.353)	[-0.001, 0.003]
		Amihud percentage	0.16%	(0.353)	[-0.62%, 1.43%]
		Amihud_vol	0.0065	(0.000)	[0.004, 0.010]
		Amihud_vol percentage	3.23%	(0.000)	[2.45%, 4.28%]
		IRC	0.0098	(0.000)	[0.004, 0.017]
		IRC percentage	4.87%	(0.000)	[2.45%, 7.26%]
		IRC_vol	0.0039	(0.007)	[0.002, 0.006]
		IRC_vol percentage	1.93%	(0.007)	[0.85%, 2.85%]
		γ	0.0205	(0.000)	[0.014, 0.030]
		γ percentage	10.12%	(0.000)	[8.06%, 13.39%]

Bond_zero	0.0014	(0.009)	[0.000, 0.003]
Bond_zero percentage	0.68%	(0.009)	[0.14%, 1.48%]
Moody_rating	0.0761	(0.000)	[0.065, 0.095]
Moody_rating percentage	37.63%	(0.000)	[32.95%, 44.26%]
Leverage	0.0093	(0.000)	[0.007, 0.012]
Leverage percentage	4.62%	(0.000)	[3.17%, 6.11%]
Interest_coverage	-0.0092	(0.001)	[-0.014, -0.007]
Interest_coverage percentage	-4.53%	(0.001)	[-6.09%, -3.53%]
FCF/Debt	0.0004	(0.433)	[-0.001, 0.002]
FCF/Debt percentage	0.22%	(0.433)	[-0.65%, 1.12%]
EBITDA/Sales	-0.0024	(0.001)	[-0.004, -0.001]
EBITDA/Sales percentage	-1.20%	(0.001)	[-1.57%, -0.85%]
Distance_to_default	-0.0084	(0.028)	[-0.013, -0.001]
Distance_to_default percentage	-4.16%	(0.028)	[-6.60%, -0.60%]
Book_to_market	0.0364	(0.000)	[0.021, 0.054]
Book_to_market percentage	18.01%	(0.000)	[11.20%, 22.19%]
Residual	0.0575	(0.000)	[4.37%, 7.85%]
Residual Percentage	28.42%	(0.000)	[24.896%, 31.764%]
Total	0.2022	(0.000)	[0.157, 0.268]
Percentage	100%		
Number of obs	78,948		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and bond volatility into a number of components each related to a candidate variable and a residual component. Stage 1 is a regression of monthly $Yield\_spread_{i,t}$ on contemporaneous $Bond\_vol_{i,t}$. Stage 2 adds candidate variables to the regression. Stage 3 regresses $Bond\_vol_{i,t}$ on the candidate variables to decompose $Bond\_vol_{i,t}$ into components each related to the candidate variable and a residual component. In Stage 4, the coefficient ρ^{dm} from Stage 1 is decomposed into components each related to the candidate variable and a residual component. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 7: Multivariate Decomposition of the Relation Between Bond Yield Spread and Equity Volatility Using Both Illiquidity and Credit Proxies As Candidate Variables

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on equity volatility	Eq_vol	0.0877	(0.000)	[0.066, 0.102]
		Adjusted R2	33.30%		[27.42%, 37.83%]
2	Add candidate variables to first-stage regressions	Eq_vol	0.0344	(0.000)	[0.026, 0.043]
		Amihud	0.0592	(0.004)	[0.014, 0.093]
		Amihud_vol	0.0657	(0.000)	[0.029, 0.074]
		IRC	1.1374	(0.000)	[0.626, 1.533]
		IRC_vol	-0.2498	(0.008)	[-0.437, -0.066]
		γ	0.0006	(0.000)	[0.000, 0.001]
		Bond_zero	-0.0056	(0.001)	[-0.007, -0.004]
		Moody_rating	0.0034	(0.000)	[0.003, 0.004]
		Leverage	0.0329	(0.000)	[0.023, 0.042]
		Interest_coverage	0.0002	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0031	(0.053)	[-0.000, 0.007]
		EBITDA/Sales	0.0046	(0.000)	[0.003, 0.006]
		Distance_to_default	0.0011	(0.000)	[0.001, 0.001]
		Book_to_market	0.0174	(0.000)	[0.012, 0.024]
		Adjusted R2	64.15%		[61.28%, 70.42%]
3	Regress on candidate variables	Amihud	-0.0627	(0.514)	[-0.118, 0.155]
		Amihud_vol	0.1300	(0.045)	[0.003, 0.190]
		IRC	5.0248	(0.000)	[2.718, 5.744]
		IRC_vol	-0.6464	(0.215)	[-1.103, 0.381]
		γ	0.0014	(0.000)	[0.001, 0.005]
		Bond_zero	-0.0331	(0.001)	[-0.050, -0.023]
		Moody_rating	0.0134	(0.000)	[0.009, 0.019]
		Leverage	0.0480	(0.152)	[-0.036, 0.096]
		Interest_coverage	0.0043	(0.000)	[0.003, 0.005]
		FCF/Debt	0.0291	(0.076)	[-0.004, 0.067]
		EBITDA/Sales	-0.1159	(0.001)	[-0.170, -0.077]
		Distance_to_default	-0.0174	(0.001)	[-0.021, -0.015]
		Book_to_market	0.0846	(0.006)	[0.028, 0.103]
		Adjusted R2	47.92%		[40.96%, 53.84%]
4	Decompose first-stage Coefficient	Amihud	-0.0002	(0.514)	[-0.000, 0.000]
		Amihud percentage	-0.19%	(0.514)	[-0.38%, 0.42%]
		Amihud_vol	0.0006	(0.045)	[0.000, 0.001]
		Amihud_vol percentage	0.66%	(0.045)	[0.02%, 0.97%]
		IRC	0.0047	(0.000)	[0.002, 0.007]
		IRC percentage	5.39%	(0.000)	[2.17%, 6.99%]
		IRC_vol	-0.0006	(0.215)	[-0.001, 0.000]
		IRC_vol percentage	-0.68%	(0.215)	[-1.22%, 0.33%]
		γ	0.0025	(0.000)	[0.002, 0.004]

γ percentage	2.80%	(0.000)	[2.19%, 4.83%]
Bond_zero	0.0002	(0.105)	[-0.000, 0.000]
Bond_zero percentage	0.26%	(0.105)	[-0.06%, 0.60%]
Moody_rating	0.0233	(0.000)	[0.019, 0.028]
Moody_rating percentage	26.56%	(0.000)	[20.75%, 35.91%]
Leverage	0.0012	(0.152)	[-0.001, 0.002]
Leverage percentage	1.35%	(0.152)	[-1.51%, 2.63%]
Interest_coverage	-0.0088	(0.001)	[-0.011, -0.007]
Interest_coverage percentage	-10.01%	(0.001)	[-13.39%, -8.85%]
FCF/Debt	-0.0007	(0.077)	[-0.001, 0.000]
FCF/Debt percentage	-0.81%	(0.077)	[-1.87%, 0.12%]
EBITDA/Sales	0.0015	(0.000)	[0.001, 0.002]
EBITDA/Sales percentage	1.74%	(0.000)	[1.07%, 2.93%]
Distance_to_default	0.0234	(0.000)	[0.017, 0.035]
Distance_to_default percentage	26.71%	(0.000)	[21.44%, 46.64%]
Book_to_market	0.0226	(0.006)	[0.004, 0.033]
Book_to_market percentage	25.80%	(0.006)	[6.03%, 33.57%]
Residual	0.0179	(0.000)	[1.42%, 2.20%]
Residual Percentage	20.41%	(0.000)	[16.821%, 26.925%]
Total	0.0877	(0.000)	[0.066, 0.102]
Percentage	100%		
Number of obs	104364		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and equity volatility into a number of components each related to a candidate variable and a residual component. Stage 1 is a regression of monthly $Yield\_spread_{i,t}$ on contemporaneous $Equity\_vol_{i,t}$. Stage 2 adds candidate variables to the regression. Stage 3 regresses $Bond\_vol_{i,t}$ on the candidate variables to decompose $Bond\_vol_{i,t}$ into components each related to the candidate variable and a residual component. In Stage 4, the Stage 1 coefficient of regressing bond yield spread on equity volatility is decomposed into components each related to the candidate variable and a residual component. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 8: Multivariate Decomposition of the Relation Between Bond Yield Spread and Bond Volatility that Is Orthogonal to Equity Volatility Using Both Illiquidity and Credit Proxies As Candidate Variables

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on orthogonalized bond volatility	Bond_vol ⊥ Eq_vol	0.1435	(0.000)	[0.107, 0.203]
		Adjusted R2	13.00%		[9.98%, 20.20%]
2	Add candidate variables to first-stage regressions	Bond_vol ⊥ Eq_vol	0.0565	(0.000)	[0.039, 0.093]
		Amihud	0.0283	(0.165)	[-0.010, 0.074]
		Amihud_vol	0.0369	(0.019)	[0.007, 0.058]
		IRC	0.8526	(0.000)	[0.434, 1.249]
		IRC_vol	-0.2451	(0.044)	[-0.412, -0.003]
		γ	0.0011	(0.000)	[0.001, 0.001]
		Bond_zero	-0.0051	(0.001)	[-0.006, -0.004]
		Moody_rating	0.0034	(0.000)	[0.003, 0.004]
		Leverage	0.0350	(0.000)	[0.015, 0.049]
		Interest_coverage	0.0003	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0075	(0.000)	[0.004, 0.009]
		EBITDA/Sales	-0.0026	(0.007)	[-0.005, -0.001]
		Distance_to_default	0.0004	(0.196)	[-0.000, 0.001]
		Book_to_market	0.0232	(0.000)	[0.010, 0.030]
		Adjusted R2	62.47%		[59.19%, 72.66%]
3	Regress on candidate variables	Amihud	0.0399	(0.332)	[-0.093, 0.164]
		Amihud_vol	0.3062	(0.000)	[0.237, 0.363]
		IRC	2.0504	(0.000)	[0.990, 2.892]
		IRC_vol	1.1411	(0.001)	[0.477, 1.733]
		γ	0.0028	(0.000)	[0.002, 0.008]
		Bond_zero	-0.0195	(0.001)	[-0.025, -0.013]
		Moody_rating	0.0045	(0.000)	[0.004, 0.005]
		Leverage	0.0568	(0.000)	[0.044, 0.066]
		Interest_coverage	-0.0001	(0.064)	[-0.000, 0.000]
		FCF/Debt	-0.0098	(0.056)	[-0.019, 0.000]
		EBITDA/Sales	0.0598	(0.000)	[0.044, 0.077]
		Distance_to_default	0.0050	(0.000)	[0.003, 0.006]
		Book_to_market	0.0239	(0.000)	[0.021, 0.031]
		Adjusted R2	20.41%		[17.81%, 25.29%]
4	Decompose first-stage Coefficient	Amihud	0.0007	(0.332)	[-0.001, 0.004]
		Amihud percentage	0.48%	(0.332)	[-0.91%, 2.34%]
		Amihud_vol	0.0086	(0.000)	[0.006, 0.012]
		Amihud_vol percentage	6.01%	(0.000)	[4.76%, 7.08%]
		IRC	0.0098	(0.000)	[0.004, 0.018]
		IRC percentage	6.80%	(0.000)	[3.01%, 10.19%]
		IRC_vol	0.0054	(0.001)	[0.003, 0.008]
		IRC_vol percentage	3.77%	(0.001)	[1.78%, 5.11%]

γ	0.0227	(0.000)	[0.017, 0.031]
γ percentage	15.78%	(0.000)	[11.93%, 21.67%]
Bond_zero	0.0014	(0.010)	[0.000, 0.003]
Bond_zero percentage	0.95%	(0.010)	[0.18%, 2.00%]
Moody_rating	0.0636	(0.000)	[0.051, 0.086]
Moody_rating percentage	44.30%	(0.000)	[38.10%, 52.26%]
Leverage	0.0120	(0.000)	[0.009, 0.017]
Leverage percentage	8.36%	(0.000)	[6.39%, 10.96%]
Interest_coverage	0.0026	(0.063)	[-0.000, 0.004]
Interest_coverage percentage	1.79%	(0.063)	[-0.12%, 2.89%]
FCF/Debt	0.0017	(0.055)	[-0.000, 0.004]
FCF/Debt percentage	1.19%	(0.055)	[-0.04%, 2.61%]
EBITDA/Sales	-0.0070	(0.001)	[-0.008, -0.005]
EBITDA/Sales percentage	-4.86%	(0.001)	[-6.22%, -3.53%]
Distance_to_default	-0.0563	(0.001)	[-0.071, -0.043]
Distance_to_default percentage	-39.24%	(0.001)	[-48.68%, -30.98%]
Book_to_market	0.0335	(0.000)	[0.023, 0.048]
Book_to_market percentage	23.32%	(0.000)	[17.71%, 26.35%]
Residual	0.0450	(0.000)	[3.16%, 6.97%]
Residual Percentage	31.34%	(0.000)	[26.781%, 37.645%]
Total	0.1435	(0.000)	[0.107, 0.203]
Percentage	100%		
Number of obs	78,896		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and bond volatility orthogonal to equity volatility into a number of components each related to a candidate variable and a residual component. Stage 0 orthogonalize *Bond_vol* by regressing $Bond\_vol_{i,t}$ on contemporaneous $Eq\_vol_{i,t}$. The residuals of this regression is the bond volatility that is orthogonal to equity volatility, $Bond\_vol_{i,t} \perp Eq\_vol_{i,t}$. Stage 1 is a regression of monthly $Yield\_spread_{i,t}$ on $Bond\_vol_{i,t} \perp Eq\_vol_{i,t}$. Stage 2 adds candidate variables to the regression. Stage 3 regresses $Bond\_vol_{i,t} \perp Eq\_vol_{i,t}$ on the candidate variables to decompose $Bond\_vol_{i,t} \perp Eq\_vol_{i,t}$ into components each related to the candidate variable and a residual component. In Stage 4, the coefficient on $Bond\_vol_{i,t} \perp Eq\_vol_{i,t}$ from Stage 1 is decomposed into components each related to the candidate variable and a residual component. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 9: Multivariate Decomposition of the Relation Between Bond Yield Spread and Bond Volatility Using Both Illiquidity and Credit Proxies As Candidate Variables for Precrisis, Crisis, and Postcrisis Periods

			Precrisis (July 2002 – March 2007)			Crisis (April 2007 – June 2009)			Postcrisis (July 2009 – December 2012)		
Stage	Description	Variable	Coefficient	p-value	Conf. interval	Coefficient	p-value	Conf. interval	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.1782	(0.000)	[0.162, 0.250]	0.2902	(0.000)	[0.259, 0.469]	0.1622	(0.000)	[0.133, 0.260]
		Adjusted R2	49.83%		[47.81%, 57.23%]	34.22%		[33.41%, 45.01%]	38.48%		[33.53%, 47.40%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.0890	(0.000)	[0.076, 0.136]	0.0965	(0.000)	[0.081, 0.185]	0.0679	(0.000)	[0.052, 0.123]
		Amihud	0.0846	(0.000)	[0.040, 0.110]	0.0183	(0.175)	[-0.030, 0.068]	0.0728	(0.000)	[0.041, 0.092]
		Amihud_vol	0.0305	(0.000)	[0.020, 0.044]	0.0091	(0.720)	[-0.077, 0.042]	0.0474	(0.000)	[0.031, 0.049]
		IRC	0.6134	(0.000)	[0.337, 0.764]	0.7776	(0.001)	[0.194, 1.547]	0.4488	(0.000)	[0.250, 0.583]
		IRC_vol	-0.1440	(0.068)	[-0.273, 0.014]	-0.2527	(0.056)	[-0.724, 0.010]	0.0196	(0.369)	[-0.056, 0.064]
		γ	0.0005	(0.000)	[0.000, 0.001]	0.0008	(0.000)	[0.000, 0.001]	0.0009	(0.000)	[0.001, 0.001]
		Bond_zero	-0.0057	(0.001)	[-0.007, -0.004]	-0.0062	(0.001)	[-0.009, -0.002]	-0.0066	(0.001)	[-0.008, -0.006]
		Moody_rating	0.0021	(0.000)	[0.002, 0.002]	0.0052	(0.000)	[0.003, 0.007]	0.0034	(0.000)	[0.003, 0.004]
		Leverage	0.0163	(0.000)	[0.014, 0.018]	0.0723	(0.000)	[0.025, 0.102]	0.0146	(0.000)	[0.013, 0.016]
		Interest_coverage	0.0003	(0.000)	[0.000, 0.000]	0.0007	(0.000)	[0.000, 0.001]	0.0002	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0034	(0.240)	[-0.002, 0.007]	0.0077	(0.001)	[0.003, 0.009]	0.0041	(0.000)	[0.003, 0.005]
		EBITDA/Sales	-0.0019	(0.050)	[-0.003, -0.000]	-0.0059	(0.001)	[-0.009, -0.002]	-0.0014	(0.089)	[-0.003, 0.000]
		Distance_to_default	0.0001	(0.230)	[-0.000, 0.000]	0.0018	(0.003)	[0.000, 0.003]	-0.0000	(0.078)	[-0.000, 0.000]
		Book_to_market	0.0093	(0.000)	[0.008, 0.011]	0.0349	(0.000)	[0.016, 0.044]	0.0075	(0.000)	[0.006, 0.009]
		Adjusted R2	73.94%		[72.39%, 77.92%]	68.19%		[65.39%, 75.79%]	79.34%		[79.15%, 82.13%]
3	Regress on candidate variables	Amihud	0.3120	(0.001)	[0.129, 0.462]	-0.3000	(0.001)	[-0.373, -0.099]	0.0367	(0.205)	[-0.053, 0.201]
		Amihud_vol	0.1633	(0.000)	[0.115, 0.256]	0.3638	(0.000)	[0.200, 0.441]	0.3232	(0.000)	[0.271, 0.402]
		IRC	3.5923	(0.026)	[0.187, 4.936]	3.5938	(0.000)	[1.272, 4.637]	0.6400	(0.072)	[-0.087, 1.439]
		IRC_vol	-0.2631	(0.556)	[-0.900, 1.166]	2.3478	(0.000)	[0.497, 2.882]	1.8247	(0.000)	[1.198, 2.014]
		γ	0.0058	(0.000)	[0.005, 0.008]	0.0022	(0.000)	[0.001, 0.006]	0.0131	(0.000)	[0.011, 0.014]
		Bond_zero	-0.0321	(0.001)	[-0.043, -0.019]	-0.0208	(0.001)	[-0.025, -0.010]	-0.0328	(0.001)	[-0.038, -0.023]
		Moody_rating	0.0062	(0.000)	[0.004, 0.008]	0.0093	(0.000)	[0.005, 0.012]	0.0065	(0.000)	[0.003, 0.009]
		Leverage	0.0780	(0.000)	[0.037, 0.093]	0.0941	(0.000)	[0.050, 0.104]	0.0325	(0.036)	[0.001, 0.061]
		Interest_coverage	0.0010	(0.000)	[0.001, 0.001]	0.0012	(0.000)	[0.000, 0.002]	0.0005	(0.006)	[0.000, 0.001]
		FCF/Debt	-0.0245	(0.099)	[-0.041, 0.003]	0.0160	(0.005)	[0.005, 0.020]	0.0022	(0.624)	[-0.016, 0.014]
		EBITDA/Sales	0.0137	(0.015)	[0.003, 0.019]	0.0461	(0.000)	[0.019, 0.057]	0.0326	(0.000)	[0.021, 0.046]
		Distance_to_default	0.0011	(0.053)	[-0.000, 0.001]	0.0024	(0.012)	[0.001, 0.003]	0.0003	(0.537)	[-0.001, 0.001]
		Book_to_market	0.0456	(0.000)	[0.025, 0.050]	0.0404	(0.000)	[0.029, 0.042]	0.0244	(0.000)	[0.010, 0.034]
		Adjusted R2	37.38%		[36.27%, 44.03%]	36.78%		[36.21%, 43.88%]	31.17%		[28.91%, 39.57%]
4	Decompose first-stage Coefficient	Amihud	0.0029	(0.001)	[0.001, 0.008]	-0.0027	(0.048)	[-0.004, -0.000]	0.0006	(0.205)	[-0.001, 0.009]
		Amihud percentage	1.65%	(0.001)	[0.62%, 3.28%]	-0.95%	(0.048)	[-1.38%, -0.00%]	0.39%	(0.205)	[-0.39%, 3.52%]
		Amihud_vol	0.0029	(0.000)	[0.002, 0.008]	0.0082	(0.000)	[0.007, 0.012]	0.0070	(0.000)	[0.005, 0.016]
		Amihud_vol percentage	1.60%	(0.000)	[1.05%, 3.35%]	2.83%	(0.000)	[1.72%, 3.58%]	4.29%	(0.000)	[3.56%, 6.50%]
		IRC	0.0127	(0.026)	[0.001, 0.016]	0.0134	(0.000)	[0.007, 0.037]	0.0021	(0.072)	[-0.000, 0.011]
		IRC percentage	7.11%	(0.026)	[0.41%, 9.46%]	4.62%	(0.000)	[2.38%, 8.11%]	1.29%	(0.072)	[-0.18%, 4.43%]
		IRC_vol	-0.0010	(0.556)	[-0.004, 0.006]	0.0074	(0.000)	[0.003, 0.009]	0.0060	(0.000)	[0.003, 0.013]
		IRC_vol percentage	-0.58%	(0.556)	[-2.04%, 2.68%]	2.54%	(0.000)	[0.81%, 2.91%]	3.71%	(0.000)	[2.34%, 5.37%]
		γ	0.0167	(0.000)	[0.013, 0.036]	0.0338	(0.000)	[0.030, 0.057]	0.0262	(0.000)	[0.019, 0.048]
		γ percentage	9.39%	(0.000)	[7.91%, 14.88%]	11.65%	(0.000)	[7.94%, 14.63%]	16.17%	(0.000)	[14.05%, 19.27%]
		Bond_zero	0.0038	(0.000)	[0.003, 0.005]	-0.0007	(0.083)	[-0.002, 0.000]	0.0018	(0.003)	[0.001, 0.006]
		Bond_zero percentage	2.14%	(0.000)	[1.55%, 2.47%]	-0.24%	(0.083)	[-0.48%, 0.18%]	1.14%	(0.003)	[0.41%, 2.36%]
		Moody_rating	0.0632	(0.000)	[0.060, 0.090]	0.1026	(0.000)	[0.094, 0.158]	0.0648	(0.000)	[0.057, 0.084]
		Moody_rating percentage	35.46%	(0.000)	[34.06%, 39.23%]	35.36%	(0.000)	[27.11%, 43.93%]	39.95%	(0.000)	[24.76%, 48.27%]
		Leverage	0.0139	(0.000)	[0.011, 0.017]	0.0163	(0.000)	[0.014, 0.034]	0.0040	(0.036)	[0.000, 0.006]
		Leverage percentage	7.83%	(0.000)	[4.77%, 8.48%]	5.60%	(0.000)	[5.03%, 7.96%]	2.48%	(0.036)	[0.08%, 3.91%]
		Interest_coverage	-0.0096	(0.001)	[-0.013, -0.008]	-0.0136	(0.001)	[-0.037, -0.010]	-0.0070	(0.007)	[-0.014, -0.003]
		Interest_coverage percentage	-5.41%	(0.001)	[-5.83%, -4.41%]	-4.68%	(0.001)	[-8.20%, -3.55%]	-4.30%	(0.007)	[-7.11%, -1.10%]
		FCF/Debt	0.0033	(0.098)	[-0.001, 0.004]	-0.0021	(0.006)	[-0.005, -0.001]	-0.0003	(0.625)	[-0.001, 0.004]
		FCF/Debt percentage	1.83%	(0.098)	[-0.34%, 2.58%]	-0.71%	(0.006)	[-1.08%, -0.42%]	-0.16%	(0.625)	[-0.96%, 1.75%]

EBITDA/Sales	-0.0013	(0.016)	[-0.002, -0.000]	-0.0054	(0.001)	[-0.009, -0.005]	-0.0019	(0.001)	[-0.005, -0.001]
EBITDA/Sales percentage	-0.73%	(0.016)	[-0.99%, -0.21%]	-1.85%	(0.001)	[-2.15%, -1.43%]	-1.15%	(0.001)	[-2.15%, -0.64%]
Distance_to_default	-0.0096	(0.054)	[-0.010, 0.000]	-0.0159	(0.013)	[-0.033, -0.007]	-0.0032	(0.538)	[-0.008, 0.017]
Distance_to_default percentage	-5.39%	(0.054)	[-5.84%, 0.07%]	-5.48%	(0.013)	[-9.08%, -1.93%]	-1.95%	(0.538)	[-5.19%, 7.89%]
Book_to_market	0.0247	(0.000)	[0.018, 0.029]	0.0880	(0.000)	[0.059, 0.167]	0.0151	(0.000)	[0.011, 0.020]
Book_to_market percentage	13.84%	(0.000)	[8.60%, 14.57%]	30.31%	(0.000)	[19.82%, 35.80%]	9.33%	(0.000)	[4.81%, 11.65%]
Residual	0.0557	(0.000)	[4.63%, 7.93%]	0.0610	(0.000)	[4.96%, 11.13%]	0.0467	(0.000)	[3.57%, 7.51%]
Residual Percentage	31.28%	(0.000)	[27.611%, 33.309%]	21.00%	(0.000)	[16.792%, 29.524%]	28.80%	(0.000)	[25.630%, 29.920%]
Total	0.1782	(0.000)	[0.162, 0.250]	0.2902	(0.000)	[0.259, 0.469]	0.1622	(0.000)	[0.133, 0.260]
Percentage	100%			100%			100%		
Number of obs	26,548			13,824			38,576		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and equity volatility into a number of components each related to a candidate variable and a residual component. We conduct the decomposition for three different subperiods: Precrisis (July 2002 to March 2007), Crisis (April 2007 to June 2009), and Postcrisis (July 2009 to December 2012). We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 10: Multivariate Decomposition of the Relation Between Bond Yield Spread and Bond Volatility Using Both Illiquidity and Credit Proxies As Candidate Variables for Short, Medium, and Long Maturities

			Short ($\leq$ 2 years)			Medium (2 – 5 years)			Long (5 – 30 years)		
Stage	Description	Variable	Coefficient	p-value	Conf. interval	Coefficient	p-value	Conf. interval	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.3185	(0.000)	[0.183, 0.569]	0.3059	(0.000)	[0.225, 0.447]	0.1762	(0.000)	[0.146, 0.235]
		Adjusted R2	45.83%		[35.23%, 59.69%]	51.78%		[47.76%, 60.89%]	34.00%		[29.84%, 38.57%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.1512	(0.000)	[0.086, 0.313]	0.1477	(0.000)	[0.104, 0.245]	0.0705	(0.000)	[0.057, 0.101]
		Amihud	-0.1981	(0.182)	[-0.437, 0.119]	0.0395	(0.307)	[-0.041, 0.093]	0.0290	(0.011)	[0.007, 0.061]
		Amihud_vol	0.2293	(0.014)	[0.040, 0.322]	-0.0016	(0.484)	[-0.055, 0.058]	0.0328	(0.000)	[0.020, 0.042]
		IRC	2.9231	(0.004)	[0.551, 5.550]	1.0487	(0.000)	[0.648, 1.582]	0.5898	(0.000)	[0.241, 0.885]
		IRC_vol	-1.2162	(0.040)	[-2.509, -0.038]	-0.1353	(0.117)	[-0.364, 0.050]	-0.1915	(0.123)	[-0.367, 0.036]
		γ	0.0026	(0.000)	[0.002, 0.003]	0.0016	(0.000)	[0.001, 0.002]	0.0004	(0.000)	[0.000, 0.001]
		Bond_zero	-0.0009	(0.101)	[-0.003, 0.001]	-0.0034	(0.016)	[-0.007, -0.001]	-0.0034	(0.001)	[-0.005, -0.002]
		Moody_rating	0.0019	(0.000)	[0.001, 0.003]	0.0026	(0.000)	[0.002, 0.003]	0.0031	(0.000)	[0.003, 0.004]
		Leverage	0.0344	(0.000)	[0.013, 0.046]	0.0306	(0.000)	[0.014, 0.040]	0.0241	(0.000)	[0.014, 0.033]
		Interest_coverage	0.0003	(0.000)	[0.000, 0.000]	0.0002	(0.000)	[0.000, 0.000]	0.0002	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0044	(0.179)	[-0.002, 0.006]	0.0080	(0.000)	[0.003, 0.010]	0.0060	(0.000)	[0.004, 0.007]
		EBITDA/Sales	-0.0003	(0.495)	[-0.003, 0.004]	-0.0013	(0.236)	[-0.003, 0.002]	-0.0012	(0.056)	[-0.003, 0.000]
		Distance_to_default	0.0008	(0.004)	[0.000, 0.001]	0.0005	(0.103)	[-0.000, 0.001]	0.0003	(0.019)	[0.000, 0.001]
		Book_to_market	0.0255	(0.000)	[0.009, 0.033]	0.0195	(0.000)	[0.008, 0.023]	0.0152	(0.000)	[0.008, 0.020]
		Adjusted R2	70.45%		[66.65%, 76.63%]	72.11%		[70.51%, 79.99%]	69.85%		[65.62%, 75.57%]
3	Regress on candidate variables	Amihud	0.0745	(0.280)	[-0.301, 0.806]	0.0472	(0.237)	[-0.102, 0.251]	-0.0574	(0.236)	[-0.182, 0.073]
		Amihud_vol	0.5354	(0.000)	[0.146, 0.715]	0.1967	(0.000)	[0.092, 0.311]	0.0781	(0.005)	[0.023, 0.125]
		IRC	3.4295	(0.184)	[-1.914, 7.831]	2.5197	(0.001)	[1.100, 3.642]	2.0390	(0.000)	[1.077, 2.542]
		IRC_vol	-0.1772	(0.469)	[-2.266, 1.953]	0.5288	(0.092)	[-0.139, 1.279]	0.5684	(0.006)	[0.187, 0.832]
		γ	0.0031	(0.000)	[0.001, 0.011]	0.0027	(0.000)	[0.001, 0.007]	0.0024	(0.000)	[0.001, 0.006]
		Bond_zero	-0.0235	(0.001)	[-0.037, -0.011]	-0.0263	(0.001)	[-0.031, -0.019]	-0.0162	(0.001)	[-0.023, -0.008]
		Moody_rating	0.0073	(0.000)	[0.003, 0.011]	0.0085	(0.000)	[0.006, 0.011]	0.0067	(0.000)	[0.005, 0.008]
		Leverage	0.0988	(0.000)	[0.045, 0.145]	0.0846	(0.000)	[0.056, 0.113]	0.0722	(0.000)	[0.045, 0.094]
		Interest_coverage	0.0011	(0.000)	[0.001, 0.002]	0.0010	(0.000)	[0.001, 0.001]	0.0008	(0.000)	[0.000, 0.001]
		FCF/Debt	0.0037	(0.256)	[-0.009, 0.020]	0.0035	(0.299)	[-0.015, 0.031]	0.0054	(0.175)	[-0.005, 0.020]
		EBITDA/Sales	0.0092	(0.094)	[-0.001, 0.019]	-0.0103	(0.101)	[-0.022, 0.002]	0.0229	(0.000)	[0.014, 0.032]
		Distance_to_default	0.0021	(0.006)	[0.000, 0.004]	0.0015	(0.002)	[0.001, 0.003]	0.0009	(0.022)	[0.000, 0.001]
		Book_to_market	0.0453	(0.000)	[0.022, 0.066]	0.0416	(0.000)	[0.030, 0.055]	0.0396	(0.000)	[0.030, 0.048]
		Adjusted R2	37.93%		[30.75%, 47.33%]	42.45%		[38.64%, 49.24%]	27.09%		[24.12%, 30.19%]
4	Decompose first-stage Coefficient	Amihud	0.0014	(0.280)	[-0.008, 0.015]	0.0008	(0.237)	[-0.002, 0.005]	-0.0007	(0.236)	[-0.002, 0.001]
		Amihud percentage	0.44%	(0.280)	[-1.73%, 5.72%]	0.25%	(0.237)	[-0.52%, 1.55%]	-0.37%	(0.236)	[-0.93%, 0.66%]
		Amihud_vol	0.0174	(0.000)	[0.006, 0.024]	0.0056	(0.000)	[0.003, 0.008]	0.0014	(0.005)	[0.000, 0.004]
		Amihud_vol percentage	5.48%	(0.000)	[2.08%, 6.51%]	1.83%	(0.000)	[1.02%, 2.74%]	0.78%	(0.005)	[0.19%, 1.72%]
		IRC	0.0150	(0.184)	[-0.005, 0.075]	0.0113	(0.001)	[0.004, 0.024]	0.0074	(0.000)	[0.004, 0.011]
		IRC percentage	4.72%	(0.184)	[-2.47%, 14.12%]	3.71%	(0.001)	[1.72%, 6.31%]	4.20%	(0.000)	[2.27%, 5.59%]
		IRC_vol	-0.0007	(0.469)	[-0.020, 0.006]	0.0024	(0.092)	[-0.001, 0.007]	0.0020	(0.006)	[0.001, 0.003]
		IRC_vol percentage	-0.23%	(0.469)	[-3.88%, 2.37%]	0.80%	(0.092)	[-0.26%, 1.99%]	1.12%	(0.006)	[0.40%, 1.59%]
		γ	0.0388	(0.000)	[0.019, 0.098]	0.0265	(0.000)	[0.014, 0.045]	0.0097	(0.000)	[0.006, 0.018]
		γ percentage	12.20%	(0.000)	[7.85%, 19.39%]	8.66%	(0.000)	[5.66%, 12.42%]	5.51%	(0.000)	[3.40%, 9.70%]
		Bond_zero	-0.0007	(0.080)	[-0.003, 0.000]	0.0013	(0.117)	[-0.000, 0.004]	0.0013	(0.000)	[0.000, 0.003]
		Bond_zero percentage	-0.23%	(0.080)	[-0.82%, 0.09%]	0.43%	(0.117)	[-0.14%, 1.32%]	0.75%	(0.000)	[0.26%, 1.44%]
		Moody_rating	0.0903	(0.000)	[0.067, 0.132]	0.1243	(0.000)	[0.105, 0.169]	0.0759	(0.000)	[0.064, 0.097]
		Moody_rating percentage	28.35%	(0.000)	[20.03%, 40.95%]	40.64%	(0.000)	[35.69%, 49.67%]	43.09%	(0.000)	[38.67%, 47.55%]
		Leverage	0.0178	(0.000)	[0.013, 0.026]	0.0188	(0.000)	[0.015, 0.028]	0.0132	(0.000)	[0.010, 0.017]
		Leverage percentage	5.57%	(0.000)	[4.20%, 7.84%]	6.14%	(0.000)	[5.45%, 7.57%]	7.47%	(0.000)	[5.83%, 8.89%]
		Interest_coverage	-0.0149	(0.001)	[-0.027, -0.011]	-0.0175	(0.001)	[-0.031, -0.013]	-0.0105	(0.001)	[-0.017, -0.007]
		Interest_coverage percentage	-4.69%	(0.001)	[-7.68%, -3.52%]	-5.72%	(0.001)	[-7.92%, -4.97%]	-5.93%	(0.001)	[-8.27%, -4.46%]
		FCF/Debt	-0.0005	(0.257)	[-0.002, 0.004]	-0.0006	(0.300)	[-0.004, 0.004]	-0.0008	(0.176)	[-0.003, 0.001]
		FCF/Debt percentage	-0.17%	(0.257)	[-0.80%, 0.80%]	-0.20%	(0.300)	[-1.52%, 1.16%]	-0.44%	(0.176)	[-1.67%, 0.46%]

EBITDA/Sales	-0.0008	(0.095)	[-0.002, 0.000]	0.0014	(0.100)	[-0.000, 0.003]	-0.0024	(0.001)	[-0.004, -0.001]
EBITDA/Sales percentage	-0.25%	(0.095)	[-0.46%, 0.06%]	0.45%	(0.100)	[-0.11%, 0.92%]	-1.37%	(0.001)	[-2.10%, -0.84%]
Distance_to_default	-0.0184	(0.007)	[-0.025, -0.011]	-0.0173	(0.003)	[-0.025, -0.011]	-0.0084	(0.023)	[-0.013, -0.002]
Distance_to_default percentage	-5.77%	(0.007)	[-9.28%, -2.54%]	-5.67%	(0.003)	[-8.48%, -3.08%]	-4.76%	(0.023)	[-7.35%, -0.83%]
Book_to_market	0.0801	(0.000)	[0.028, 0.145]	0.0640	(0.000)	[0.033, 0.101]	0.0367	(0.000)	[0.024, 0.055]
Book_to_market percentage	25.15%	(0.000)	[12.22%, 32.32%]	20.91%	(0.000)	[13.46%, 24.48%]	20.81%	(0.000)	[14.26%, 26.57%]
Residual	0.0938	(0.000)	[5.46%, 17.04%]	0.0849	(0.000)	[6.16%, 12.88%]	0.0514	(0.000)	[4.14%, 7.22%]
Residual Percentage	29.44%	(0.000)	[22.899%, 34.814%]	27.77%	(0.000)	[24.632%, 30.460%]	29.15%	(0.000)	[26.338%, 32.502%]
Total	0.3185	(0.000)	[0.183, 0.569]	0.3059	(0.000)	[0.225, 0.447]	0.1762	(0.000)	[0.146, 0.235]
Percentage	100%			100%			100%		
Number of obs	12,248			23,515			43,090		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and bond volatility into a number of components each related to a candidate variable and a residual component. We conduct the decomposition for three different maturities: Short (maturity $\leq$ 2 years), Medium ($2 <$ maturity ≤ 5), and ($5 <$ maturity ≤ 30) Long Maturities. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 11: Multivariate Decomposition of the Relation Between Bond Yield Spread and Bond Volatility Using Both Illiquidity and Credit Proxies As Candidate Variables for Investment Grade and Non-investment Grade

			Investment grade			Non-investment grade		
Stage	Description	Variable	Coefficient	p-value	Conf. interval	Coefficient	p-value	Conf. interval
1	Regress yield spread	Bond_vol	0.0938	(0.000)	[0.072, 0.134]	0.1942	(0.000)	[0.138, 0.284]
	on bond volatility	Adjusted R2	21.17%		[15.95%, 30.36%]	29.63%		[25.18%, 40.62%]
2	Add candidate	Bond_vol	0.0522	(0.000)	[0.038, 0.083]	0.0779	(0.000)	[0.050, 0.129]
	variables to	Amihud	0.0620	(0.000)	[0.042, 0.080]	0.0728	(0.129)	[-0.023, 0.124]
	first-stage	Amihud_vol	0.0287	(0.000)	[0.016, 0.038]	0.0552	(0.066)	[-0.004, 0.115]
	regressions	IRC	0.3400	(0.000)	[0.205, 0.417]	1.1373	(0.000)	[0.411, 2.329]
		IRC_vol	-0.0412	(0.240)	[-0.081, 0.033]	-0.4250	(0.051)	[-0.931, -0.000]
		γ	0.0004	(0.000)	[0.000, 0.001]	0.0016	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0018	(0.001)	[-0.003, -0.001]	-0.0075	(0.017)	[-0.014, -0.002]
		Moody_rating	0.0017	(0.000)	[0.001, 0.002]	0.0032	(0.000)	[0.002, 0.004]
		Leverage	0.0112	(0.000)	[0.005, 0.018]	0.0612	(0.000)	[0.027, 0.080]
		Interest_coverage	0.0001	(0.000)	[0.000, 0.000]	0.0005	(0.021)	[0.000, 0.001]
		FCF/Debt	0.0065	(0.000)	[0.004, 0.008]	0.0023	(0.521)	[-0.009, 0.009]
		EBITDA/Sales	0.0012	(0.069)	[-0.000, 0.003]	-0.0103	(0.001)	[-0.015, -0.005]
		Distance_to_default	-0.0001	(0.156)	[-0.000, 0.000]	0.0014	(0.004)	[0.000, 0.002]
		Book_to_market	0.0103	(0.000)	[0.006, 0.014]	0.0260	(0.000)	[0.012, 0.031]
		Adjusted R2	53.84%		[48.33%, 61.07%]	57.68%		[55.71%, 67.63%]
3	Regress on candidate	Amihud	0.1469	(0.024)	[0.017, 0.256]	0.0567	(0.287)	[-0.183, 0.308]
	variables	Amihud_vol	0.3448	(0.000)	[0.255, 0.426]	0.1883	(0.002)	[0.090, 0.258]
		IRC	1.7995	(0.001)	[0.686, 2.746]	3.7800	(0.000)	[1.929, 4.646]
		IRC_vol	1.2895	(0.001)	[0.552, 1.971]	0.3486	(0.172)	[-0.298, 1.505]
		γ	0.0036	(0.000)	[0.002, 0.009]	0.0026	(0.000)	[0.002, 0.006]
		Bond_zero	-0.0140	(0.001)	[-0.021, -0.008]	-0.0508	(0.001)	[-0.065, -0.033]
		Moody_rating	0.0026	(0.000)	[0.002, 0.004]	0.0128	(0.000)	[0.008, 0.016]
		Leverage	0.0029	(0.317)	[-0.005, 0.011]	0.1127	(0.000)	[0.059, 0.191]
		Interest_coverage	0.0001	(0.214)	[-0.000, 0.000]	-0.0003	(0.531)	[-0.002, 0.002]
		FCF/Debt	-0.0035	(0.269)	[-0.008, 0.004]	-0.0232	(0.081)	[-0.044, 0.003]
		EBITDA/Sales	0.0284	(0.000)	[0.021, 0.036]	0.0418	(0.004)	[0.014, 0.064]
		Distance_to_default	-0.0005	(0.002)	[-0.001, -0.000]	-0.0001	(0.676)	[-0.002, 0.003]
		Book_to_market	0.0150	(0.000)	[0.011, 0.019]	0.0377	(0.000)	[0.028, 0.057]
		Adjusted R2	18.26%		[16.05%, 22.13%]	33.50%		[29.84%, 39.72%]
4	Decompose first-stage	Amihud	0.0019	(0.024)	[0.000, 0.005]	0.0008	(0.287)	[-0.002, 0.006]
	Coefficient	Amihud percentage	2.03%	(0.024)	[0.21%, 3.89%]	0.39%	(0.287)	[-1.17%, 2.37%]
		Amihud_vol	0.0059	(0.000)	[0.004, 0.008]	0.0039	(0.002)	[0.001, 0.008]
		Amihud_vol percentage	6.27%	(0.000)	[4.69%, 7.70%]	2.00%	(0.002)	[0.90%, 3.28%]
		IRC	0.0043	(0.001)	[0.002, 0.008]	0.0125	(0.000)	[0.005, 0.023]
		IRC percentage	4.57%	(0.001)	[1.83%, 7.02%]	6.43%	(0.000)	[3.29%, 8.69%]
		IRC_vol	0.0031	(0.001)	[0.001, 0.005]	0.0012	(0.172)	[-0.001, 0.006]
		IRC_vol percentage	3.34%	(0.001)	[1.52%, 4.78%]	0.63%	(0.172)	[-0.59%, 2.77%]
		γ	0.0112	(0.000)	[0.008, 0.016]	0.0198	(0.000)	[0.011, 0.033]
		γ percentage	11.90%	(0.000)	[8.26%, 16.04%]	10.22%	(0.000)	[7.73%, 12.35%]
		Bond_zero	0.0001	(0.466)	[-0.000, 0.001]	0.0057	(0.000)	[0.002, 0.012]
		Bond_zero percentage	0.11%	(0.466)	[-0.38%, 0.92%]	2.93%	(0.000)	[1.25%, 6.23%]
		Moody_rating	0.0125	(0.000)	[0.009, 0.017]	0.0521	(0.000)	[0.042, 0.066]
		Moody_rating percentage	13.30%	(0.000)	[9.12%, 17.52%]	26.82%	(0.000)	[20.58%, 34.83%]
		Leverage	0.0001	(0.295)	[-0.000, 0.000]	0.0126	(0.000)	[0.008, 0.020]
		Leverage percentage	0.06%	(0.295)	[-0.06%, 0.32%]	6.49%	(0.000)	[4.34%, 10.88%]
		Interest_coverage	-0.0007	(0.215)	[-0.003, 0.001]	0.0006	(0.530)	[-0.003, 0.005]
		Interest_coverage percentage	-0.71%	(0.215)	[-2.79%, 0.82%]	0.28%	(0.530)	[-1.80%, 2.24%]
		FCF/Debt	0.0002	(0.268)	[-0.000, 0.001]	0.0008	(0.080)	[-0.000, 0.003]
		FCF/Debt percentage	0.24%	(0.268)	[-0.24%, 0.60%]	0.43%	(0.080)	[-0.03%, 1.45%]
		EBITDA/Sales	0.0001	(0.292)	[-0.000, 0.001]	-0.0036	(0.005)	[-0.008, -0.001]

EBITDA/Sales percentage	0.06%	(0.292)	[-0.33%, 0.90%]	-1.88%	(0.005)	[-3.42%, -0.65%]
Distance_to_default	0.0031	(0.001)	[0.001, 0.006]	0.0002	(0.675)	[-0.008, 0.004]
Distance_to_default percentage	3.34%	(0.001)	[1.27%, 5.62%]	0.12%	(0.675)	[-3.77%, 2.38%]
Book_to_market	0.0094	(0.000)	[0.006, 0.014]	0.0359	(0.000)	[0.014, 0.071]
Book_to_market percentage	9.98%	(0.000)	[6.47%, 12.92%]	18.49%	(0.000)	[9.48%, 27.41%]
Residual	0.0427	(0.000)	[3.12%, 6.59%]	0.0517	(0.000)	[3.34%, 7.86%]
Residual Percentage	45.51%	(0.000)	[41.220%, 51.523%]	26.64%	(0.000)	[21.323%, 30.051%]
Total	0.0938	(0.000)	[0.072, 0.134]	0.1942	(0.000)	[0.138, 0.284]
Percentage	100%			100%		
Number of obs	65,201			13,747		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between yield spreads and bond volatility into a number of components each related to a candidate variable and a residual component. We separately conduct the decomposition for investment grade and non-investment grade bonds. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 12: Multivariate Decomposition of the Relation Between Bond Yield Spread and Bond Volatility Using Portfolios Sorted by Bond Volatility

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.2248	(0.000)	[0.150, 0.332]
		Adjusted R2	54.22%		[46.97%, 72.90%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.0308	(0.031)	[0.003, 0.074]
		Amihud	0.2690	(0.002)	[0.088, 0.369]
		Amihud_vol	0.1577	(0.013)	[0.026, 0.226]
		IRC	0.9222	(0.029)	[0.116, 2.090]
		IRC_vol	-0.5716	(0.004)	[-0.809, -0.127]
		γ	0.0025	(0.000)	[0.001, 0.004]
		Bond_zero	-0.0138	(0.001)	[-0.019, -0.008]
		Moody_rating	0.0031	(0.000)	[0.002, 0.004]
		Leverage	0.0605	(0.000)	[0.024, 0.088]
		Interest_coverage	0.0003	(0.004)	[0.000, 0.001]
		FCF/Debt	0.0052	(0.398)	[-0.007, 0.012]
		EBITDA/Sales	-0.0047	(0.110)	[-0.012, 0.002]
		Distance_to_default	0.0026	(0.013)	[0.000, 0.004]
		Book_to_market	0.0366	(0.000)	[0.013, 0.055]
		Adjusted R2	83.71%		[82.79%, 90.88%]
3	Regress on candidate variables	Amihud	0.1369	(0.219)	[-0.212, 0.626]
		Amihud_vol	0.5994	(0.000)	[0.353, 1.104]
		IRC	6.2530	(0.014)	[1.819, 8.615]
		IRC_vol	2.7008	(0.057)	[-0.080, 3.838]
		γ	0.0031	(0.000)	[0.001, 0.019]
		Bond_zero	-0.0545	(0.001)	[-0.077, -0.028]
		Moody_rating	0.0202	(0.000)	[0.012, 0.027]
		Leverage	0.1076	(0.006)	[0.016, 0.169]
		Interest_coverage	-0.0004	(0.244)	[-0.002, 0.000]
		FCF/Debt	-0.0325	(0.303)	[-0.081, 0.035]
		EBITDA/Sales	0.0882	(0.001)	[0.046, 0.111]
		Distance_to_default	0.0059	(0.096)	[-0.001, 0.011]
		Book_to_market	0.0476	(0.000)	[0.024, 0.070]
		Adjusted R2	69.34%		[64.76%, 76.93%]
4	Decompose first-stage Coefficient	Amihud	0.0020	(0.219)	[-0.003, 0.011]
		Amihud percentage	0.89%	(0.219)	[-1.30%, 4.40%]
		Amihud_vol	0.0129	(0.000)	[0.007, 0.024]
		Amihud_vol percentage	5.73%	(0.000)	[3.70%, 8.71%]
		IRC	0.0195	(0.014)	[0.004, 0.041]
		IRC percentage	8.68%	(0.014)	[2.30%, 14.68%]
		IRC_vol	0.0089	(0.057)	[-0.000, 0.018]
		IRC_vol percentage	3.95%	(0.057)	[-0.14%, 5.86%]

γ	0.0258	(0.000)	[0.010, 0.055]
γ percentage	11.49%	(0.000)	[5.35%, 26.75%]
Bond_zero	0.0011	(0.018)	[0.000, 0.003]
Bond_zero percentage	0.48%	(0.018)	[0.05%, 1.32%]
Moody_rating	0.1210	(0.000)	[0.082, 0.144]
Moody_rating percentage	53.83%	(0.000)	[39.51%, 63.65%]
Leverage	0.0130	(0.006)	[0.003, 0.017]
Leverage percentage	5.78%	(0.006)	[1.11%, 8.44%]
Interest_coverage	0.0019	(0.243)	[-0.003, 0.007]
Interest_coverage percentage	0.83%	(0.243)	[-1.28%, 3.52%]
FCF/Debt	0.0018	(0.302)	[-0.001, 0.007]
FCF/Debt percentage	0.80%	(0.302)	[-0.77%, 2.77%]
EBITDA/Sales	-0.0062	(0.002)	[-0.012, -0.002]
EBITDA/Sales percentage	-2.75%	(0.002)	[-3.82%, -1.31%]
Distance_to_default	-0.0199	(0.097)	[-0.026, 0.004]
Distance_to_default percentage	-8.84%	(0.097)	[-15.73%, 1.46%]
Book_to_market	0.0336	(0.000)	[0.012, 0.061]
Book_to_market percentage	14.93%	(0.000)	[6.39%, 20.31%]
Residual	0.0094	(0.031)	[0.11%, 1.78%]
Residual Percentage	4.19%	(0.031)	[0.455%, 8.924%]
Total	0.2248	(0.000)	[0.150, 0.332]
Percentage	100%		
Number of obs	11,598		

We use panel regressions with cross-sectionally demeaned variables to decompose the relation between portfolio yield spreads and portfolio bond volatility into a number of components with each related to a portfolio candidate variable and a residual component. Each month, we sort individual bonds into 100 portfolios by bond volatility. The portfolio-level variable is the weighted average of the corresponding individual bond-level variable within a portfolio using amount outstanding as the weight. We use both illiquidity measures and credit risk measures as candidate variables. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, *EBITDA/Sales*, *Distance_to_default*, and *Book_to_market*. All variables are used in decimals. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on Goncalves (2011) (see Appendix B). The numbers in parentheses are t-values, and the numbers in square-brackets are confidence intervals. The p-value is defined as the fraction of bootstrap estimates that are less (greater) than zero if the point estimate is greater (less) than zero. The confidence interval is between the 5th and 95th percentiles of the bootstrap estimates. See Table 13 for variable descriptions.

Table 13: Variable Descriptions

Variable	Description
Yield_spread	Bond yield based on the average price using trades from the 21st of the month or later for a bond in the month minus the relevant end-of-month Treasury yield for the bond.
Bond_vol	Monthly volatility of bond returns using value-weighted bond prices as in Bao and Pan (2013) and data from the previous 12 months.
Maturity	A bond's time to maturity in years.
Amt.	A bond's amount outstanding in $mm of face value.
Moody_rating	A numerical translation of Moody's rating, where 1=Aaa and 21=C.
Bond_zero	Defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012).
Amihud	The price impact of a trade per unit traded at the monthly frequency. This variable is calculated on the subset of trades of at least $100k face value. We first calculate the daily price impact using transactions within each day and then use the median of daily values over the last month. It is similarly defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012).
Amihud_vol	The standard deviation of the daily Amihud values over the past month using trades of at least $100k face value. It is similarly defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012).
IRC	The imputed round trip trades using trades of at least $100k face value. We first calculate daily imputed round trip trades for each day and then use the mean of daily values over the last month. It is similarly defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012).
IRC_vol	The standard deviation of the daily IRC measure over the past month using trades of at least $100k face value. It is similarly defined and calculated as in Dick-Nielsen, Feldhutter, and Lando (2012).
γ	The negative covariance between the price changes in two consecutive periods. We construct this measure monthly using daily data as in Bao, Pan, and Wang (2011) requiring at least 10 observations of paired price changes.
Assets	Compustat data item AT.
Sales	Compustat data item SALE.
Leverage	Total liabilities divided by total assets (LT/AT).
EBITDA/Sales	Earnings before interest divided by sales.
Interest_coverage	Operating income after depreciation plus interest and related expense divided by Interest and Related Expense ((OIADP+XINT)/XINT) based on Blume, Lim, and MacKinlay (1998). The ratio is set to 100 if it is greater than 100 or if firm has 0 or negative interest expense.

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Variable	Description
FCF/Debt	Free cash flow divided by total liability. Free cash flow is defined using Compustat data as EBITDA minus change in current assets (ACT) plus change in current liabilities (LCT) minus capital expenditures (CAPX).
Equity_vol	The volatility of equity returns using the data from the previous 12 months.
Distance_to_default	Distance-to-default, calculated as in Campbell, Hilscher, and Szilagyi (2008) and Bao and Hou (2013).
Book_to_market	Book equity (CEQ) divided by market equity. Market equity is PRCC_F×CSHO from Compustat, adjusted for returns without dividends from CRSP.

This table reports the name, description, and data source of the variables used in this paper.