Prices and Volatilities in the Corporate Bond Market

Jack Bao, Jia Chen, Kewei Hou, and Lei Lu*

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Abstract

We document a strong cross-sectional positive relation between corporate bond yield spreads and bond return volatilities. A ten percentage point increase in return volatility is associated with a two percentage point increase in yield spread. As both yield spreads and bond return volatilities tend to be higher for lower credit quality and more illiquid bonds, the yield spread-return volatility relation is potentially attributable to both credit and illiquidity. To quantify the relative contributions of these two sources, we decompose the coefficient from the yield spread-return volatility regression into a component related to credit, a component related to illiquidity, and a residual component. Collectively, the credit and illiquidity components can explain approximately two-thirds of the yield spread-return volatility relation with credit and illiquidity contributing in a 1.76:1 ratio. Ratings are the most important credit risk proxy while many illiquidity proxies, including autocovariances of log returns and implied round-trip costs, all contribute to the yield spread-return volatility relation. The credit-to-illiquidity contribution ratio is smaller during the subprime crisis, suggesting that heightened illiquidity during the crisis changes the dynamics of the yield spread-return volatility relation. We also find the ratio to be higher for the speculative-grade subsample, consistent with credit risk being relatively more important for understanding the price dynamics of speculative-grade bonds.

*Bao is at the Fisher College of Business, Ohio State University, bao_40@fisher.osu.edu. Chen is at the Guanghua School of Management, Peking University, chen.1002@gmail.com. Hou is at the Fisher College of Business, Ohio State University and CAFR, hou.28@osu.edu. Lu is at the Guanghua School of Management, Peking University, leilu@gsm.pku.edu.cn.

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) and Campbell (1996)) shows that in a multi-period 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,[1] a topic that has received significantly less attention in the literature. Bao and Pan (2013) find that high empirical bond volatility is associated with both poorer credit quality and lower liquidity. We document that bond return volatility on its own can explain 37.0% 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 1.46%.[2] In comparison, the average A yield spread in our sample is 1.40% as compared to the average Baa yield spread of 2.05%.

The strong cross-sectional relation between yield spreads and bond return volatilities can be understood through the lens of both credit risk and the illiquidity of corporate bonds. A simple Merton (1974) model predicts that firms with greater return volatility will have higher credit spreads. Empirical results such as Chen, Lesmond, and Wei (2007) and Bao, Pan, and Wang (2011) suggest that corporate bond illiquidity is priced. Dick-Nielsen, Feldhutter, and

[1] Campbell and Taksler (2003) find that yield spreads are strongly related to equity volatility, but bond return volatilities are a significant more relevant metric for bond investors in gauging the risk of investing in corporate bonds.

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

Lando (2012) find that the volatility of illiquidity is also priced. To the extent that highly illiquid bonds also have more time-varying illiquidity, this also predicts that yield spreads and bond return volatility should be positively related.

To quantify the relative contributions of credit risk and illiquidity in explaining the yield spread-return volatility relation, we turn to the decomposition methodology of Hou and Loh (2013). The methodology allows for a multistage analysis where the coefficient on the yield spread-return volatility regression is decomposed into parts explained by a series of candidate variables proxying for credit risk and illiquidity. 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 proxies, we consider Moody's ratings, leverage, interest coverage ratio, free cash flow-to-debt, and EBITDA-to-sales. We find that the credit proxies together can explain 42.29% of the relation between yield spreads and volatility, but the illiquidity proxies are also important, explaining 23.99%. The ratio of these two fractions is 1.76:1.

Next, 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.[3] We then decompose the relation between yield spreads and equity volatility into credit quality and bond illiquidity components, finding that credit quality has nearly four 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.

We also consider the price-return volatility relation in a number of sample cuts. We find that during the subprime crisis, the relative explanatory power of illiquidity in the yield spread-return volatility relation increases. In particular, the ratio of credit-to-illiquidity in explaining the yield spread-return volatility relation drops to 1.43 as compared to 1.86

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

precrisis. This is consistent with the literature on bond illiquidity, which suggests that illiquidity was a main driver of yield spreads in the crisis.[4] Turning to maturity, we find that the relative contribution of illiquidity to explaining the yield spread-volatility relation is stronger for shorter maturity bonds. Finally, 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 credit fundamentals can explain a greater proportion of speculative-grade yield spreads.

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.[5] The R^2 values found in these studies are typically in the range of 50%, 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.

Huang and Huang (2012) document that in explaining the credit spread puzzle, 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.[6] 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

[4] For example, see Bao, Pan, and Wang (2011), Dick-Nielsen, Feldhutter, and Lando (2012), and Friewald, Jankowitsch, and Subrahmanyam (2012).

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

[6] 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.

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 return volatility. Section 4 decomposes the yield spread-bond return volatility relation into credit and illiquidity components. In Section 5, we consider a number of sample cuts and Section 6 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 somewhat 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.[7]

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

[7] 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.

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.

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.[8] Bonds without equity information are also dropped as we use CRSP information to determine industry classification. Finally, bonds without a rating are also dropped.

Table 1 summarizes the corporate bonds in our sample. The average yield spread in our sample is 2.24%.[9] We have 12,178 bonds in our sample and 465,719 bond-month observations. The average maturity of bonds is 8.38 years, the average face value is $358.70 million, and the average Moody's rating (*Moody_rating*) is 8.01 (corresponding to a Baa1 rating). These numbers are similar to the broader Mergent FISD as reported in Bao and Pan (2013). The average volatility of bond returns calculated using value-weighted bond prices (*Bond_vol*) is 7.87% compared to 6.86% in Bao and Pan (2013).[10] The average fraction of bond zero-trading days (*Bond_zero*) is 66.11%. 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 average *Amihud* and *Amihud_vol* are 0.012 and

[8]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.

[9]Yield spreads are calculated using the yield based on the last trade in a month minus a comparable Treasury yield interpolated from the Constant Maturity Treasury series. Results using yields obtained from value-weighted bond prices are not materially different.

[10]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.

0.0151, respectively, and the average *IRC* and *IRC_vol* are 0.0026 and 0.0027, respectively. We follow Bao, Pan, and Wang (2011) and define γ as the negative covariance between the price changes in two consecutive periods. The mean and median of γ are 1.76 and 0.48, respectively.

In Table 2, we report summary statistics for the firms corresponding to our corporate bond sample. There are 833 unique firms in our sample. The average of book leverage (*Leverage*), which defined as total liabilities divided by total assets, is 0.71, a number equal to the median of this variable. As a measure of operational efficiency, we use *EBITDA/Sales*, defined using Compustat data as OIADP/AT. It has a mean of 0.21. *Interest_coverage* is defined as (OIADP+ XINT)/XINT following Blume, Lim, and MacKinlay (1998) and has a mean of 6.61. On average, the free cash flow to debt (*FCF/Debt*) and volatility of equity returns (*Equity_vol*) are 0.10 and 28.88%, respectively.

2.3 Decomposition methodology

We use the methodology developed in Hou and Loh (2013) to first quantify the relation between bond yield spread and bond return volatility and then to explain this relation through credit quality and illiquidity variables. In particular, we first estimate panel regressions of bond yield spread on bond return volatility:

$$Yield\_spread^{dm}_{i,t} = \rho^{dm} Bond\_vol^{dm}_{i,t} + \epsilon^{dm}_{i,t}. \qquad (1)$$

We use cross-sectionally demeaned variables indicated by the superscript dm to examine the cross-sectional relation between bond yield spread and bond return volatility. $Yield\_spread^{dm}_{i,t}$ denotes the yield spread of bond and $Bond\_vol^{dm}_{i,t}$ is bond return volatility. ρ^{dm} measures the cross-sectional relation between bond yield spread and bond return volatility. In our baseline regressions, the estimated ρ^{dm} is 0.205 with a t-value of 10.35 (see Table 3). This positive relation between bond yield spread and bond return volatility is robust when we control for a number of illiquidity and credit risk measures.

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

$$Bond\_vol^{dm}_{i,t} = \delta^{dm} Candidate^{dm}_{i,t} + \mu^{dm}_{i,t}. \tag{2}$$

This regression allows us to assess the cross-sectional relation between bond return volatility and the candidate variable using the demeaned variables. As noted by Hou and Loh (2013), any candidate variable that can potentially explain the relation between bond yield spread and bond return volatility should be correlated with bond return volatility.[11] We then use the regression coefficient estimates to decompose $Bond\_vol^{dm}_{i,t}$ into two orthogonal components: (1) $\delta^{dm} Candidate^{dm}_{i,t}$ is the component of $Bond\_vol^{dm}_{i,t}$ that is related to the candidate variable, and (2) $\mu^{dm}_{i,t}$ is the 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 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 the candidate variable. We determine the statistical significance by using the Moving Blocks Bootstrap (MBB) method based on

[11] A high correlation with bond return volatility does not guarantee that the candidate variable can explain a large fraction of the yield spread-return volatility relation because the part of bond return 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.

Goncalves (2011).[12] In each iteration of the bootstrap, we randomly pick with replacement blocks of consecutive cross sections from the actual sample to form a new sample. We then estimate panel regressions using this new sample and calculate the p-value and 5th and 95th percentiles of the bootstrap estimates. We resample the entire cross-sections to deal with the correlation of observations across firms and use blocks of consecutive cross-sections to preserve the serial dependence of the data. We set the length of blocks to be 6 months and use 12- and 24-month blocks to check the robustness of the results. We conduct 1000 bootstrap iterations, and 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.

3 The Relation Between Bond Yield Spread and Bond Return Volatility

In this section, we document the relation between yield spread and bond return volatility. Specifically, we estimate a regression of bond yield spread on bond return volatility (*Bond_vol*). We then control for a number of illiquidity and credit risk measures in the regressions. The illiquidity measures include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*, and the credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, and *EBITDA/Sales*.

In Table 3, we present the estimation results of regressions of bond yield spread on *Bond_vol* and illiquidity and credit risk measures using 82,272 bond-month observations.[13] The relation between bond yield spread and *Bond_vol* is positive and both statistically and economically significant. The estimated coefficient on *Bond_vol* is 0.205, and the t-value is 10.35. A one standard deviation increase in *Bond_vol* is associated with an increase of 1.46%

[12]See Appendix A for a more detailed discussion.

[13]The number of observations is 82,272 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.

in bond yield spread, which is 65% of the overall mean of yield spread in our sample. Based on the adjusted R^2, bond return volatility can explain 37% of the cross-sectional variation in bond yield spread. 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 9.98 to 11.2 and an adjusted R^2 ranging from 0.370 to 0.416.

In addition, most of the coefficients on illiquidity measures are positive and statistically significant at 1% confidence level. For example, the coefficient of γ is 0.00165 with a t-value of 3.90, which is consistent with Bao, Pan, and Wang (2011). The coefficients of *Amihud*, *Amihud_vol*, *IRC*, and *IRC_vol* are 0.160, 0.141, 1.210, and 0.711 with t-values of 4.40, 5.81, 8.07, and 6.84, respectively. These results are consistent with the findings of Dick-Nielsen, Feldhutter, and Lando (2012) that these variables are positively related to yield spread. Consistent with the results of Bao, Pan, and Wang (2011) and Dick-Nielsen, Feldhutter, and Lando (2012), *Bond_zero* is not significantly related to yield spread.[14] Controlling for all six illiquidity measures, *Bond_vol* is still positive and significant at the 1% confidence level (=0.170, t-value=10.79), and the adjusted R^2 is 0.428.

Next, we present the results of regressions of yield spread on bond return volatility and credit risk measures. The coefficient on *Bond_vol* remains positive and significant when we control for *Moody_rating* (=0.131, t-value=7.43). Adding *Moody_rating* to the base regression increases the adjusted R^2 to 0.540. Furthermore, in the same regression, *Moody_rating* is positively related to yield spread with a coefficient of 0.00334 and a t-value of 18.87. Both *Bond_vol* and *Moody_rating* have strong explanatory power for bond yield spread. Since *Moody_rating* does not drive out the explanatory power of *Bond_vol*, a part of the relation between bond yield spread and bond return volatility is independent of *Moody_rating*.

When we control for *Leverage*, the coefficients of *Bond_vol* and *Leverage* are both positive and statistically significant at 1% confidence level. The coefficients of *Interest_coverage*, *FCF/Debt*, and *EBITDA/Sales* are negative and significant when we control for them one

[14] 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).

at a time. These models are all consistent with firms in better financial positions having lower yield spreads. When we control for all five credit risk measures, *Bond_vol* is still positive and significant with a coefficient of 0.120 and the t-value of 7.39. Interestingly, many of the credit risk measures lose significance or flip signs when we control for *Moody_rating*. The adjusted R^2 of the regressions with credit variables ranges from 0.370 to 0.545. Finally, controlling for all six illiquidity and five credit risk measures, we find that *Bond_vol* remains positive and significant (=0.102, t-value=7.32) and the adjusted R^2 is 0.589. Thus, we find a strong and robust relation between yield spread and *Bond_vol*.

4 Decomposition of the Relation Between Bond Yield Spread and Bond Return Volatility

Bond return 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 shocks in underlying firm value,[15] leading to larger return volatility. Greater illiquidity is also associated with greater return volatility 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 return 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 return volatility relation using illiquidity measures. Panel A conducts the univariate analysis, and Panel B conducts multivariate analysis. We explain the univariate analysis results using γ as an example. Stage 1 reports the contemporaneous panel regressions of bond yield spread on

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

value-weighted bond return volatility. The estimated coefficient of *Bond_vol* using the whole sample is 0.2152[16] with a p-value of 0.000. The 5th and 95th percentile of the bootstrap estimates are 0.152 and 0.290, respectively, which are reported between square brackets. The adjusted R^2 is 36.17% with the 5th and 95th percentiles of 29.35% and 37.43%, respectively.

In Stage 2, we add γ to the first stage panel regression. The estimated coefficient of γ is 0.0015 with a p-value of 0.000 and the 5th and 95th percentiles of 0.001 and 0.002, respectively. These numbers are consistent with Bao, Pan, and Wang (2011) who find that γ captures an illiquidity effect and thus yield spread is positively related to γ. We find that, even controlling for γ, the estimated coefficient of *Bond_vol* is still positive and statistically significant (=0.1818, p-value=0.000) and that the adjusted R^2 of the regression is 42.56%.

In Stage 3, we estimate 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 the 5th and 95th percentile of 0.004 and 0.012, respectively. The adjusted R^2 is 11.98% with the 5th and 95th percentiles of 9.25% and 16.62%, respectively. These results demonstrate that γ is positively significantly related to *Bond_vol* and can explain 11.98% of the variation in *Bond_vol*.

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 0.0552 with a p-value of 0.000 and the 5th and 95th percentiles of 0.035 and 0.085, respectively. The coefficient of ρ^R is 0.1601 with a p-value of 0.000 and the 5th and 95th percentiles of 0.1182 and 0.2198, respectively. The sum of $\rho^{\gamma,dm}$ and $\rho^{R,dm}$ equals to the Stage 1 coefficient of *Bond_vol*, 0.2152. Therefore, the relative contribution of γ in explaining the yield spread-return volatility relation is 25.63% ($=\rho^{\gamma,dm}/\rho$=0.0552/0.2152, with a p-value of 0.000 and the 5th and 95th percentiles of 20.46% and 30.78%, respectively), and the relative contribution of residual is 74.37%, with a p-value of 0.000 and 5th and 95th percentiles of 70.44% and 83.70%, respectively). This analysis shows that γ can explain a substantial

[16]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 136,382 while the number of observations in Table 3 is 82,272.

fraction of the yield spread-return 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.[17]

Using the same decomposition method, we examine the other five illiquidity measures (e.g., *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, and *Bond_zero*). The coefficients of candidate variables at the Stage 2 show that most of the illiquidity measures are positive and significantly related to yield spread. The only exception is *Bond_zero*, which is negatively related to yield spread. The coefficients of illiquidity measures of Stage 3 show that the illiquidity measures (except *Bond_zero*) are significantly related to bond volatility with p-values of 0.000 and adjusted R^2s ranging from 4.39% (for *Amihud*) to 8.61% (for *IRC_vol*). In Stage 4, *Amihud*, *Amihud_vol*, *IRC*, and *IRC_vol* can respectively explain 7.75%, 14.31%, 11.07%, and 12.64% of yield spread-return volatility relation. However, *Bond_zero* can explain only 0.03% of the relation and this fraction is statistically insignificant. In sum, the univariate decomposition analyses demonstrate that most of the illiquidity measures can explain a fraction of the yield spread-return volatility relation.

Panel B reports the results of multivariate analysis consisting of all six illiquidity measures. Through this analysis, we can calculate not only the marginal contribution of each illiquidity measure but also the total contribution of six illiquidity measures in explaining the yield spread-return volatility relation. The coefficients of Stage 3 show that, except for *Bond_zero*, other five illiquidity measures are positively related to *Bond_vol* with p-values less than 0.05, while *Bond_zero* is negatively related to *Bond_vol*. These results are consistent with the univariate analysis. Stage 4 demonstrates that among all illiquidity measures, γ contributes the most to the yield spread-return volatility relation, explaining 20.90% of the relation. The next most important measure is *IRC* explaining 8.38%, compared to 11.07% explanatory power in the univariate analysis. The fractions of the relation explained by

[17] 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.

Amihud, *Amihud_vol*, and *IRC_vol* are 1.24%, 6.60%, and 1.72%, respectively. These fractions are small relative to that explained by γ. The variable that explains the least fraction is *Bond_zero*, which explains 0.40%. In addition, the total contribution of the six illiquidity measures is 39.23%, leaving 60.77% of the yield spread-return volatility relation unexplained by these six illiquidity measures. These results show that the illiquidity measures can explain a substantial fraction of yield spread-return volatility relation.

4.2 Credit Risk Measures

Table 5 reports the decomposition results on 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=18.58%) 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-return volatility relation. This fraction is larger than the fraction explained by any of the other five illiquidity measures. *Leverage* and *Interest_coverage* have the next highest explanatory power among the credit variables, explaining 7.19% and 6.96%, and *FCF/Debt* and *EBITDA/Sales* explain 3.06% and 3.66%, respectively. 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 high fraction of the yield spread-return volatility relation than any of the illiquidity measures.[18]

Panel B presents the multivariate analysis that uses five credit risk measures. The fraction explained by *Moody_rating* is 44.02%, which is close to the fraction explained by *Moody_rating* in the univariate analysis (42.74%). Thus, other credit risk measures do not affect the importance of *Moody_rating* in explaining the yield spread-return volatility relation. The fraction explained by the other four credit risk measures are either small or negative. For example,

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

the fraction explained by *Leverage*, *FCF/Debt*, and *EBITDA/Sales* are 1.29%, 0.51%, and 0.05%, compared to 7.19%, 3.06%, and 3.66% in the univariate analysis. *Interest_coverage* experiences the largest change in explanatory power: a fall from 6.96% in the univariate analysis to -2.86% in the multi-variate analysis. The total fraction explained all five credit risk measures is 43.00%.

To directly compare between all illiquidity measures and credit risk measures, we conduct 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* is the most important candidate variable in explaining the yield spread-return volatility relation: the fraction explained is 44.84%. The fraction explained by γ is 12.42%, which is ranked second. The next four relatively important candidate variables are *IRC*, *Amihud_vol*, *IRC_vol*, and *Leverage*, whose fractions explained are 5.36%, 3.32%, 1.86%, and 1.73%, respectively.

The directly comparison allows us to quantify the relative contribution of illiquidity and credit risk in explaining the yield spread-return volatility relation. The total fraction explained by all illiquidity measures is 23.99%, and the total fraction explained by all credit risk measures is 42.29%. 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 a 1.76:1 ratio. In total, the six illiquidity and five credit risk measures contribute 66.27% of the yield spread-return volatility relation, leaving 33.73% of the relation unexplained. Credit risk and illiquidity measures together can explain a substantial fraction of the relation between bond yield spread and bond return volatility.

5 Additional Tests

In this section, we further examine the yield spread-volatility relation. First, we use an alternative volatility measure – equity volatility – to examine the relative contributions of illiquidity and credit risk measures in explaining the yield spread-equity return volatility relation. Second, we separate the whole sample into three periods: precrisis, crisis, and postcrisis periods. Third, we classify the bonds into short-, medium-, and long-term maturity. Finally, we separately examine investment- and speculative-grade bonds.

5.1 Alternative Volatility Measure: Equity Volatility

Previous literature, starting with Campbell and Taksler (2003), has found 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 return volatility, there is no direct relation between equity return 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 is significantly related to most of the candidate variables, including a positive relation with proxies for illiquidity. However, the most economically significant variable is *Moody_rating* as 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 2.87 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* alone explains 59.29% of the yield spread-equity volatility relation. In contrast, our six illiquidity proxies together explain only 14.61% of the yield spread-equity volatility relation, with *IRC* being the most significant contributor at 9.09%. In contrast to the yield spread-bond return volatility relation where the relative credit-to-illiquidity contribution ratio is less than 2:1, the ratio here is close to 4:1, reflecting the fact that equity volatility is a direct measure of credit quality, but not illiquidity.

5.2 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 corporate bond market liquidity deteriorated and yield spreads spiked during the Subprime mortgage crisis. Furthermore, these papers attribute much of the spike in yield spreads to the contemporaneous spike in illiquidity rather than a deterioration in credit quality. Thus, it is potentially possible that the proportion of the yield spread-bond return volatility that can be explained by illiquidity variables changes around the subprime crisis. To address this possibility, we split our sample into three periods, following the time splits in Dick-Nielsen, Feldhutter, and Lando (2012). The precrisis period is defined as the period up to March 2007, the crisis period as April 2007 to June 2009, and the postcrisis period as July 2009 and onwards.

Table 8 presents the decomposition results with multivariate analysis. We first examine the precrisis period. Similar to the results of Table 6, *Moody_rating* and γ are the two most important variables with the explanatory power of 43.12% and 10.66%, respectively. *IRC* and *Leverage* are also important with the explanatory power larger than 5% (8.03% and 5.31%, respectively). *Amihud*, *Amihud_vol*, and *FCF/Debt* have smaller contributions in explaining the yield spread-equity volatility relation (2.09%, 1.93%, and 1.63%, respectively). When we turn to the crisis and postcrisis periods, most of the results are similar to the precrisis period. For example, *Moody_rating* and γ dominate other candidate variables with the explanatory power of 40.40% and 16.46% during crisis period, and 47.61% and 16.05% during postcrisis period, respectively. *Amihud_vol* and *IRC* are less important with the explanatory power of 3.21% and 5.29% for crisis period and 3.99% and 1.33% during postcrisis period, respectively. However, there are some minor differences: *IRC_vol* has explanatory power of 2.00% and 3.40% during crisis and postcrisis periods, respectively, while it has negative explanatory power of -0.17% during precrisis period. In addition, *Leverage* and *FCF/Debt* have almost no explanatory power during crisis and postcrisis periods. We find a fairly high total contribution from illiquidity and credit regardless of period – the explanatory power is 70.74%, 62.44%, and 69.84% during precrisis, crisis, and postcrisis periods, respectively. However, we find some differences in the relative contributions of credit and illiquidity. During the financial crisis, the ratio of credit-to-illiquidity in explaining the yield spread-return volatility relation is 1.43 as compared to 1.86 and 1.66 for the pre- and post-crisis periods, respectively. Our results are consistent with the crisis largely affecting illiquidity in the corporate bond market and thus affecting the relative contribution of illiquidity to the yield spread-return volatility relation.

5.3 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-return volatility relation.

Table 9 presents the decomposition results with multivariate analysis. We first examine the short-term bonds. The results of Stage 4 show that three illiquidity measures (e.g., γ, *Amihud_vol*, and *IRC*) and two credit risk measures (e.g., *Moody_rating* and *Leverage*) are important in explaining the yield spread-return volatility relation. *Moody_rating* and γ still dominate other candidates with the explanatory power of 30.44% and 18.58%, and *Amihud_vol*, *IRC*, and *Leverage* explain 8.06%, 7.95%, and 3.13%, respectively. When we turn to medium- and long-term maturities, the order of the importance of candidate variables in explaining the yield spread-return volatility relation does not change.

The relative contribution of illiquidity and credit risk measures, however, differ between different maturities. The total contribution of all illiquidity measures is 20.07% and 15.68% for medium and long-term maturity bonds, respectively, while it is 33.1% for short-term maturity bonds. The total contribution of all credit risk measures is 46.19% and 50.56% for medium and long-term maturity bonds, respectively, while it is 29.57% for short-term maturity bonds. This means that credit risk and illiquidity contribute to the yield spread-return volatility relation in ratios of 2.30 and 3.22 for medium and long-term maturity bonds and in a ratio of 0.89 for short-term maturity bonds.[19] Illiquidity is relatively more important for short-term maturity bonds than for other maturities in explaining the yield spread-return volatility.

[19]The total contribution of illiquidity and credit risk measures does not significantly change across maturities (62.66%, 64.25%, and 66.25% for short-, medium-, and long-term maturity, respectively).

5.4 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. We use value-weighted bond volatility to examine the relative contributions of illiquidity and credit risk measures in explaining the yield spread-return volatility relation for bonds with different credit qualities.

Table 10 shows the multi-variate decomposition results. We first examine investment-grade bonds. *Moody_rating* and γ are still the two most important variables with the explanatory power of 18.81% and 12.96%, respectively. The next most powerful variable is *Amihud_vol* and *IRC*, whose contribution are 6.34% and 4.79%, respectively. In addition, *IRC_vol* and *Amihud* explain 3.31% and 2.26% of the yield spread-return volatility relation. Among all credit risk variables, only *Moody_rating* explains a large and statistically significant fraction of the yield spread-return volatility relation. The total contribution of six illiquidity measures is 29.64%, and the total contribution of five credit risk measures is 20.27%, leaving 50.09% unexplained by illiquidity and credit risk measures.

When we move to the speculative bonds, γ is still important variable with a contribution of 13.82%. The contribution of other illiquidity measures is different from that in the investment-grade bond analysis. For example, *Amihud*, *Amihud_vol*, and *IRC_vol* have less contribution at 0.68%, 2.93%, and 0.94%, while *IRC* becomes more important with a contribution of 6.86%. Furthermore, *Moody_rating* becomes more important: it explains 37.12% for speculative bonds versus 18.81% for investment-grade bonds. In addition, the total contribution of illiquidity and credit risk measures is around 49.9% for investment-grade bonds while it is 66.08% for speculative bonds. The decrease in the total contribution of these candidates for investment-grade bonds is mainly due to by the decrease in the marginal contribution of *Moody_rating* (18.81% for investment-grade bonds versus 37.12% for speculative bonds).

In sum, our sample cuts confirm the results that illiquidity and credit risk measures explain a large fraction of the yield spread-return volatility relation in the corporate bond market. In particular, *Moody_rating* and γ dominate other variables in their explanatory power. Meanwhile, we also find some interesting results when we classify the bonds according to maturity and rating or when we divide our sample into subperiods around the subprime crisis.

6 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 return volatility is associated with a 1.46 percentage point increase in the yield spread. 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-return 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 five credit risk proxies, we find that our proxies can explain approximately two-thirds of the yield spread-return volatility relation. Importantly, this methodology also allows us to quantify the relative contributions of credit and illiquidity to the magnitude of the yield spread-return volatility relation at 1.76:1.

We also perform a series of additional tests on subsamples to test the strength of the price-volatility relation for different periods of time and types of bonds. We find that the relative contribution of illiquidity increases during the subprime mortgage crisis, consistent with the bond illiquidity literature which has argued that much of the increase in yield spreads during that period of time was due to deterioration in liquidity rather than the deterioration of credit quality. In a cut of investment-grade vs. speculative-grade bonds, we find results consistent with Huang and Huang (2012) that credit risk is proportionally more important for speculative-grade bonds than for investment-grade bonds. Overall, we find that the contributions of credit and illiquidity to the yield spread-return volatility relation exhibits many properties that are similar to the current understanding of the drivers of yield spreads.

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Appendix

A 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 ($i =, 1, 2..., n; t = 1, 2, ...T$)

$$y_{it} = \alpha_i + x_{it}^{'}\beta + \varepsilon_{it} \quad (4)$$

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 $n\,(p+1) \times 1$ 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.

B 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:

$$Yield\_spread_{i,t} = \alpha_t + \rho_t Bond\_vol_{i,t} + \epsilon_{i,t}. \tag{5}$$

$Yield\_spread_{i,t}$ 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 ($Candidate_{i,t}$):

$$Bond\_vol_{i,t} = a_t + \delta_t Candidate_{i,t} + \mu_{i,t}. \tag{6}$$

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 (5) into two components given by:

$$\begin{aligned}\rho_t &= \frac{Cov(Yield\_spread_{i,t}, Bond\_vol_{i,t})}{Var(Bond\_vol_{i,t})} \\ &= \frac{Cov(Yield\_spread_{i,t}, \delta Candidate_{i,t} + a_t + \mu_{i,t})}{Var(Bond\_vol_{i,t})} \\ &= \frac{Cov(Yield\_spread_{i,t}, \delta Candidate_{i,t})}{Var(Bond\_vol_{i,t})} + \frac{Cov(Yield\_spread_{i,t}, a_t + \mu_{i,t})}{Var(Bond\_vol_{i,t})} \\ &= \rho_t^C + \rho_t^R.\end{aligned} \tag{7}$$

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-value	p-value
1	Regress yield spread on bond volatility	Constant	0.0025	(2.56)	[0.012]
		Bond_vol	0.2522	(13.48)	[0.000]
		Adjusted R2	49.20%		
2	Add candidate variables to First-stage regressions	Constant	-0.0223	(-6.13)	[0.000]
		Bond_vol	0.1235	(11.43)	[0.000]
		Amihud	0.0527	(3.56)	[0.001]
		Amihud_vol	0.0190	(4.29)	[0.000]
		IRC	0.6049	(6.70)	[0.000]
		IRC_vol	-0.1746	(-3.17)	[0.002]
		γ	0.0009	(6.57)	[0.000]
		Bond_zero	-0.0060	(-8.02)	[0.000]
		Moody_rating	0.0035	(7.10)	[0.000]
		Leverage	0.0075	(6.17)	[0.000]
		Interest_coverage	0.0002	(5.10)	[0.000]
		FCF/Debt	0.0008	(0.88)	[0.382]
		EBITDA/Sales	-0.0076	(-3.01)	[0.003]
		Adjusted R2	77.86%		
3	Regress on candidate variables	Constant	-0.0168	(-1.84)	[0.069]
		Amihud	0.1242	(1.56)	[0.121]
		Amihud_vol	0.2889	(9.42)	[0.000]
		IRC	1.9001	(4.37)	[0.000]
		IRC_vol	1.2160	(3.97)	[0.000]
		γ	0.0096	(11.21)	[0.000]
		Bond_zero	-0.0320	(-9.33)	[0.000]
		Moody_rating	0.0079	(5.24)	[0.000]
		Leverage	0.0170	(2.85)	[0.005]
		Interest_coverage	0.0005	(4.84)	[0.000]
		FCF/Debt	-0.0102	(-1.60)	[0.112]
		EBITDA/Sales	0.0169	(2.98)	[0.004]
		Adjusted R2	43.86%		
4	Regress Stage 1 Coefficient	Amihud	0.0051	(2.63)	[0.010]
		Amihud percentage	2.03%		
		Amihud_vol	0.0095	(7.22)	[0.000]
		Amihud_vol percentage	3.75%		
		IRC	0.0104	(4.79)	[0.000]
		IRC percentage	4.14%		
		IRC_vol	0.0059	(4.11)	[0.000]
		IRC_vol percentage	2.34%		
		γ	0.0426	(10.84)	[0.000]
		γ percentage	16.90%		
		Bond_zero	0.0033	(3.99)	[0.000]
		Bond_zero percentage	1.31%		
		Moody_rating	0.1113	(10.32)	[0.000]
		Moody_rating percentage	44.14%		
		Leverage	0.0043	(2.60)	[0.011]
		Leverage percentage	1.70%		
		Interest_coverage	-0.0081	(-4.89)	[0.000]
		Interest_coverage percentage	-3.20%		
		FCF/Debt	0.0023	(2.34)	[0.021]
		FCF/Debt percentage	0.91%		
		EBITDA/Sales	-0.0021	(-2.67)	[0.009]
		EBITDA/Sales percentage	-0.82%		
		Residual	0.0676	(10.67)	[0.000]
		Residual Percentage	26.81%		
		Total	0.2522	(13.48)	[0.000]
		Percentage	100%		

Number of obs	82,272

We uses cross-sectional Fama-MacBeth regressions to decompose the positive relation between bond yield spread 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 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 a residual component and components each related to the candidate variable. 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 include *Amihud*, *Amihud_vol*, *IRC*, *IRC_vol*, γ, and *Bond_zero*. The credit risk measures include *Moody_rating*, *Leverage*, *Interest_coverage*, *FCF/Debt*, and *EBITDA/Sales*. 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	465,719						
Bonds	12,178						
Yield_spread	2.24	2.97	0.39	0.90	1.51	2.58	6.14
Bond_vol	7.87	8.21	1.27	3.30	5.68	9.35	21.98
Maturity	8.38	8.32	0.88	2.54	5.04	9.63	27.54
Amt.	358.70	414.40	3.32	67.00	250.00	500.00	1150.00
Moody_rating	8.01	3.23	3.00	6.00	8.00	10.00	14.00
Bond_zero	66.11	27.43	9.52	47.62	75.00	90.00	95.24
Amihud	1.20	1.98	0.02	0.16	0.48	1.31	4.99
Amihud_vol	1.51	2.05	0.04	0.32	0.84	1.89	5.21
IRC	0.26	0.38	0.00	0.04	0.13	0.32	0.97
IRC_vol	0.27	0.37	0.00	0.06	0.16	0.34	0.88
γ	1.76	6.38	0.01	0.14	0.48	1.46	6.32

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 bond 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 100 times monthly volatility of bond returns using value-weighted bond prices as in Bao and Pan (2013) and data from the previous 12 months. *Maturity* is a bond's time to maturity in years. *Amt.* 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 price changes in two consecutive periods based on Bao, Pan, and Wang (2011). See Table 11 for variable description.

Table 2: Firm Summary Statistics

	Mean	SD	5%	25%	Med.	75%	95%
Bond-months	465,719						
Firms	833						
Assets	112,89	189.56	3.45	13.16	30.87	96.48	67.33
Sales	49.973	62.27	2.19	7.95	18.35	61.13	182.01
Leverage	0.71	0.16	0.45	0.60	0.71	0.83	0.97
EBITDA/Sales	0.21	0.13	0.05	0.12	0.18	0.29	0.44
Interest_coverage	6.61	7.34	1.40	2.97	4.32	7.19	20.03
FCF/Debt	0.10	0.13	-0.07	0.03	0.09	0.17	0.32
Equity_vol	28.88	17.87	10.90	17.46	24.70	34.76	61.13

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 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* is 100 times the volatility of equity returns using the data from the previous 12 months. See Table 11 for variable description.

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

Bond_vol	Amihud	Amihud_vol	IRC	IRC_vol	γ	Bond_zero	Moody_rating	Leverage	Interest_coverage	$\frac{FCF}{Debt}$	$\frac{EBITDA}{Sales}$	N	adj. R^2
0.205												82272	0.370
(10.35)													
0.199	0.160											82272	0.377
(10.15)	(4.40)												
0.196		0.141										82272	0.379
(10.12)		(5.81)											
0.192			1.210									82272	0.383
(10.02)			(8.07)										
0.196				0.711								82272	0.376
(9.98)				(6.84)									
0.181					0.00165							82272	0.416
(11.31)					(3.90)								
0.204						-0.000395						82272	0.370
(10.32)						(-0.24)							
0.170	0.0136	0.0317	1.581	-0.696	0.00157	-0.00509						82272	0.428
(10.79)	(0.41)	(2.12)	(4.90)	(-3.28)	(3.66)	(-3.50)							
0.131							0.00334					82272	0.540
(7.43)							(18.87)						
0.193								0.0278				82272	0.399
(9.95)								(6.94)					
0.193									-0.000507			82272	0.401
(9.89)									(-8.70)				
0.198										-0.0228		82272	0.383
(10.26)										(-6.61)			
0.203											-0.0190	82272	0.381
(10.35)											(-4.15)		
0.129							0.00343	0.00559	0.000154	0.00160	-0.00761	82272	0.545
(7.39)							(18.16)	(2.79)	(3.58)	(0.72)	(-2.51)		
0.102	0.0344	0.0215	0.885	-0.392	0.00147	-0.00620	0.00332	0.00613	0.000147	0.00159	-0.00573	82272	0.589
(7.32)	(1.23)	(1.78)	(2.92)	(-1.94)	(3.43)	(-6.90)	(18.54)	(3.40)	(3.76)	(0.79)	(-2.32)		

All regressions are panel regressions using bond-month observations. The dependent variable is 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 11 for variable description.

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	0.2184	0.2259	0.2194	0.2267	0.2152	0.2136
	spread on		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	value-weighted		[0.152, 0.291]	[0.148, 0.286]	[0.151, 0.289]	[0.152, 0.285]	[0.152, 0.290]	[0.150, 0.284]
	bond volatility	Adjusted R2	35.50%	37.01%	35.91%	38.03%	36.17%	34.34%
			[29.30%, 37.60%]	[29.34%, 37.77%]	[29.42%, 37.34%]	[29.28%, 37.75%]	[29.35%, 37.43%]	[29.31%, 37.39%]
2	Add candidate	Bond_vol	0.2107	0.2115	0.2096	0.2167	0.1818	0.2135
	variable to		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	first-stage		[0.149, 0.296]	[0.148, 0.294]	[0.148, 0.292]	[0.153, 0.295]	[0.135, 0.254]	[0.151, 0.288]
	regression	Candidate	0.1521	0.2083	0.9288	0.8873	0.0015	-0.0016
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.103, 0.185]	[0.139, 0.245]	[0.698, 1.139]	[0.657, 1.185]	[0.001, 0.002]	[-0.003, -0.001]
		Adjusted R2	36.45%	38.65%	36.88%	38.82%	42.56%	34.36%
			[32.17%, 41.81%]	[34.51%, 44.83%]	[32.74%, 42.00%]	[34.80%, 45.11%]	[38.82%, 46.92%]	[30.23%, 38.67%]
3	Regress bond	Candidate	0.8706	1.2224	6.5271	7.6271	0.0054	-0.0023
	volatility on		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	candidate variable		[0.692, 1.030]	[0.956, 1.459]	[5.014, 7.680]	[5.838, 9.419]	[0.004, 0.012]	[-0.008, 0.006]
		Adjusted R2	4.39%	8.46%	6.90%	8.61%	11.98%	0.01%
			[3.58%, 5.99%]	[6.81%, 10.93%]	[5.01%, 8.76%]	[6.74%, 10.98%]	[9.25%, 16.62%]	[-0.00%, 0.11%]
4		Candidate	0.0169	0.0323	0.0243	0.0287	0.0552	0.0001
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.401)
			[0.011, 0.027]	[0.020, 0.050]	[0.015, 0.037]	[0.019, 0.044]	[0.035, 0.085]	[-0.000, 0.000]
		Percentage	7.75%	14.31%	11.07%	12.64%	25.63%	0.03%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.401)
			[6.64%, 10.37%]	[12.62%, 17.95%]	[9.37%, 13.80%]	[11.94%, 16.63%]	[20.46%, 30.78%]	[-0.04%, 0.24%]
		Residual	0.2015	0.1936	0.1951	0.1981	0.1601	0.2135
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[14.28%, 27.86%]	[13.66%, 26.10%]	[14.04%, 26.91%]	[14.20%, 26.46%]	[11.82%, 21.98%]	[15.09%, 28.78%]
		Percentage	92.25%	85.69%	88.93%	87.36%	74.37%	99.97%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[91.83%, 97.53%]	[87.96%, 95.12%]	[89.75%, 94.88%]	[89.54%, 96.97%]	[70.44%, 83.70%]	[99.60%, 101.48%]
		Total	0.2184	0.2259	0.2194	0.2267	0.2152	0.2136
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.152, 0.291]	[0.148, 0.286]	[0.151, 0.289]	[0.152, 0.285]	[0.152, 0.290]	[0.150, 0.284]
			100%	100%	100%	100%	100%	100%
		Number of obs	152410	120860	151588	113860	136382	182907

Panel B: Multivariate analysis					
Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield_spread on bond volatility	Bond_vol	0.2254	(0.000)	[0.149, 0.286]
		Adjusted R2	39.07%		[29.34%, 37.36%]
2	Add candidate variables to First-stage regressions	Bond_vol	0.1737	(0.000)	[0.129, 0.242]
		Amihud	0.0457	(0.131)	[-0.015, 0.094]
		Amihud_vol	0.0902	(0.000)	[0.041, 0.128]
		IRC	1.3359	(0.000)	[0.959, 1.726]
		IRC_vol	-0.5921	(0.001)	[-0.735, -0.298]
		γ	0.0018	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0055	(0.001)	[-0.007, -0.003]
		Adjusted R2	48.06%		[44.58%, 52.68%]
3	Regress on candidate variables	Amihud	0.1373	(0.037)	[0.007, 0.278]
		Amihud_vol	0.5230	(0.000)	[0.392, 0.631]
		IRC	5.0466	(0.000)	[2.473, 6.398]
		IRC_vol	1.0103	(0.032)	[0.079, 2.067]
		γ	0.0049	(0.000)	[0.003, 0.013]
		Bond_zero	-0.0322	(0.001)	[-0.040, -0.022]
		Adjusted R2	21.11%		[16.96%, 27.07%]
4	Regress Stage 1 Coefficient	Amihud	0.0028	(0.037)	[0.000, 0.007]
		Amihud percentage	1.24%	(0.037)	[0.07%, 3.29%]
		Amihud_vol	0.0149	(0.000)	[0.008, 0.025]
		Amihud_vol percentage	6.60%	(0.000)	[5.25%, 9.02%]
		IRC	0.0189	(0.000)	[0.008, 0.036]
		IRC percentage	8.38%	(0.000)	[4.71%, 13.38%]
		IRC_vol	0.0039	(0.032)	[0.000, 0.007]
		IRC_vol percentage	1.72%	(0.032)	[0.17%, 3.42%]
		γ	0.0471	(0.000)	[0.028, 0.068]
		γ percentage	20.90%	(0.000)	[15.71%, 27.32%]
		Bond_zero	0.0009	(0.007)	[0.000, 0.002]
		Bond_zero percentage	0.40%	(0.007)	[0.10%, 1.26%]
		Residual	0.1370	(0.000)	[10.48%, 18.18%]
		Residual Percentage	60.77%	(0.000)	[58.634%, 74.523%]
		Total	0.2254	(0.000)	[0.149, 0.286]
		Percentage	100%		
		Number of obs	94,239		

In Panel A, we uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread and bond volatility into a component related to a 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.($Candidate_{i,t}$) ($Bond\_vol^{dm}_{i,t} = \delta^{dm} Candidate^{dm}_{i,t} + \mu^{dm}_{i,t}$) 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 positive relation between bond yield spread and bond volatility into a number of components each related to a 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 A). 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 11 for variable description.

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
1	Regress yield	Bond_vol	0.2127	0.2127	0.2129	0.1933	0.2127
	spread on		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	value-weighted		[0.150, 0.291]	[0.150, 0.285]	[0.150, 0.289]	[0.151, 0.281]	[0.152, 0.292]
	bond volatility	Adjusted R2	33.56%	33.56%	33.60%	31.55%	33.57%
			[29.32%, 37.78%]	[29.10%, 37.68%]	[29.26%, 37.70%]	[29.34%, 37.73%]	[29.30%, 37.52%]
2	Add candidate	Bond_vol	0.1495	0.2023	0.2032	0.1899	0.2073
	variable to		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	first-stage		[0.091, 0.217]	[0.141, 0.272]	[0.141, 0.276]	[0.144, 0.245]	[0.147, 0.285]
	regression	Candidate	0.0030	0.0298	-0.0006	-0.0153	-0.0270
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.003, 0.004]	[0.025, 0.036]	[-0.001, -0.000]	[-0.019, -0.014]	[-0.034, -0.021]
		Adjusted R2	46.51%	36.78%	36.29%	32.29%	35.48%
			[42.46%, 60.73%]	[32.38%, 42.81%]	[32.59%, 41.91%]	[28.12%, 38.43%]	[31.44%, 39.75%]
3	Regress bond	Candidate	0.0090	0.0697	-0.0014	-0.0590	-0.0562
	volatility on		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	candidate variable		[0.006, 0.012]	[0.044, 0.099]	[-0.002, -0.001]	[-0.076, -0.041]	[-0.082, -0.030]
		Adjusted R2	18.58%	2.43%	2.52%	1.32%	1.13%
			[15.73%, 21.81%]	[1.50%, 3.43%]	[1.99%, 3.30%]	[0.70%, 2.04%]	[0.53%, 1.82%]
4		Candidate	0.0909	0.0153	0.0148	0.0059	0.0078
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.073, 0.118]	[0.011, 0.022]	[0.012, 0.020]	[0.004, 0.009]	[0.005, 0.012]
		Percentage	42.74%	7.19%	6.96%	3.06%	3.66%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[38.16%, 51.19%]	[5.48%, 10.20%]	[6.10%, 9.18%]	[1.89%, 4.26%]	[2.34%, 5.11%]
		Residual	0.1218	0.1974	0.1981	0.1874	0.2049
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[7.46%, 17.74%]	[13.81%, 26.57%]	[13.68%, 26.94%]	[14.20%, 24.10%]	[14.56%, 28.21%]
		Percentage	57.26%	92.81%	93.04%	96.94%	96.34%
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[48.814%, 61.844%]	[89.798%, 94.524%]	[90.797%, 93.900%]	[84.834%, 95.568%]	[94.914%, 97.705%]
		Total	0.2127	0.2127	0.2129	0.1933	0.2127
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			[0.150, 0.291]	[0.150, 0.285]	[0.150, 0.289]	[0.151, 0.281]	[0.152, 0.292]
			100%	100%	100%	100%	100%
		Number of obs	198894	198891	197832	170803	198438

Panel B: Multivariate analysis

Stage	Description	Variable	Coefficient	p-value	Conf. interval
1	Regress yield spread on bond volatility	Bond_vol	0.1935	(0.000)	[0.150, 0.282]
		Adjusted R2	31.60%		[29.50%, 37.65%]
2	Add candidate variables to First-stage regressions	Bond_vol	0.1314	(0.000)	[0.088, 0.177]
		Moody_rating	0.0033	(0.000)	[0.003, 0.004]
		Leverage	0.0055	(0.000)	[0.005, 0.009]
		Interest_coverage	0.0001	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0023	(0.009)	[0.000, 0.004]
		EBITDA/Sales	-0.0080	(0.001)	[-0.012, -0.005]
		Adjusted R2	48.86%		[43.07%, 66.55%]
3	Regress on candidate variables	Moody_rating	0.0087	(0.000)	[0.006, 0.012]
		Leverage	0.0140	(0.015)	[0.003, 0.025]
		Interest_coverage	0.0005	(0.000)	[0.000, 0.001]
		FCF/Debt	-0.0097	(0.154)	[-0.022, 0.005]
		EBITDA/Sales	-0.0010	(0.410)	[-0.012, 0.009]
		Adjusted R2	16.07%		[12.95%, 19.90%]
4	Regress Stage 1 Coefficient	Moody_rating	0.0852	(0.000)	[0.072, 0.105]
		Moody_rating percentage	44.02%	(0.000)	[35.06%, 51.27%]
		Leverage	0.0025	(0.015)	[0.000, 0.005]
		Leverage percentage	1.29%	(0.015)	[0.21%, 2.59%]
		Interest_coverage	-0.0055	(0.001)	[-0.008, -0.004]
		Interest_coverage percentage	-2.86%	(0.001)	[-3.77%, -1.94%]
		FCF/Debt	0.0010	(0.153)	[-0.000, 0.003]
		FCF/Debt percentage	0.51%	(0.153)	[-0.22%, 1.33%]
		EBITDA/Sales	0.0001	(0.409)	[-0.001, 0.001]
		EBITDA/Sales percentage	0.05%	(0.409)	[-0.49%, 0.55%]
		Residual	0.1103	(0.000)	[7.30%, 14.96%]
		Residual Percentage	57.00%	(0.000)	[46.115%, 56.270%]
		Total	0.1935	(0.000)	[0.150, 0.282]
		Percentage	100%		
		Number of obs	169823		

In Panel A, we uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread 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 positive relation between bond yield spread 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*, *Inter-*

est_coverage, *FCF/Debt*, and *EBITDA/Sales*. 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 A). 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 11 for variable description.

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	0.2045	(0.000)	[0.153, 0.284]
		Adjusted R2	36.98%		[29.38%, 37.22%]
2	Add candidate variables to First-stage regressions	Bond_vol	0.1021	(0.000)	[0.073, 0.145]
		Amihud	0.0344	(0.103)	[-0.011, 0.089]
		Amihud_vol	0.0215	(0.196)	[-0.016, 0.041]
		IRC	0.8854	(0.000)	[0.532, 1.339]
		IRC_vol	-0.3924	(0.002)	[-0.566, -0.112]
		γ	0.0015	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0062	(0.001)	[-0.007, -0.004]
		Moody_rating	0.0033	(0.000)	[0.003, 0.004]
		Leverage	0.0061	(0.000)	[0.006, 0.009]
		Interest_coverage	0.0001	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0016	(0.245)	[-0.001, 0.003]
		EBITDA/Sales	-0.0057	(0.001)	[-0.009, -0.003]
		Adjusted R2	58.95%		[54.95%, 73.60%]
3	Regress on candidate variables	Amihud	0.0358	(0.381)	[-0.120, 0.213]
		Amihud_vol	0.3403	(0.000)	[0.254, 0.411]
		IRC	3.2336	(0.000)	[1.660, 4.333]
		IRC_vol	1.1325	(0.000)	[0.460, 1.549]
		γ	0.0042	(0.000)	[0.003, 0.008]
		Bond_zero	-0.0328	(0.001)	[-0.040, -0.024]
		Moody_rating	0.0088	(0.000)	[0.006, 0.011]
		Leverage	0.0173	(0.001)	[0.006, 0.027]
		Interest_coverage	0.0006	(0.000)	[0.000, 0.001]
		FCF/Debt	-0.0088	(0.199)	[-0.020, 0.008]
		EBITDA/Sales	0.0171	(0.000)	[0.008, 0.025]
		Adjusted R2	32.43%		[29.30%, 38.78%]
4	Regress Stage 1 Coefficient	Amihud	0.0005	(0.381)	[-0.001, 0.005]
		Amihud percentage	0.22%	(0.381)	[-0.54%, 2.13%]
		Amihud_vol	0.0068	(0.000)	[0.005, 0.010]
		Amihud_vol percentage	3.32%	(0.000)	[2.47%, 4.52%]
		IRC	0.0110	(0.000)	[0.006, 0.019]
		IRC percentage	5.36%	(0.000)	[3.31%, 7.36%]
		IRC_vol	0.0038	(0.000)	[0.002, 0.006]
		IRC_vol percentage	1.86%	(0.000)	[0.81%, 2.75%]
		γ	0.0254	(0.000)	[0.018, 0.040]
		γ percentage	12.42%	(0.000)	[10.08%, 16.76%]
		Bond_zero	0.0016	(0.010)	[0.000, 0.003]
		Bond_zero percentage	0.81%	(0.010)	[0.17%, 1.81%]
		Moody_rating	0.0910	(0.000)	[0.079, 0.118]
		Moody_rating percentage	44.48%	(0.000)	[37.56%, 55.47%]

Leverage	0.0035	(0.001)	[0.001, 0.006]
Leverage percentage	1.71%	(0.001)	[0.54%, 2.79%]
Interest_coverage	-0.0076	(0.001)	[-0.011, -0.006]
Interest_coverage percentage	-3.69%	(0.001)	[-5.01%, -2.86%]
FCF/Debt	0.0011	(0.198)	[-0.001, 0.004]
FCF/Debt percentage	0.52%	(0.198)	[-0.39%, 1.65%]
EBITDA/Sales	-0.0015	(0.001)	[-0.003, -0.001]
EBITDA/Sales percentage	-0.73%	(0.001)	[-1.19%, -0.32%]
Residual	0.0690	(0.000)	[4.94%, 9.22%]
Residual Percentage	33.73%	(0.000)	[28.426%, 36.418%]
Total	0.2045	(0.000)	[0.153, 0.284]
Percentage	100%		
Number of obs	82,272		

We uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread 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*, and *EBITDA/Sales*. 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 A). 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 11 for variable description.

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	Equity_vol	0.0904	(0.000)	[0.067, 0.121]
		Adjusted R2	33.24%		[24.18%, 32.96%]
2	Add candidate variables to First-stage regressions	Equity_vol	0.0406	(0.000)	[0.024, 0.048]
		Amihud	0.0367	(0.047)	[0.002, 0.097]
		Amihud_vol	0.0831	(0.000)	[0.020, 0.082]
		IRC	1.7373	(0.000)	[0.600, 1.796]
		IRC_vol	-0.4559	(0.032)	[-0.559, -0.026]
		γ	0.0010	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0067	(0.001)	[-0.008, -0.005]
		Moody_rating	0.0035	(0.000)	[0.003, 0.004]
		Leverage	0.0084	(0.000)	[0.007, 0.010]
		Interest_coverage	0.0001	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0004	(0.091)	[-0.001, 0.005]
		EBITDA/Sales	0.0030	(0.182)	[-0.001, 0.004]
		Adjusted R2	56.92%		[53.63%, 69.45%]
3	Regress on candidate variables	Amihud	0.0133	(0.176)	[-0.055, 0.296]
		Amihud_vol	0.2121	(0.057)	[-0.005, 0.267]
		IRC	8.2989	(0.000)	[3.382, 7.700]
		IRC_vol	-1.4985	(0.104)	[-1.522, 0.174]
		γ	0.0025	(0.000)	[0.002, 0.006]
		Bond_zero	-0.0718	(0.001)	[-0.083, -0.048]
		Moody_rating	0.0287	(0.000)	[0.021, 0.033]
		Leverage	-0.0300	(0.194)	[-0.053, 0.015]
		Interest_coverage	0.0029	(0.000)	[0.002, 0.003]
		FCF/Debt	-0.0870	(0.018)	[-0.124, -0.013]
		EBITDA/Sales	-0.1465	(0.001)	[-0.223, -0.119]
		Adjusted R2	35.23%		[30.90%, 37.52%]
4	Regress Stage 1 Coefficient	Amihud	0.0000	(0.176)	[-0.000, 0.001]
		Amihud percentage	0.04%	(0.176)	[-0.13%, 1.06%]
		Amihud_vol	0.0010	(0.057)	[-0.000, 0.001]
		Amihud_vol percentage	1.11%	(0.057)	[-0.02%, 1.31%]
		IRC	0.0082	(0.000)	[0.002, 0.007]
		IRC percentage	9.09%	(0.000)	[2.77%, 7.72%]
		IRC_vol	-0.0014	(0.104)	[-0.001, 0.000]
		IRC_vol percentage	-1.60%	(0.104)	[-1.31%, 0.13%]
		γ	0.0049	(0.000)	[0.002, 0.008]
		γ percentage	5.45%	(0.000)	[3.06%, 6.94%]
		Bond_zero	0.0005	(0.191)	[-0.000, 0.001]
		Bond_zero percentage	0.52%	(0.191)	[-0.22%, 0.93%]
		Moody_rating	0.0536	(0.000)	[0.044, 0.064]

Moody_rating percentage	59.29%	(0.000)	[49.65%, 71.25%]
Leverage	-0.0010	(0.194)	[-0.002, 0.000]
Leverage percentage	-1.12%	(0.194)	[-2.54%, 0.60%]
Interest_coverage	-0.0061	(0.001)	[-0.008, -0.005]
Interest_coverage percentage	-6.70%	(0.001)	[-9.03%, -5.57%]
FCF/Debt	0.0022	(0.017)	[0.000, 0.004]
FCF/Debt percentage	2.43%	(0.017)	[0.30%, 4.19%]
EBITDA/Sales	0.0022	(0.000)	[0.002, 0.003]
EBITDA/Sales percentage	2.41%	(0.000)	[2.07%, 3.93%]
Residual	0.0263	(0.000)	[1.60%, 3.15%]
Residual Percentage	29.09%	(0.000)	[21.328%, 29.386%]
Total	0.0904	(0.000)	[0.067, 0.121]
Percentage	100%		
Number of obs	108509		

We uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread 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*, and *EBITDA/Sales*. 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 A). 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 11 for variable description.

Table 8: 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	0.1929	(0.000)	[0.152, 0.288]	0.2974	(0.000)	[0.150, 0.301]	0.1555	(0.000)	[0.148, 0.282]
		Adjusted R2	52.05%		[29.58%, 38.00%]	35.49%		[29.22%, 38.21%]	37.98%		[29.49%, 37.41%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.0954	(0.000)	[0.074, 0.144]	0.1655	(0.000)	[0.073, 0.153]	0.0671	(0.000)	[0.073, 0.140]
		Amihud	0.1167	(0.106)	[-0.015, 0.095]	0.0416	(0.127)	[-0.014, 0.089]	0.0775	(0.105)	[-0.011, 0.093]
		Amihud_vol	0.0249	(0.171)	[-0.014, 0.041]	-0.0127	(0.778)	[-0.016, 0.042]	0.0432	(0.190)	[-0.014, 0.042]
		IRC	0.9302	(0.000)	[0.502, 1.328]	1.1234	(0.000)	[0.518, 1.343]	0.5148	(0.000)	[0.508, 1.330]
		IRC_vol	-0.3477	(0.004)	[-0.568, -0.097]	-0.6039	(0.005)	[-0.588, -0.097]	-0.0133	(0.006)	[-0.579, -0.079]
		γ	0.0006	(0.000)	[0.001, 0.002]	0.0014	(0.000)	[0.001, 0.002]	0.0009	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0069	(0.001)	[-0.007, -0.004]	-0.0083	(0.001)	[-0.007, -0.004]	-0.0075	(0.001)	[-0.007, -0.004]
		Moody_rating	0.0025	(0.000)	[0.003, 0.004]	0.0057	(0.000)	[0.003, 0.004]	0.0036	(0.000)	[0.003, 0.004]
		Leverage	0.0099	(0.000)	[0.005, 0.009]	0.0092	(0.000)	[0.005, 0.009]	0.0055	(0.000)	[0.006, 0.009]
		Interest_coverage	0.0002	(0.000)	[0.000, 0.000]	0.0003	(0.000)	[0.000, 0.000]	0.0001	(0.000)	[0.000, 0.000]
		FCF/Debt	0.0006	(0.252)	[-0.001, 0.003]	0.0058	(0.237)	[-0.001, 0.003]	0.0001	(0.269)	[-0.001, 0.003]
		EBITDA/Sales	-0.0030	(0.003)	[-0.009, -0.003]	-0.0235	(0.001)	[-0.009, -0.003]	-0.0025	(0.001)	[-0.009, -0.003]
		Adjusted R2	73.57%		[54.79%, 73.96%]	54.76%		[54.41%, 73.82%]	77.68%		[54.84%, 74.19%]
3	Regress on candidate variables	Amihud	0.3551	(0.355)	[-0.124, 0.255]	-0.3098	(0.610)	[-0.151, 0.211]	0.0470	(0.346)	[-0.134, 0.214]
		Amihud_vol	0.2023	(0.000)	[0.247, 0.412]	0.4037	(0.000)	[0.254, 0.417]	0.3204	(0.000)	[0.261, 0.416]
		IRC	4.0547	(0.000)	[1.639, 4.407]	4.4695	(0.000)	[1.599, 4.484]	0.6982	(0.000)	[1.561, 4.385]
		IRC_vol	-0.0810	(0.998)	[0.386, 1.585]	2.0066	(0.001)	[0.423, 1.582]	1.8120	(0.002)	[0.410, 1.626]
		γ	0.0062	(0.000)	[0.003, 0.008]	0.0030	(0.000)	[0.003, 0.009]	0.0135	(0.000)	[0.003, 0.009]
		Bond_zero	-0.0381	(0.001)	[-0.041, -0.024]	-0.0247	(0.001)	[-0.040, -0.024]	-0.0378	(0.001)	[-0.041, -0.024]
		Moody_rating	0.0078	(0.000)	[0.006, 0.011]	0.0109	(0.000)	[0.006, 0.012]	0.0077	(0.000)	[0.006, 0.012]
		Leverage	0.0387	(0.001)	[0.005, 0.028]	0.0126	(0.011)	[0.004, 0.026]	0.0025	(0.009)	[0.005, 0.026]
		Interest_coverage	0.0008	(0.000)	[0.000, 0.001]	0.0008	(0.000)	[0.000, 0.001]	0.0004	(0.000)	[0.000, 0.001]
		FCF/Debt	-0.0239	(0.206)	[-0.022, 0.006]	0.0171	(0.773)	[-0.021, 0.007]	-0.0047	(0.213)	[-0.020, 0.007]
		EBITDA/Sales	0.0001	(0.012)	[0.007, 0.025]	0.0228	(0.002)	[0.008, 0.026]	0.0253	(0.002)	[0.007, 0.026]
		Adjusted R2	40.80%		[29.65%, 39.44%]	32.27%		[29.39%, 38.77%]	30.08%		[29.43%, 38.53%]
4	Regress Stage 1 Coefficient	Amihud	0.0040	(0.355)	[-0.001, 0.005]	-0.0030	(0.611)	[-0.001, 0.005]	0.0007	(0.346)	[-0.001, 0.004]
		Amihud percentage	2.09%	(0.355)	[-0.58%, 2.40%]	-1.01%	(0.611)	[-0.67%, 2.10%]	0.48%	(0.346)	[-0.63%, 2.07%]
		Amihud_vol	0.0037	(0.000)	[0.005, 0.010]	0.0093	(0.000)	[0.005, 0.011]	0.0062	(0.000)	[0.005, 0.010]
		Amihud_vol percentage	1.93%	(0.000)	[2.37%, 4.52%]	3.12%	(0.000)	[2.41%, 4.48%]	3.99%	(0.000)	[2.41%, 4.57%]
		IRC	0.0155	(0.000)	[0.005, 0.020]	0.0157	(0.000)	[0.005, 0.020]	0.0020	(0.000)	[0.005, 0.019]
		IRC percentage	8.03%	(0.000)	[3.15%, 7.72%]	5.29%	(0.000)	[3.14%, 7.54%]	1.31%	(0.000)	[3.01%, 7.56%]
		IRC_vol	-0.0003	(0.998)	[0.001, 0.006]	0.0060	(0.001)	[0.002, 0.006]	0.0053	(0.002)	[0.002, 0.006]
		IRC_vol percentage	-0.17%	(0.998)	[0.69%, 2.78%]	2.00%	(0.001)	[0.71%, 2.83%]	3.40%	(0.002)	[0.72%, 2.79%]
		γ	0.0206	(0.000)	[0.018, 0.041]	0.0489	(0.000)	[0.018, 0.042]	0.0249	(0.000)	[0.018, 0.041]
		γ percentage	10.66%	(0.000)	[9.89%, 16.82%]	16.46%	(0.000)	[10.08%, 17.10%]	16.05%	(0.000)	[9.95%, 16.96%]
		Bond_zero	0.0043	(0.012)	[0.000, 0.004]	-0.0007	(0.971)	[0.000, 0.003]	0.0016	(0.009)	[0.000, 0.003]
		Bond_zero percentage	2.23%	(0.012)	[0.15%, 1.96%]	-0.23%	(0.971)	[0.11%, 1.79%]	1.05%	(0.009)	[0.17%, 1.82%]
		Moody_rating	0.0832	(0.000)	[0.080, 0.119]	0.1201	(0.000)	[0.078, 0.122]	0.0740	(0.000)	[0.078, 0.116]
		Moody_rating percentage	43.12%	(0.000)	[37.26%, 55.33%]	40.40%	(0.000)	[37.13%, 55.33%]	47.61%	(0.000)	[37.57%, 56.22%]
		Leverage	0.0102	(0.001)	[0.001, 0.006]	0.0024	(0.011)	[0.001, 0.006]	0.0004	(0.009)	[0.001, 0.006]
		Leverage percentage	5.31%	(0.001)	[0.53%, 3.03%]	0.81%	(0.011)	[0.45%, 2.79%]	0.25%	(0.009)	[0.51%, 2.87%]
		Interest_coverage	-0.0079	(0.001)	[-0.011, -0.006]	-0.0087	(0.001)	[-0.012, -0.006]	-0.0057	(0.001)	[-0.011, -0.006]
		Interest_coverage percentage	-4.07%	(0.001)	[-5.17%, -2.90%]	-2.92%	(0.001)	[-5.14%, -2.80%]	-3.65%	(0.001)	[-5.15%, -2.87%]
		FCF/Debt	0.0031	(0.205)	[-0.001, 0.004]	-0.0022	(0.774)	[-0.001, 0.004]	0.0005	(0.212)	[-0.001, 0.004]
		FCF/Debt percentage	1.63%	(0.205)	[-0.31%, 1.80%]	-0.72%	(0.774)	[-0.39%, 1.73%]	0.33%	(0.212)	[-0.36%, 1.66%]
		EBITDA/Sales	-0.0000	(0.013)	[-0.003, -0.001]	-0.0026	(0.003)	[-0.003, -0.001]	-0.0015	(0.003)	[-0.003, -0.001]
		EBITDA/Sales percentage	-0.01%	(0.013)	[-1.21%, -0.31%]	-0.88%	(0.003)	[-1.22%, -0.35%]	-0.98%	(0.003)	[-1.23%, -0.32%]
		Residual	0.0564	(0.000)	[4.98%, 9.32%]	0.1120	(0.000)	[4.94%, 9.77%]	0.0469	(0.000)	[4.90%, 9.17%]
		Residual Percentage	29.26%	(0.000)	[28.149%, 36.218%]	37.66%	(0.000)	[28.347%, 36.436%]	30.16%	(0.000)	[28.070%, 36.227%]

Total Percentage	0.1929 100%	(0.000)	[0.152, 0.288]	0.2974 100%	(0.000)	[0.150, 0.301]	0.1555 100%	(0.000)	[0.148, 0.282]
Number of obs	28,144			14,256			39,872		

We uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread 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*, and *EBITDA/Sales*. 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 A). 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 11 for variable description.

Table 9: 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	0.3169	(0.000)	[0.153, 0.297]	0.2749	(0.000)	[0.148, 0.291]	0.1839	(0.000)	[0.149, 0.285]
		Adjusted R2	47.64%		[29.27%, 37.72%]	50.69%		[29.37%, 37.85%]	36.09%		[29.20%, 37.40%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.1878	(0.000)	[0.076, 0.148]	0.1533	(0.000)	[0.072, 0.148]	0.0855	(0.000)	[0.074, 0.140]
		Amihud	-0.2045	(0.889)	[-0.013, 0.092]	0.0758	(0.133)	[-0.015, 0.091]	0.0373	(0.106)	[-0.011, 0.092]
		Amihud_vol	0.2453	(0.192)	[-0.016, 0.041]	-0.0060	(0.789)	[-0.015, 0.042]	0.0309	(0.182)	[-0.013, 0.042]
		IRC	3.7328	(0.000)	[0.493, 1.315]	1.1618	(0.000)	[0.501, 1.347]	0.7173	(0.000)	[0.512, 1.293]
		IRC_vol	-1.7033	(0.003)	[-0.569, -0.093]	-0.1988	(0.005)	[-0.562, -0.092]	-0.2598	(0.004)	[-0.556, -0.091]
		γ	0.0033	(0.000)	[0.001, 0.002]	0.0020	(0.000)	[0.001, 0.002]	0.0008	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0029	(0.001)	[-0.007, -0.004]	-0.0058	(0.001)	[-0.007, -0.004]	-0.0052	(0.001)	[-0.007, -0.004]
		Moody_rating	0.0020	(0.000)	[0.003, 0.004]	0.0029	(0.000)	[0.003, 0.004]	0.0033	(0.000)	[0.003, 0.004]
		Leverage	0.0017	(0.000)	[0.005, 0.009]	0.0028	(0.000)	[0.006, 0.009]	0.0053	(0.000)	[0.006, 0.009]
		Interest_coverage	0.0001	(0.000)	[0.000, 0.000]	0.0001	(0.000)	[0.000, 0.000]	0.0001	(0.000)	[0.000, 0.000]
		FCF/Debt	-0.0060	(0.738)	[-0.001, 0.003]	0.0015	(0.276)	[-0.001, 0.003]	0.0019	(0.242)	[-0.001, 0.003]
		EBITDA/Sales	-0.0005	(0.001)	[-0.009, -0.003]	-0.0027	(0.001)	[-0.009, -0.003]	-0.0040	(0.001)	[-0.009, -0.003]
		Adjusted R2	64.85%		[54.67%, 73.84%]	67.33%		[54.34%, 73.76%]	65.34%		[54.90%, 73.60%]
3	Regress on candidate variables	Amihud	0.0361	(0.379)	[-0.141, 0.228]	0.1671	(0.356)	[-0.122, 0.222]	-0.0566	(0.662)	[-0.123, 0.218]
		Amihud_vol	0.7873	(0.000)	[0.249, 0.421]	0.2198	(0.000)	[0.253, 0.419]	0.0991	(0.000)	[0.255, 0.417]
		IRC	5.9350	(0.000)	[1.569, 4.421]	2.7040	(0.000)	[1.555, 4.361]	2.4967	(0.000)	[1.674, 4.354]
		IRC_vol	-1.2180	(0.999)	[0.410, 1.608]	0.9759	(0.001)	[0.443, 1.593]	0.5960	(0.003)	[0.457, 1.585]
		γ	0.0048	(0.000)	[0.003, 0.009]	0.0041	(0.000)	[0.003, 0.009]	0.0029	(0.000)	[0.003, 0.009]
		Bond_zero	-0.0328	(0.001)	[-0.040, -0.024]	-0.0327	(0.001)	[-0.040, -0.024]	-0.0222	(0.001)	[-0.040, -0.024]
		Moody_rating	0.0081	(0.000)	[0.006, 0.011]	0.0101	(0.000)	[0.006, 0.011]	0.0083	(0.000)	[0.006, 0.011]
		Leverage	0.0401	(0.008)	[0.004, 0.026]	0.0301	(0.006)	[0.005, 0.026]	0.0247	(0.002)	[0.005, 0.026]
		Interest_coverage	0.0011	(0.000)	[0.000, 0.001]	0.0010	(0.000)	[0.000, 0.001]	0.0005	(0.000)	[0.000, 0.001]
		FCF/Debt	-0.0063	(0.214)	[-0.021, 0.007]	-0.0027	(0.226)	[-0.021, 0.007]	-0.0011	(0.211)	[-0.020, 0.008]
		EBITDA/Sales	0.0024	(0.002)	[0.008, 0.026]	-0.0243	(0.997)	[0.007, 0.026]	0.0118	(0.001)	[0.008, 0.026]
		Adjusted R2	36.95%		[29.43%, 38.68%]	39.46%		[29.10%, 38.70%]	27.43%		[29.18%, 38.84%]
4	Regress Stage 1 Coefficient	Amihud	0.0007	(0.378)	[-0.002, 0.005]	0.0023	(0.356)	[-0.001, 0.005]	-0.0007	(0.662)	[-0.001, 0.004]
		Amihud percentage	0.22%	(0.378)	[-0.64%, 2.26%]	0.83%	(0.356)	[-0.57%, 2.21%]	-0.39%	(0.662)	[-0.58%, 2.04%]
		Amihud_vol	0.0255	(0.000)	[0.005, 0.011]	0.0052	(0.000)	[0.005, 0.011]	0.0018	(0.000)	[0.005, 0.010]
		Amihud_vol percentage	8.06%	(0.000)	[2.42%, 4.54%]	1.87%	(0.000)	[2.44%, 4.62%]	0.98%	(0.000)	[2.47%, 4.44%]
		IRC	0.0252	(0.000)	[0.005, 0.021]	0.0104	(0.000)	[0.005, 0.020]	0.0093	(0.000)	[0.005, 0.020]
		IRC percentage	7.95%	(0.000)	[3.03%, 7.86%]	3.77%	(0.000)	[3.07%, 7.53%]	5.07%	(0.000)	[3.06%, 7.57%]
		IRC_vol	-0.0050	(0.999)	[0.002, 0.006]	0.0038	(0.001)	[0.002, 0.006]	0.0021	(0.003)	[0.002, 0.006]
		IRC_vol percentage	-1.59%	(0.999)	[0.73%, 2.83%]	1.39%	(0.001)	[0.79%, 2.85%]	1.15%	(0.003)	[0.81%, 2.75%]
		γ	0.0589	(0.000)	[0.018, 0.041]	0.0318	(0.000)	[0.018, 0.040]	0.0146	(0.000)	[0.018, 0.039]
		γ percentage	18.58%	(0.000)	[9.89%, 17.32%]	11.55%	(0.000)	[10.10%, 16.82%]	7.97%	(0.000)	[10.00%, 16.53%]
		Bond_zero	-0.0004	(0.979)	[0.000, 0.004]	0.0018	(0.008)	[0.000, 0.004]	0.0017	(0.011)	[0.000, 0.003]
		Bond_zero percentage	-0.12%	(0.979)	[0.11%, 1.87%]	0.66%	(0.008)	[0.15%, 1.87%]	0.90%	(0.011)	[0.18%, 1.76%]
		Moody_rating	0.0965	(0.000)	[0.078, 0.121]	0.1305	(0.000)	[0.078, 0.120]	0.0955	(0.000)	[0.079, 0.118]
		Moody_rating percentage	30.44%	(0.000)	[37.42%, 55.29%]	47.46%	(0.000)	[37.60%, 55.82%]	51.96%	(0.000)	[37.98%, 55.53%]
		Leverage	0.0099	(0.008)	[0.001, 0.006]	0.0078	(0.006)	[0.001, 0.006]	0.0057	(0.002)	[0.001, 0.006]
		Leverage percentage	3.13%	(0.008)	[0.46%, 2.87%]	2.83%	(0.006)	[0.51%, 2.87%]	3.11%	(0.002)	[0.51%, 2.74%]
		Interest_coverage	-0.0133	(0.001)	[-0.011, -0.006]	-0.0145	(0.001)	[-0.011, -0.006]	-0.0072	(0.001)	[-0.011, -0.006]
		Interest_coverage percentage	-4.19%	(0.001)	[-5.02%, -2.79%]	-5.26%	(0.001)	[-5.12%, -2.81%]	-3.90%	(0.001)	[-5.09%, -2.87%]
		FCF/Debt	0.0008	(0.213)	[-0.001, 0.004]	0.0004	(0.225)	[-0.001, 0.004]	0.0002	(0.210)	[-0.001, 0.004]
		FCF/Debt percentage	0.26%	(0.213)	[-0.40%, 1.74%]	0.15%	(0.225)	[-0.38%, 1.69%]	0.09%	(0.210)	[-0.40%, 1.65%]
		EBITDA/Sales	-0.0002	(0.003)	[-0.003, -0.001]	0.0028	(0.996)	[-0.003, -0.001]	-0.0013	(0.002)	[-0.003, -0.001]
		EBITDA/Sales percentage	-0.07%	(0.003)	[-1.24%, -0.35%]	1.01%	(0.996)	[-1.26%, -0.31%]	-0.70%	(0.002)	[-1.23%, -0.34%]
		Residual	0.1183	(0.000)	[5.09%, 9.64%]	0.0928	(0.000)	[4.97%, 9.60%]	0.0621	(0.000)	[4.99%, 9.11%]
		Residual Percentage	37.34%	(0.000)	[28.337%, 36.228%]	33.75%	(0.000)	[28.292%, 36.342%]	33.75%	(0.000)	[28.350%, 36.319%]

Total Percentage	0.3169 100%	(0.000)	[0.153, 0.297]	0.2749 100%	(0.000)	[0.148, 0.291]	0.1839 100%	(0.000)	[0.149, 0.285]
Number of obs	12,764			24,754			44,658		

We uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread 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 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*, and *EBITDA/Sales*. 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 A). 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 11 for variable description.

Table 10: 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 on bond volatility	Bond_vol	0.0876	(0.000)	[0.152, 0.285]	0.1937	(0.000)	[0.150, 0.285]
		Adjusted R2	18.70%		[29.13%, 37.30%]	31.39%		[29.61%, 37.49%]
2	Add candidate variables to first-stage regressions	Bond_vol	0.0532	(0.000)	[0.073, 0.141]	0.0984	(0.000)	[0.073, 0.144]
		Amihud	0.0670	(0.129)	[-0.014, 0.087]	0.0890	(0.119)	[-0.013, 0.089]
		Amihud_vol	0.0254	(0.201)	[-0.016, 0.042]	0.0645	(0.198)	[-0.014, 0.041]
		IRC	0.3994	(0.000)	[0.511, 1.321]	1.3740	(0.000)	[0.510, 1.334]
		IRC_vol	-0.0813	(0.003)	[-0.562, -0.111]	-0.5791	(0.006)	[-0.577, -0.110]
		γ	0.0005	(0.000)	[0.001, 0.002]	0.0022	(0.000)	[0.001, 0.002]
		Bond_zero	-0.0027	(0.001)	[-0.007, -0.004]	-0.0135	(0.001)	[-0.007, -0.004]
		Moody_rating	0.0020	(0.000)	[0.003, 0.004]	0.0041	(0.000)	[0.003, 0.004]
		Leverage	0.0001	(0.000)	[0.006, 0.009]	0.0026	(0.000)	[0.006, 0.009]
		Interest_coverage	-0.0000	(1.001)	[0.000, 0.000]	-0.0001	(1.001)	[0.000, 0.000]
		FCF/Debt	0.0015	(0.223)	[-0.001, 0.003]	0.0094	(0.231)	[-0.001, 0.003]
		EBITDA/Sales	-0.0004	(0.001)	[-0.009, -0.003]	-0.0099	(0.001)	[-0.009, -0.003]
		Adjusted R2	43.22%		[54.73%, 73.77%]	50.52%		[54.89%, 73.52%]
3	Regress on candidate variables	Amihud	0.1633	(0.394)	[-0.140, 0.201]	0.0903	(0.376)	[-0.116, 0.215]
		Amihud_vol	0.3498	(0.000)	[0.260, 0.424]	0.2727	(0.000)	[0.254, 0.416]
		IRC	1.8787	(0.000)	[1.602, 4.352]	4.1034	(0.000)	[1.650, 4.395]
		IRC_vol	1.2930	(0.000)	[0.443, 1.571]	0.5411	(0.002)	[0.425, 1.561]
		γ	0.0038	(0.000)	[0.003, 0.009]	0.0035	(0.000)	[0.003, 0.009]
		Bond_zero	-0.0171	(0.001)	[-0.040, -0.024]	-0.0545	(0.001)	[-0.041, -0.024]
		Moody_rating	0.0035	(0.000)	[0.006, 0.012]	0.0174	(0.000)	[0.006, 0.012]
		Leverage	-0.0140	(0.995)	[0.004, 0.025]	0.0106	(0.005)	[0.005, 0.028]
		Interest_coverage	-0.0001	(1.001)	[0.000, 0.001]	-0.0016	(1.001)	[0.000, 0.001]
		FCF/Debt	-0.0121	(0.211)	[-0.021, 0.008]	-0.0004	(0.221)	[-0.021, 0.008]
		EBITDA/Sales	0.0259	(0.002)	[0.008, 0.026]	0.0204	(0.001)	[0.007, 0.025]
		Adjusted R2	17.45%		[29.12%, 38.50%]	33.22%		[29.41%, 38.65%]
4	Regress Stage 1 Coefficient	Amihud	0.0020	(0.394)	[-0.001, 0.004]	0.0013	(0.376)	[-0.001, 0.005]
		Amihud percentage	2.26%	(0.394)	[-0.61%, 1.94%]	0.68%	(0.376)	[-0.56%, 2.13%]
		Amihud_vol	0.0056	(0.000)	[0.005, 0.010]	0.0057	(0.000)	[0.004, 0.011]
		Amihud_vol percentage	6.34%	(0.000)	[2.44%, 4.52%]	2.93%	(0.000)	[2.43%, 4.55%]
		IRC	0.0042	(0.000)	[0.005, 0.020]	0.0133	(0.000)	[0.005, 0.020]
		IRC percentage	4.79%	(0.000)	[3.03%, 7.58%]	6.86%	(0.000)	[3.10%, 7.68%]
		IRC_vol	0.0029	(0.000)	[0.002, 0.006]	0.0018	(0.002)	[0.002, 0.006]
		IRC_vol percentage	3.31%	(0.000)	[0.80%, 2.75%]	0.94%	(0.002)	[0.75%, 2.73%]
		γ	0.0114	(0.000)	[0.018, 0.041]	0.0268	(0.000)	[0.017, 0.040]
		γ percentage	12.96%	(0.000)	[10.02%, 16.76%]	13.82%	(0.000)	[9.89%, 16.67%]
		Bond_zero	-0.0000	(0.992)	[0.000, 0.003]	0.0047	(0.008)	[0.000, 0.003]
		Bond_zero percentage	-0.02%	(0.992)	[0.14%, 1.77%]	2.45%	(0.008)	[0.17%, 1.80%]
		Moody_rating	0.0165	(0.000)	[0.079, 0.117]	0.0719	(0.000)	[0.078, 0.120]
		Moody_rating percentage	18.81%	(0.000)	[37.74%, 55.43%]	37.12%	(0.000)	[37.41%, 55.25%]
		Leverage	-0.0004	(0.995)	[0.001, 0.006]	0.0014	(0.005)	[0.001, 0.006]
		Leverage percentage	-0.40%	(0.995)	[0.48%, 2.84%]	0.75%	(0.005)	[0.52%, 2.96%]
		Interest_coverage	0.0007	(1.000)	[-0.011, -0.006]	0.0028	(1.000)	[-0.011, -0.006]
		Interest_coverage percentage	0.85%	(1.000)	[-5.13%, -2.92%]	1.45%	(1.000)	[-5.14%, -2.92%]
		FCF/Debt	0.0008	(0.210)	[-0.001, 0.004]	0.0000	(0.220)	[-0.001, 0.004]
		FCF/Debt percentage	0.91%	(0.210)	[-0.41%, 1.72%]	0.01%	(0.220)	[-0.40%, 1.69%]
		EBITDA/Sales	0.0001	(0.998)	[-0.003, -0.001]	-0.0018	(0.002)	[-0.003, -0.001]
		EBITDA/Sales percentage	0.10%	(0.998)	[-1.23%, -0.32%]	-0.93%	(0.002)	[-1.22%, -0.33%]
		Residual	0.0439	(0.000)	[4.97%, 9.17%]	0.0657	(0.000)	[4.96%, 9.23%]
		Residual Percentage	50.09%	(0.000)	[28.237%, 36.192%]	33.92%	(0.000)	[28.243%, 36.077%]
		Total	0.0876	(0.000)	[0.152, 0.285]	0.1937	(0.000)	[0.150, 0.285]

Percentage	100%	100%
Number of obs	66,285	15,987

We uses panel regressions with cross-sectionally demeaned variables to decompose the positive relation between bond yield spread and equity volatility into a number of components each related to a candidate variable and a residual component. We separately conduct the decomposition for 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*, and *EBITDA/Sales*. 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 A). 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 11 for variable description.

Table 11: Variable Description

Variable	Description
Yield_spread	Bond 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	100 times 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.

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