Review of Finance, 2016, 631–661
doi: 10.1093/rof/rfv022
Advance Access Publication Date: 11 June 2015

Rollover Risk and Credit Spreads: Evidence from International Corporate Bonds*

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Abstract

Using a new dataset on corporate bonds placed in international markets by emerging and developed borrowers, this article demonstrates that a high proportion of short-term debt exacerbates the effect of debt market illiquidity on corporate bond spreads. This effect is present during both periods of financial stability and of financial distress, and it is smaller in the banking sector than in other sectors. The article's major finding is robust when controlling for potential endogeneity. Moreover, the results are consistent with the predictions of structural credit risk models that argue that a higher proportion of short-term debt increases a firm's exposure to debt market illiquidity through a "rollover risk" channel.

JEL classification: G12, G13, G15, G32, G33

1. Introduction

The recent financial crisis of 2008–09 affected international debt markets severely and produced a significant widening of corporate bond spreads. According to the literature on the determinants of corporate bond spreads, the primary factors that may have affected these spreads during the crisis are default and liquidity risks, which have generally been treated as independent determinants of corporate bond spreads. However, the financial crisis also highlighted the importance of rollover risk as a significant factor to consider in the pricing

* I am especially grateful to Vikrant Vig (the Co-Editor) and two anonymous reviewers for their constructive suggestions. I have also benefited from helpful comments from Franklin Allen, Dion Bongaerts, Elena Carletti, Giancarlo Corsetti, Zhiguo He, and Jun Qian, as well as seminar participants in the IADB Research Department, the Central Bank of Chile, the Riksbank, University Carlos III, the CREDIT Conference, the CRSP Forum, the EUROFIDAI-AFFI International Paris Finance Meeting, the SFA Annual Meeting, the European Finance Association Doctoral Tutorial, the Chicago Quantitative Fall Conference, and the FMA Annual Meeting. I would like to thank Jack Bao, Jun Pan, and Jiang Wang for access to their gamma measure and Krista Schwarz for access to her KfW spread. I acknowledge financial support from Fondecyt Initiation Project # 11130390 and the Institute for Research in Market Imperfections and Public Policy, ICM *IS130002*, Ministerio de Economía, Fomento y Turismo.

of corporate bonds. Despite a rich body of literature examining the influence of default risk and market illiquidity on corporate bond spreads (e.g., Merton, 1974; Collin-Dufresne, Goldstein, and Spencer, 2001; Campbell and Taksler, 2003; Longstaff, Mithal, and Neis, 2005; Chen, Lesmond, and Wei, 2007; Covitz and Downing, 2007; Bao, Pan, and Wang, 2011; Dick-Nielsen, Feldhütter, and Lando, 2012), empirical research on the role of rollover risk in corporate debt markets remains in its infancy.

Rollover risk refers to the risk faced by firms when their debt is about to mature and must be rolled over into new debt. If interest rates rise adversely, then firms must refinance their debt at a higher rate and incur more losses (interest charges) in the future. Therefore, rollover risk appears to be particularly relevant during episodes of market illiquidity for firms that need to refinance a significant proportion of their debt.

Using a new dataset on corporate bonds placed in international markets for the period from January 2004 to June 2009, this article shows that the effect of debt market illiquidity on corporate bond spreads is exacerbated by high levels of short-term debt over total debt. This effect is present during both periods of financial distress and of financial stability. The results also indicate that banks are more resilient to the marginal effect of debt market illiquidity through a rollover risk channel. These findings are consistent with the predictions of first-passage structural credit risk models, such as the model introduced by He and Xiong (2012) in which debt market illiquidity affects corporate bond spreads through a rollover risk channel.

The results in this article are statistically and economically significant even after controlling for the standard determinants of corporate bond spreads, internal liquidity, and potential heterogeneous effects of debt market illiquidity on corporate bond spreads (e.g., flight-to-quality and too-big-to-fail effects). Moreover, the results are robust to alternative measures of debt market illiquidity; to the inclusion of bond, rating, and time fixed effects; and to potential endogeneity bias.[1]

To overcome the endogeneity of short-term debt and to identify the causal effect of a firm's maturity debt structure on its corporate bond spreads, this article conducts two robustness tests. First, this article examines whether the main results are robust to an alternative measure of exposure to rollover risk defined as the ratio of long-term debt maturing within the year over total long-term debt. Using the proportion of maturing long-term debt rather than the proportion of short-term debt, this article is able to isolate the exogenous effect of rollover risk on corporate bond spreads from the response of firm managers to episodes of financial market distress. Second, this article replicates its baseline specification using a two-step efficient IV-GMM estimator that instruments for the proportion of short-term debt using the firm's pre-established target in its maturity debt structure.

This article is related to the empirical literature on the association between firms' maturity debt structures and corporate credit risk. As a consequence of the financial crisis of 2008–09, recent empirical studies using US data have highlighted the maturity debt structures of firms as an important component of corporate bond spreads. Gopalan, Song, and Yerramilli (2014) show that long-term bonds issued by firms with a higher proportion of short-term debt (long-term debt maturing within the year) trade at higher credit spreads and are more likely to experience credit rating downgrades than firms with lower

[1] As firm managers choose the maturity debt structure of a firm according to the firm's credit risk profile (Diamond, 1991; Barclay and Smith, 1995), the choice of the firm's debt structure is an endogenous decision.

proportions of short-term debt. Hu (2010) argues that US firms with a proportion of maturing long-term debt higher than 0.2 experienced higher spreads during the second half of 2008, a period that coincides with the bankruptcy of Lehman Brothers. In addition, Chen, Xu, and Yang (2013) show that firms that had a larger portion of long-term debt maturing in 2008 experienced a stronger increase in CDS spreads compared with firms with less-maturing, long-term debt. This effect is particularly strong for firms with high leverage or high-cashflow betas and for CDSs with shorter maturity.

A related strand of the literature on the relationship between maturity debt structures and credit risk has shifted from US data analysis by exploiting within-country variation. Analyzing banks in the five East Asian countries most affected by the 1997 Asian financial crisis, Benmelech and Dvir (2013) find that long-term debt that was issued before the crisis but that became due during or immediately after the crisis had a negative, although not always statistically significant, effect on the probability of bank failure.

This article contributes to the literature in at least four ways. First, this article takes an additional step beyond the previously mentioned papers by exploring how a high proportion of maturing debt amplifies the effect of debt market illiquidity on corporate bond spreads through a rollover risk channel. This finding is consistent with recent theoretical arguments that suggest an interaction between liquidity and default premiums, whereby debt market illiquidity increases a firm's probability of default through increased rollover losses. Ignoring this channel when considering the effect of debt market illiquidity on spreads and adhering to standard models on the pricing of corporate bonds may be undesirable during periods of market illiquidity, as this approach may bias the results.

Second, in contrast to most studies that focus on US domestic bond markets, this article utilizes an unexploited dataset on corporate bonds placed in international markets by emerging and developed borrowers. Thus, this article presents new evidence of a rollover risk channel in international debt markets. The study of international debt financing is important, as recent empirical studies emphasize that debt issues in international markets are an important source of capital for firms. According to Gozzi, Levine, and Schmukler (2010), the total amount raised through debt issues abroad in developed economies represents 35% of the total amount raised through debt issues. This magnitude reaches 47% in emerging economies.

Third, this article explores the relationship between rollover risk and corporate bond spreads during both periods of financial distress and of financial stability. Therefore, this study is a departure from most recent studies that exclusively focus their analysis on the period covering the bankruptcy of Lehman Brothers, which was a peculiar period of financial distress, particularly for the US financial market. Finally, by showing that banks are less affected by the marginal effect of debt market illiquidity through a rollover risk channel, this article contributes to the current debate regarding the regulation of nonbank financial corporations.

The remainder of the article is organized as follows. Section 2 briefly presents the theoretical framework that supports the empirical tests conducted in this article. Section 3 describes the characteristics of the data and the sample. Section 4 presents the empirical strategy and main results. Section 5 reports additional results and robustness checks. Section 6 concludes the article.

2. The Theoretical Framework

Rollover risk refers to the situation in which a firm's funding costs rise adversely and in which the firm suffers losses from issuing new bonds to replace maturing bonds. This section presents a brief theoretical discussion of two related channels through which rollover risk influences corporate bond spreads. First-passage structural credit risk models such as those introduced by Leland and Toft (1996) and He and Xiong (2012) frame the most important issues.

Leland and Toft (1996) provide a framework in which rollover losses occur because a firm's funding cost rises as a consequence of lower bond prices. The model assumes a stationary debt structure that implies that when a bond matures, firms replace it by issuing a new, identical bond at market price, which can be higher or lower than the principal of the maturing bond. If the market price of the newly issued bond decreases below its principal value, then firms incur rollover losses. To avoid default, the equity holders of a firm bear these rollover losses, while maturing debt holders are paid in full, and endogenously decide to default when the equity value of the firm decreases to zero.

He and Xiong (2012) extend Leland and Tofts's structural credit risk model by adding an illiquid debt market and demonstrate that rollover losses can also occur when a firm's bonds become illiquid. When market illiquidity deteriorates, bondholders must sell their bonds at a proportional cost, which increases the rollover losses of firms issuing new bonds to replace maturing bonds. Given that rollover losses are greater in firms with higher ratios of short-term debt to total debt because short-term debt is rolled over at a higher frequency than long-term debt, equity holders choose to default earlier if debt maturity is relatively low. Thus, the model predicts that the effect of market illiquidity on corporate bond spreads is amplified in firms with high levels of short-term debt over total debt through a rollover risk channel.

Although this article primarily tests whether the effect of market illiquidity on corporate bond spread is exacerbated in firms with higher ratios of short term to total debt, this study also controls for the potential effect of deteriorating general credit conditions.

3. Sample Characteristics and Data Description

Using Bloomberg Professional, I construct a new set of data on corporate bonds placed in international markets by developed and emerging market borrowers. The period under study is from January 2004 to June 2009. The dataset consists of month-end data and considers all fixed-rate bonds denominated in US dollars and available to Bloomberg in June 2009.[2]

This article focuses on the international dimension of the data and excludes bonds issued by firms located in the USA or UK. The rationale for excluding these two countries is to reduce potential endogeneity biases stemming from the causal effect of debt market illiquidity on corporate bond spreads. It is well known that the financial distress of some individual financial institutions in the USA and UK generated great declines in market illiquidity during the recent financial crisis. For example, Aragon and Strahan (2012) show that stocks held by Lehman-connected funds experienced greater declines in market liquidity following the bankruptcy than other stocks. Therefore, during the crisis period, the debt market illiquidity measures used in this article and explained in Section 3.2 are more likely to represent an exogenous factor in corporate debt markets of countries other than USA and UK.

2 The countries included in the final sample are Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Malaysia, Mexico, the Netherlands, New Zealand, Norway, Panama, Peru, the Philippines, Singapore, South Korea, Spain, Sweden, Switzerland, and Thailand.

Despite these exclusions, the behavior of my spread data is consistent with the behavior of the spread indices that are widely used by investors and that represent nearly the entire universe of corporate bonds denominated in US dollars. The dataset contains bonds issued by publicly traded firms in the financial and nonfinancial sectors. The distribution of issuers by sector in the final sample is as follows: industrial (53.9%), banking (17.1%), financial (9.0%), utility (8.6%), telephone (7.8%), oil and gas (2.4%), and transportation (1.2%).

Given that only certain types of firms choose to access the offshore financing market versus the onshore financing market, the results in this article cannot be extrapolated to the entire universe of firms around the world. The sample of firms in this article is only representative of firms that issue international bonds denominated in US dollars. However, the study of international debt financing denominated in US dollars is important. According to Gozzi Levine, and Schmukler (2010), debt issues in public markets are a more important source of capital for firms than equity issues are, and debt markets are more internationalized than equity markets are. Moreover, international debt issues tend to be denominated in foreign currencies, particularly US dollars (Hausmann and Panizza, 2010; Gozzi et al., 2012).

To reduce potential coding errors, I clean the data in four ways. First, I eliminate the top and bottom 0.5% of the spreads from my analysis. Second, I exclude all observations in which any of the accounting variables exceeds the sample mean by more than five standard deviations. Third, I do not consider bonds issued in countries in which the total number of observations was lower than 30.[3] Fourth, I restrict the sample to bonds issued by firms with a Standard and Poor's (S&P) credit rating between AAA and B-. After the cleaning of the data, the final sample, including all control variables, contains 20,465 bond-month observations.

3.1 Corporate Bond Spreads

The dependent variable is the *option-adjusted spread* (OAS) from Bloomberg Professional. It measures the yield on a corporate bond in excess of US Treasuries after accounting for the value of any embedded option. Given that the main objective of the OAS analysis is to isolate the yield premium from the option premium, the OAS captures the credit spread, a liquidity premium, and the richness or cheapness of the bond after removing the effect of any embedded option (Fabozzi, 2006; Miller, 2007). Appendix A explains in detail how Bloomberg Professional computes OASs for callable and noncallable bonds (i.e., bonds with and without embedded options, respectively).

The use of the OAS in this study is important, as many corporate bonds contain embedded options. In fact, 57% of the sample observations correspond to bonds with contingent cash flows as a result of call, put, or sink features. The OAS analysis makes it feasible to compare spreads not only across corporate bonds with different maturity profiles, but also with different cash flow structures. In contrast, standard yield spreads on bonds with embedded options are meaningless because the exact maturity date of those bonds is unknown. In practical terms, this enables us to expand the sample size beyond a few bonds that match among all the dimensions.[4]

3 The bonds eliminated in this data cleaning step are bonds issued in the Bahamas, China, and Hong Kong.

4 Other studies using OASs include Becchetti, Carpentieri, and Hasan (2012), Cavallo and Valenzuela (2010), Huang and Kong (2003), and Pedrosa and Roll (1998).

While using the OAS greatly increases the sample of bonds, it does so at the cost of potential model misspecification. Accounting for the value of any embedded option depends on the specific model used to derivate OAS. Therefore, the behavior of OASs might be explained by a misspecification in the Bloomberg Professional model from which different interest rate scenarios are generated and the OAS is computed. However, the main results in this article are robust to a subsample of noncallable bonds. As explained in Appendix A, the OAS of a noncallable bond is simply computed as the constant spread that must be added to the Treasury spot rate to make the price of the risk-free bond identical to the observed market price of the corporate bond. Thus, the OAS computation of bonds without embedded options is analogous to the Z-spread and it is not dependent on interest rate models as it does not need to generate different interest rate scenarios. This suggests that the results from a sample of noncallable bonds are unlikely to be driven solely by misspecification of the pricing model.[5]

To explore whether my OAS data suffer from any selection bias, it is interesting to compare my OAS data with OAS indices. Figure 1 shows the OAS indices constructed from my data adjacent to the OAS indices reported by Bank of America (BofA) Merrill Lynch.[6] The figure displays each series for each credit rating category with their respective correlations. It is noteworthy that the indices constructed from my dataset adequately mimic the behavior of the BofA Merrill Lynch OAS indices and, therefore, the universe of bonds given a set of characteristics, such as credit rating, currency, amount issued, and time to maturity. This analysis suggests that the results presented here are unlikely to be affected by sample selection bias.

Table I summarizes the mean spread using the S&P credit rating and the number of years to maturity. The table shows that OASs' increase as the quality of the credit rating decreases and that OASs' are considerably greater during the period of financial distress that included the Lehman Brothers bankruptcy.

3.2 Debt Market Illiquidity and Credit Market Conditions

It is generally known that there is a significant level of commonality in measures of bond illiquidity that indicates a significant systemic illiquidity component (Chordia, Sarkar, and Subrahmanyam, 2005; Bao, Pan, and Wang, 2011). Therefore, in view of the financial crisis of 2008–09 and its effects, this article focuses on the systematic implications of debt market illiquidity and utilizes debt market illiquidity measures rather than bond-specific measures.

The four measures of debt market illiquidity used in this article are the gamma measure, the noise measure, the on/off-the-run US Treasury spread, and the KfW spread. Appendix B

5 Although it is certainly true that OASs of callable bonds are model dependent, the results documented in this article are difficult to reconcile with the view that OASs are simple "noise" caused by model misspecification.

6 The BofA Merrill Lynch OAS indices correspond to weighted averages based on the outstanding amount of each bond. Because of data restrictions, the OAS weighted averages from my data are based on the amount issued. In addition, given that the US Corporate BofA Merrill Lynch indices by credit rating are available only for bonds issued in investment-grade countries of risk, in the construction of my indices, I do not consider bonds issued in countries granted a lower than investment-grade credit rating. The index criteria used by BofA Merrill Lynch are available at http://www.mlindex.ml.com.

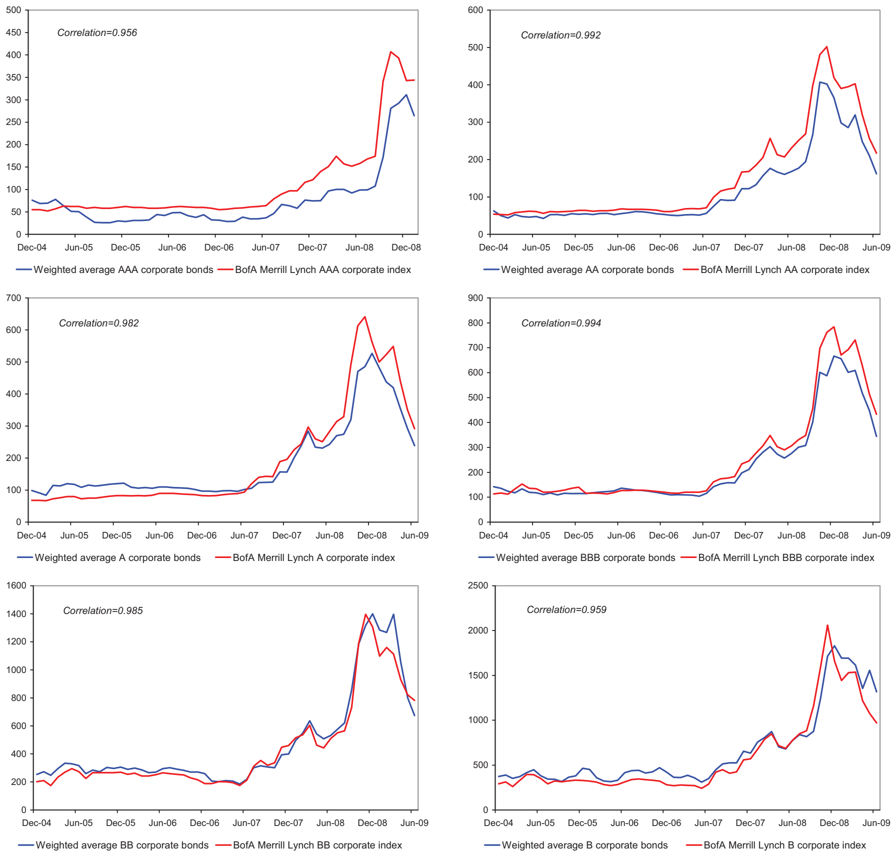

Figure 1. Corporate OASs.

For each credit rating category, the panels in the figure depict the weighted average OASs calculated from the bond-level data used in this article, in addition to the BofA Merrill Lynch OAS indices. The AAA, AA, A, and BBB US Corporate Indices are a subset of the BofA Merrill Lynch US Corporate Index, which include securities with an investment-grade rating and an investment-grade-rated country of risk. The BB and B US High Yield Indices are a subset of the BofA Merrill Lynch US High Yield Index, which includes securities with a lower than investment-grade rating and an investment-grade-rated country of risk. Simple correlations between both indices are reported for each credit rating category.

describes these four proxies of debt market illiquidity and Figure 2 plots their monthly time series variation.[7] I report all my results using the gamma measure and use the other three measures largely for the purpose of demonstrating robustness in my baseline regressions.

The main idea of using proxies of debt market illiquidity related to other debt markets is to reduce potential endogeneity biases. On the one hand, the gamma variable provides a measure of debt market illiquidity that refers to the US corporate debt market, and

7 The KfW spread is adopted from Schwarz (2014) and it is available from April 2007.

Table I. Average corporate OASs

Using panel data between January 2004 and June 2009, this table reports corporate option-adjusted spreads in basis points by credit rating and years to maturity. All bonds are denominated in US dollars. The table reports option-adjusted spreads for the periods before and after the Lehman Brothers bankruptcy.

Corporate bond spreads (bps)	S&P Credit Rating					
	AAA	AA	A	BBB	BB	B
	January 2004–December 2007					
Short maturity (0–3 years)	65	87	94	142	290	472
Medium maturity (3–7 years)	40	89	98	130	264	403
Long maturity (7–15 years)	92	82	98	150	302	414
	January 2008–June 2009					
Short maturity (0–3 years)	172	265	309	514	871	1152
Medium maturity (3–7 years)	118	247	335	420	827	939
Long maturity (7–15 years)		271	335	429	747	1200

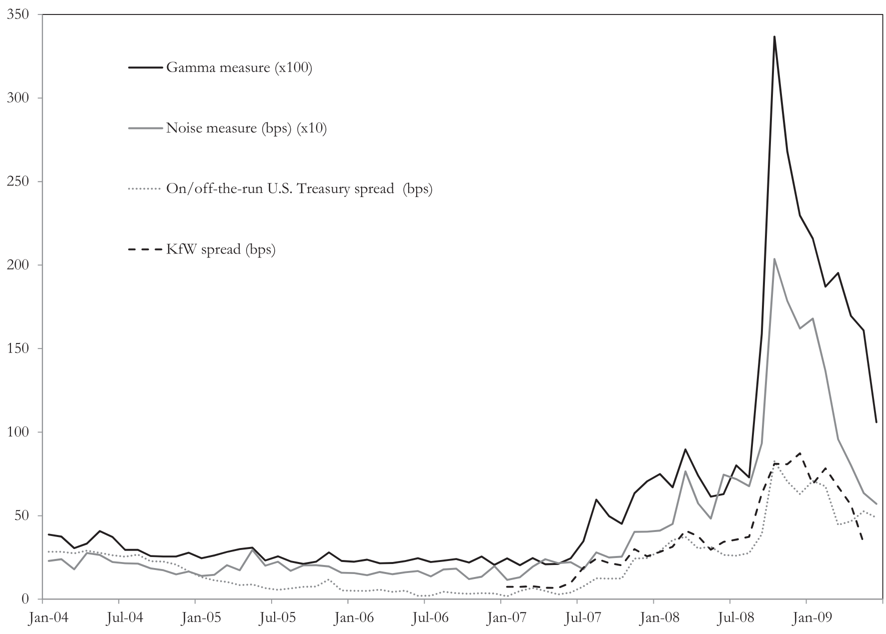

Figure 2. Monthly time series variation of debt market illiquidity.

The figure plots the monthly time series variation of the four debt market illiquidity measures used in this article: the gamma measure, the noise measure, the on/off-the-run US Treasury spread, and the KfW spread.

therefore it is much more likely to be an exogenous variable in the estimation of the parameters of interest in a sample of countries other than the USA. On the other hand, the noise measure, the on/off-the-run US Treasury spread, and the KfW spread are proxies of debt illiquidity that does not refer to the corporate debt market, and thus they are more likely to be exogenous in the regressions conducted in this article than other measures based on corporate bond data.

The results are qualitatively similar regardless of the measure used. Table AI in the Appendix shows the correlation matrix for those measures. The high correlation among the five measures suggest high levels of commonality and contagion in market illiquidity across debt markets, suggesting that those variables can be used as comprehensive measures of market illiquidity in bond markets.

Given that most measures of debt market illiquidity typically proxy general credit conditions (Hu, Pan and Wang, 2013), this article also utilizes two measures of systemic credit risk. The first variable is the 3-month Libor–OIS spread, which is the difference between the London inter-bank offer rate and the overnight index swap rate. The second variable is the 3-month TED spread, which is the difference between the interest rate on inter-bank loans and the T-bill rate. It is generally understood that these spreads contain both liquidity and default premiums. Schwarz (2014) decomposes the Libor–OIS spread on market illiquidity and credit risk, finding that market illiquidity explains more than two-thirds of the widening of the euro Libor–OIS spread.

3.3 Short-term and Long-Term Debt Maturing within a Year

According to the theoretical framework introduced by He and Xiong (2012), rollover losses increase with debt market illiquidity, and this effect is stronger for firms with higher ratios of short-term debt to total debt. Therefore, the empirical model presented in the next section considers debt market illiquidity, the ratio of short-term debt to total debt and the interaction of both as determinants of corporate bond spreads. The ratio of short-term debt to total debt is constructed using accounting data from Bloomberg and is calculated as the ratio of short-term borrowings to total borrowings.

Considering that short-term debt is endogenous, this article also utilizes the proportion of long-term debt maturing within the year rather than the proportion of short-term debt. Using the proportion of maturing long-term debt rather than the proportion of short-term debt, this article is able to isolate the exogenous effect of pure rollover risk on corporate bond spreads from the responses of firm managers to changes in credit risk conditions. The ratio of long-term debt maturing within the year to total long-term debt is also constructed using accounting data from Bloomberg.

3.4. Other Corporate Bond Spreads Determinants

To control for all variables that could directly affect corporate bond spreads, all specifications consider a comprehensive set of variables. The choice of the control variables is based primarily on structural credit risk models and the empirical literature on the determinants of corporate bond spreads (see, e.g., Collin-Dufresne, Goldstein, and Spencer, 2001 and Campbell and Taksler, 2003). The descriptions, units, frequency, and sources of the variables are presented in Table AII in the Appendix.

At the bond level, all regressions include bond fixed effects and control for the time to maturity. Bond fixed effects control for the endogeneity arising from time-invariant bond and/or firm heterogeneity. At the firm level, all models include S&P corporate credit rating dummies. Because credit ratings primarily consider the long-term and structural components of default risk (Löffler, 2004), following Campbell and Taskler (2003), I also consider the issuer's equity volatility and a standard set of accounting variables: operating income to sales, the ratio of short-term debt to total debt, the ratio of total debt to assets and firm size.[8] Finally, all models consider the ratio of cash holdings to total debt to control for the tendency of firms to mitigate refinancing risk by increasing their cash holdings (Harford, Klasa, and Maxwell, 2014). As balance sheet variables are generally reported quarterly, I estimate monthly observations using linear interpolation, but the main results in this article are nearly identical when using quarterly data.

At the country level, I include the S&P sovereign credit rating to control for a broad range of country-level factors correlated with sovereign risk that could affect the credit risk of private firms. Borensztein, Cowan, and Valenzuela (2013) show that sovereign credit ratings remain a significant determinant of corporate credit risk even after controlling for firm-level financial indicators of creditworthiness and macroeconomic conditions in the country. Finally, I consider the interaction between corporate credit rating and debt market liquidity to control for a potential "flight-to-quality" effect in which investors abandon risky bonds in favor of safer bonds during periods of market illiquidity. As part of the robustness checks in this article, I also consider a number of additional interaction terms to control for other potential heterogeneous effects of debt market illiquidity on corporate bond spreads. Table II characterizes the variables considered in my final sample of bonds for each year.

4. Regression Analysis

4.1 Corporate Bond Spreads and Rollover Risk

The central question of this study is to explore whether, consistent with a rollover risk channel, the effect of debt market illiquidity on corporate bond spreads is amplified for firms with high levels of short-term debt relative to total debt. Thus, the baseline specification is as follows:

$$\begin{aligned}\text{Bond Spread}_{bfct} = \eta_0 & + \eta_1 \text{Maturity}_{bfct} + \eta_2 \text{Equity Volatility}_{fct} \\ & + \eta_3 \text{Operating Income/Sales}_{fct} \\ & + \eta_4 \text{Debt/Assets}_{fct} + \eta_5 \text{Cash/Debt}_{fct} + \eta_6 \text{Size}_{ct} \\ & + \eta_7 \text{Sovereign Rating}_{ct} \\ & + \eta_8 \text{ST Debt/Debt}_{fct} + \eta_9 \text{Rating}_{jct} \text{x Market Illiquidity}_t \\ & + \eta_{10} \text{ST Debt/ Debt}_{fct} \text{x Market Illiquidity}_t \\ & + \mathbf{A}_b + \mathbf{B}_r + \mathbf{C}_t + \varepsilon_{bfct},\end{aligned}$$

where the subscript "*bfct*" refers to bond *b*, firm *f*, country *c*, and time *t*. $\mathbf{A}_b$, $\mathbf{B}_r$, and $\mathbf{C}_t$ are vectors of bond, credit rating, and time dummy variables, respectively, and ε_{bfct} is the error term. To attenuate potential endogeneity concerns, I also re-estimate all models using the proportion of long-term debt maturing within a year rather than the ratio of short-term debt to total debt.

Table III presents the main results from the estimation of my baseline regression by ordinary least squares with errors clustered at the bond level. Columns 1 and 2 report the

8 Although my main results are robust to the inclusion of the pretax interest coverage, I exclude this variable in my baseline regression because my sample size decreases considerably when this variable is added.

Table II. Sample characterization

Using panel data between January 2004 and June 2009, this table presents simple averages by year for the variables considered in the empirical model. ST = short-term.

Variables	2004	2005	2006	2007	2008	2009
Bond spreads (OAS)	171.32	157.17	147.27	158.75	399.32	571.67
Years to maturity	8.51	7.60	6.69	5.88	5.18	4.65
Issue size	19.51	19.26	19.12	19.16	19.26	19.31
Coupon rate	685.63	662.61	647.12	639.66	641.06	632.50
Equity volatility	27.05	25.84	27.85	27.71	44.65	72.80
Credit rating	13.61	13.57	13.97	14.38	14.31	14.26
Operating income to sales	0.17	0.18	0.17	0.14	0.11	0.07
ST debt to total debt	0.17	0.21	0.25	0.28	0.27	0.25
Proportion maturing long-term debt	0.10	0.10	0.11	0.12	0.10	0.10
Total debt to asset	0.31	0.31	0.33	0.34	0.33	0.33
Cash holdings to total debt	0.17	0.19	0.20	0.19	0.19	0.18
Size	9.74	9.87	10.16	10.49	10.61	10.60
Sovereign credit rating	19.41	19.14	19.12	19.13	19.16	19.15
Gamma measure	31.41	25.34	22.88	39.35	132.07	173.49
Noise measure	2.07	1.93	1.58	2.46	9.40	10.19
On/off-the-run US Treasury spread	24.59	8.45	3.94	10.37	41.61	55.43
KfW spread				16.09	49.28	61.84

results of my baseline regression setting η_9 and η_{10} to zero to estimate the average rollover risk effect. The positive and statistically significant coefficients associated with the proportion of short-term debt and the proportion of the maturing long-term debt, respectively, are consistent with existing empirical literature on debt maturity structure and credit spreads (e.g., Gopalan, Song, and Yerramilli, 2014). This effect is economically significant. A one-standard deviation increase in the proportion of short-term debt is associated with an increase of 26 bps in credit spreads. A one-standard deviation increase in the proportion of maturing long-term debt is associated with an increase of 13 bps in credit spreads.

Columns 3 and 4 report the results of estimating my full baseline regression. The results indicate that a higher proportion of short-term debt (proportion of maturing long-term debt) increases a firm's exposure to debt market illiquidity. All the coefficients of the interaction term between the proportion of short-term debt (proportion of maturing long-term debt) and debt market illiquidity are positive and highly statistically significant. This empirical finding is consistent with the theoretical framework introduced by He and Xiong (2012) on the relationship among market illiquidity, a firm's maturity debt structure, and credit spreads. Moreover, the negative and statistically significant coefficients associated with the interaction between corporate credit rating and debt market illiquidity suggest the presence of a "flight to quality" effect whereby bonds that are less risky in terms of their credit rating quality are less affected by episodes of market illiquidity than riskier bonds are.

Most of the coefficients associated with the control variables have the expected sign, but only a few are statistically significant. However, it is noteworthy that in unreported regressions that include industry and country fixed effects rather than bond fixed effects, nearly all coefficients are highly significant in the expected directions, and their magnitudes are

Table III. Corporate bond spreads and rollover risk

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond, rating, and time fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

	(1)	(2)	(3)	(4)
Years to maturity	−55.622***	−24.842***	−94.755***	−79.559***
	(4.814)	(4.643)	(4.800)	(5.752)
Equity volatility	0.740*	3.006***	1.801***	2.834***
	(0.416)	(0.585)	(0.344)	(0.477)
Operating income to sales	−40.774	−24.515	−61.380**	−31.163
	(28.436)	(30.256)	(28.588)	(26.150)
Total debt to asset	−160.116	21.927	7.702	122.608
	(107.322)	(126.692)	(82.451)	(94.501)
Cash holdings to total debt	−27.610*	−22.108	−14.449	−17.737
	(15.035)	(14.737)	(11.375)	(11.940)
Size	−30.064	−26.344	−18.505	−6.344
	(26.428)	(26.216)	(20.329)	(18.795)
Sovereign credit rating	16.825	11.436	−8.888	−26.215**
	(12.505)	(13.898)	(9.974)	(11.642)
ST debt to total debt	102.370**		−26.253	
	(40.310)		(30.280)	
Proportion LT debt maturing within the year		100.428***		−118.141***
		(36.503)		(29.092)
Credit rating × Gamma			−0.391***	−0.355***
			(0.025)	(0.026)
ST debt to total debt × Gamma			1.774***	
			(0.263)	
Proportion LT debt maturing within the year × Gamma				3.646***
				(0.718)
Observations	20,465	15,851	20,465	15,851
Number of bonds	587	441	587	441
R^2 within	0.588	0.625	0.685	0.707
R^2 between	0.429	0.588	0.305	0.361
R^2 overall	0.440	0.548	0.396	0.463

consistent with those reported by Campbell and Taksler (2003). This finding suggests that the variation across bonds and firms constitutes the explanatory power behind those variables.

Subsequently, I explore whether my previous results are robust to alternative measures of debt market illiquidity. Table IV presents the results for three additional measures of debt market illiquidity: the noise measure, the on/off-the-run US Treasury spread, and the KfW spread. I report the results for both specifications, using the proportion of maturing short- and long-term debt. All coefficients associated with the interaction between the proportion of short-term debt (the proportion of maturing long-term debt) and debt market illiquidity are positive and highly statistically significant. Thus, the main finding in this

Table IV. Different measures of debt market illiquidity

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond, rating, and time fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

Market Illiquidity	Noise		On/off-the-run spread		KfW spread	
	(1)	(2)	(3)	(4)	(5)	(6)
Years to maturity	−79.072***	−64.459***	−125.608***	−111.532***	−323.490***	−287.728***
	(4.385)	(5.174)	(5.744)	(6.579)	(14.753)	(16.834)
Equity volatility	1.675***	2.906***	1.768***	2.616***	2.143***	2.939***
	(0.346)	(0.490)	(0.346)	(0.468)	(0.411)	(0.565)
Operating income to sales	−64.274**	−29.356	−62.027**	−32.632	−76.515***	−51.622*
	(29.087)	(26.811)	(28.422)	(25.801)	(29.551)	(27.309)
Total debt to asset	−26.701	105.827	−9.332	97.834	−234.097	−61.060
	(86.229)	(99.815)	(83.045)	(94.570)	(162.381)	(175.022)
Cash holdings to total debt	−17.193	−18.590	−16.565	−19.462	−63.925***	−63.183***
	(11.587)	(12.246)	(11.915)	(12.518)	(19.621)	(21.584)
Size	−19.887	−7.722	−22.190	−11.807	−84.470**	−47.553
	(21.010)	(19.640)	(20.317)	(19.154)	(38.773)	(38.102)
Sovereign credit rating	−5.429	−23.145**	−8.584	−30.207***	−51.709**	−66.688***
	(10.097)	(11.631)	(10.375)	(10.536)	(22.791)	(22.664)
ST debt to total debt	−6.474		−42.207		−53.738	
	(31.320)		(31.345)		(59.340)	
Proportion LT debt maturing within the year		−104.831***		−132.781***		−157.704***
		(29.228)		(33.912)		(59.953)
Credit rating × Market illiquidity	−5.659***	−5.168***	−1.337***	−1.226***	−1.336***	−1.234***
	(0.381)	(0.389)	(0.081)	(0.086)	(0.085)	(0.086)
ST debt to total debt × Market illiquidity	25.264***		5.811***		6.025***	
	(4.043)		(0.894)		(0.946)	
Proportion LT debt maturing within the year × Market illiquidity		54.573***		11.985***		12.005***
		(9.871)		(2.519)		(2.037)
Observations	20,465	15,851	20,315	15,733	11,875	8,991
Number of bonds	587	441	587	441	562	419
R^2 within	0.674	0.698	0.680	0.706	0.675	0.698
R^2 between	0.380	0.451	0.203	0.225	0.0810	0.0629
R^2 overall	0.450	0.523	0.294	0.342	0.121	0.127

article is robust not only to controlling for the potential endogeneity of short-term debt, but also to alternative measures of debt market illiquidity.

Given that market illiquidity only fluctuates over time, I cannot simultaneously control for market illiquidity and time dummies. Table AIII in the Appendix reestimates the baseline specification including market illiquidity and other global variables, as in Duffee

(1998). This specification thus relies on market illiquidity, the 10-year US Treasury rate and the slope of the US Treasury rate rather than time dummies. The main finding in this article remains practically identical in both specifications. As expected, the results indicate that market illiquidity is positively related to corporate bond spreads and that this effect is greater in firms with high levels of short-term debt over total debt (the proportion of maturing long-term debt). The negative and statistically significant coefficients on the US Treasury rate and the slope of the US Treasury rate are consistent with previous findings on the relationship between treasury yields and corporate bond yield spreads (Duffee, 1998). Considering that the main focus of this article is associated with the interaction between a firm's maturity debt structure and market illiquidity, I report my results using time dummies, as this approach controls for all factors that simultaneously affect all corporate bond spreads over time. My main findings remain qualitatively identical regardless of the specification used.

4.2 Rollover Risk and Bond Maturity

Thus far, I have shown that the effect of market illiquidity on corporate bond spreads is greater in firms with a high proportion of short-term debt (proportion of maturing long-term debt). Table V divides the sample into short-, medium-, and long-maturity bonds to explore the results according to the maturity dimension. I define short-maturity bonds as those with a time to maturity of under three years, medium-maturity bonds as those with a time to maturity between three and seven years, and long-maturity bonds as those with a time to maturity greater than seven years. The results show that the finding that debt market illiquidity affects corporate bond spreads through a rollover risk channel is present in subsamples of bonds maturing in short, medium, and long term.

The results show that the magnitude of the estimated coefficient associated with the interaction term between the proportion of short-term debt and debt market illiquidity is somewhat smaller in the sample of bonds maturing in the long term than in the sample of bonds maturing in the short term. However, the results from the regressions that control for potential endogeneity using the proportion of long-term debt maturing within the year rather than the proportion of short-term debt do not show any significant difference between the estimated coefficients from the three different subsamples of bonds.

4.3 Periods of Financial Distress Versus Periods of Financial Stability

This article complements several contemporaneous studies that have specifically exploited the year 2008 to study the effect of rollover risk on corporate bond spreads (Hu, 2010; Chen, Xu and Yang, 2013). Because the year 2008 includes the bankruptcy of Lehman Brothers, which is a particularly striking period, the results are likely to be driven by this event. Given that the sample period of the dataset used in this article is not confined to only the 2008–09 crisis period, Table VI explores whether the main results in this article are present during both periods of financial distress and of financial stability. Columns 1 and 2 present the results for the sample covering the 2004–07 period. Columns 3 and 4 present the results for the sample covering the 2008–09 period. The results indicate that the effect of debt market illiquidity through a rollover risk channel remains positive and significant in both periods. Thus, this article presents new evidence that a higher proportion of maturing debt contributes to amplifying the effect of market illiquidity on corporate bond spreads both in periods of financial stability and of distress.

Table V. Rollover risk and bond maturity

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond, rating, and time fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

Market Illiquidity	Years to maturity ≤ 3		3 < Years to maturity < 7		Years to maturity ≥ 7	
	(1)	(2)	(3)	(4)	(5)	(6)
Years to maturity	−230.265***	−224.513***	−90.375***	−76.535***	−91.037***	−80.231***
	(27.567)	(34.517)	(7.052)	(7.381)	(12.020)	(13.984)
Equity volatility	0.164	−1.011	1.554***	2.822***	1.427***	2.096***
	(0.699)	(0.916)	(0.472)	(0.611)	(0.535)	(0.646)
Operating income to sales	−101.971*	−97.122	−38.968	−18.114	−161.271***	−121.382**
	(58.290)	(58.815)	(24.705)	(19.240)	(43.522)	(49.065)
Total debt to asset	−594.976	−939.716*	41.954	111.198	246.073**	452.685***
	(468.272)	(509.749)	(98.778)	(127.984)	(119.755)	(130.759)
Cash holdings to total debt	−74.850*	−91.059*	−54.254***	−53.004***	−12.614	−14.246
	(40.001)	(46.138)	(16.429)	(17.496)	(12.708)	(15.053)
Size	−151.213	−292.323**	−12.720	−10.720	−40.336*	−31.507
	(108.341)	(147.405)	(30.420)	(31.382)	(21.524)	(19.625)
Sovereign credit rating	−49.904	−70.570	−16.546	−21.325*	−27.448*	−47.084**
	(42.769)	(47.082)	(12.149)	(11.330)	(15.276)	(23.256)
ST debt to total debt	159.569		8.808		−67.114**	
	(173.177)		(44.517)		(29.240)	
Proportion LT debt maturing within the year		10.919		−67.785*		−148.424***
		(166.038)		(34.527)		(45.465)
Credit rating × Gamma	−0.344***	−0.259***	−0.353***	−0.316***	−0.345***	−0.327***
	(0.052)	(0.055)	(0.038)	(0.033)	(0.050)	(0.058)
ST debt to total debt × Gamma	1.876***		1.701***		1.164***	
	(0.545)		(0.414)		(0.407)	
Proportion LT debt maturing within the year × Gamma		2.816***		2.527***		2.597***
		(0.952)		(0.678)		(0.958)
Observations	2,713	1,893	9,691	7,673	8,057	6,281
Number of bonds	198	140	417	323	339	274
R^2 within	0.553	0.542	0.667	0.696	0.702	0.740
R^2 between	0.432	0.185	0.418	0.518	0.220	0.247
R^2 overall	0.409	0.179	0.487	0.576	0.357	0.352

4.4 Banks Versus Nonbanks Institutions

During periods of market illiquidity, bonds issued by banks exhibit higher spreads than bonds issued by nonbank institutions. A potential reason for this difference is that banks are more exposed to rollover losses as a result of their higher levels of short-term debt over total debt. However, because banks often have, among other characteristics, a lender of last resort that may alleviate the cost of rolling over their maturing debt during periods of market illiquidity, the bonds issued by banks may be more resilient to the influence of the marginal effect of debt market illiquidity.

Table VI. Periods of financial stability versus Periods of financial distress

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond, rating, and time fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

	2004–2007		2008–2009	
	(1)	(2)	(3)	(4)
Years to maturity	−47.116***	−43.214***	−181.214***	−134.426***
	(6.415)	(6.398)	(15.465)	(17.478)
Equity volatility	1.938***	2.154***	1.224***	2.554***
	(0.423)	(0.444)	(0.412)	(0.649)
Operating income to sales	−7.743	−2.599	−168.539***	−141.155***
	(5.610)	(4.797)	(44.482)	(47.839)
Total debt to asset	204.237***	200.218***	−513.576**	−184.043
	(35.791)	(39.861)	(223.219)	(278.791)
Cash holdings to total debt	5.453	0.628	−126.621***	−116.224***
	(5.199)	(5.854)	(33.181)	(34.726)
Size	6.895	14.447	−132.675*	−82.298
	(9.601)	(9.493)	(76.585)	(83.130)
Sovereign credit rating	−10.120**	−14.613*	−37.960	−73.129
	(4.320)	(7.782)	(38.980)	(46.958)
ST debt to total debt	−57.683***		75.769	
	(13.193)		(98.742)	
Proportion LT debt		−29.047		−174.942
maturing within the year		(19.186)		(116.430)
Credit rating × Gamma	−0.330***	−0.291***	−0.344***	−0.304***
	(0.051)	(0.045)	(0.027)	(0.024)
ST debt to total debt × Gamma	1.888***		1.700***	
	(0.342)		(0.281)	
Proportion LT debt maturing		1.716***		3.178***
within the year × Gamma		(0.624)		(0.565)
Observations	12,595	9,993	7,870	5,858
Number of bonds	428	327	555	409
R^2 within	0.462	0.469	0.586	0.592
R^2 between	0.141	0.123	0.362	0.440
R^2 overall	0.154	0.150	0.313	0.379

To explore whether the effect of debt market illiquidity on corporate bond spreads through a rollover risk channel differs across sectors, Table VII divides the sample into banks and nonbanks. The results indicate that, conditional on the level of the maturity debt structure, banks are less affected than nonbank institutions by the marginal effect of debt market illiquidity through a rollover risk channel. In the bank sample, a marginal increase in debt market illiquidity, measured by gamma, increases credit spreads by 1.303× (short-term debt to total debt), whereas in the nonbank sample, a marginal increase in debt market illiquidity increases credit spreads by 3.351× (short-term debt to total debt).

Table VII. Banks versus Nonbanks

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond, rating, and time fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

	Banks		Nonbanks	
	(1)	(2)	(3)	(4)
Years to maturity	−105.835***	−42.323***	−86.230***	−78.834***
	(13.315)	(15.544)	(5.809)	(6.488)
Equity volatility	0.813*	1.822**	2.775***	3.070***
	(0.449)	(0.891)	(0.552)	(0.537)
Operating income to sales	−162.035***	−162.175**	−54.711*	−15.319
	(55.495)	(71.855)	(28.967)	(22.459)
Total debt to asset	96.920	384.538***	−65.857	83.854
	(74.087)	(142.338)	(100.481)	(105.484)
Cash holdings to total debt	−31.872	427.584	−13.093	−21.026*
	(66.302)	(267.928)	(11.271)	(12.137)
Size	−96.283*	−8.862	−13.272	−3.634
	(50.459)	(47.599)	(21.698)	(19.470)
Sovereign credit rating	−28.811	−37.526	−10.910	−26.502**
	(23.357)	(31.277)	(9.591)	(11.938)
ST debt to total debt	−67.853		−119.867***	
	(45.431)		(38.438)	
Proportion LT debt maturing within the year		579.009***		−141.582***
		(200.083)		(31.047)
Credit rating × Gamma	−0.369***	−0.070	−0.386***	−0.362***
	(0.063)	(0.064)	(0.027)	(0.029)
ST debt to total debt × Gamma	1.303***		3.351***	
	(0.427)		(0.603)	
Proportion LT debt maturing within the year × Gamma		2.141***		3.895***
		(0.754)		(0.789)
Observations	4,057	1,416	16,408	14,435
Number of bonds	165	74	422	367
R^2 within	0.715	0.741	0.694	0.711
R^2 between	0.226	0.159	0.348	0.418
R^2 overall	0.242	0.249	0.435	0.485

This difference is qualitatively identical when using the proportion of long-term debt maturing within the year rather than the proportion of short-term debt.

5. Additional Results and Robustness Checks

5.1 Subsamples

Although the OAS methodology is a standard approach used in financial markets for removing the effect of the eventual embedded option of a bond; as explained in Section 3.1, this methodology may introduce some errors into the measurement of the dependent variable. To

Table VIII. Additional subsamples

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond, rating, and time fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

	Bonds without options		Quarterly data	
	(1)	(2)	(3)	(4)
Years to maturity	−99.332***	−75.984***	−119.266***	−101.283***
	(7.531)	(8.355)	(6.180)	(8.097)
Equity volatility	1.614***	3.184***	2.101***	3.051***
	(0.436)	(0.728)	(0.329)	(0.483)
Operating income to sales	−28.651	−1.037	−50.480**	−21.641
	(21.302)	(15.317)	(23.802)	(23.048)
Total debt to asset	89.707	265.303	106.174	230.244***
	(120.618)	(162.097)	(70.269)	(84.594)
Cash holdings to total debt	−25.126	−16.004	−25.243*	−29.130**
	(24.661)	(32.141)	(13.767)	(13.613)
Size	22.140	24.531	7.165	6.971
	(43.707)	(39.198)	(19.430)	(18.886)
Sovereign credit rating	−8.000	−17.870	−14.442	−40.116***
	(11.505)	(11.991)	(11.531)	(13.751)
ST debt to total debt	−68.657		−25.559	
	(51.225)		(29.357)	
Proportion LT debt maturing within the year		−61.716		−153.773***
		(43.877)		(41.716)
Credit rating × Gamma	−0.420***	−0.348***	−0.490***	−0.443***
	(0.036)	(0.038)	(0.032)	(0.038)
ST debt to total debt × Gamma	1.178***		1.952***	
	(0.401)		(0.334)	
Proportion LT debt maturing within the year × Gamma		2.810***		4.143***
		(0.835)		(0.944)
Observations	8,715	5,493	6,997	5,408
Number of bonds	271	166	587	441
R^2 within	0.679	0.698	0.714	0.740
R^2 between	0.279	0.268	0.167	0.205
R^2 overall	0.367	0.417	0.297	0.359

explore whether the OAS methodology is driving the results of this study, Columns 1 and 2 in Table VIII report the results for the sample of noncallable bonds. As explained in Appendix A, the OAS of a noncallable bond is simply calculated as the constant spread that must be added to the spot interest rate to make the price of the risk-free bond identical to the observed market price of the corporate bond. The coefficients of the interaction terms for debt market illiquidity and the proportion of short-term debt (the proportion of maturing long-term debt) remain positive and highly significant in both specifications.

Table VIII also investigates whether the interpolation of my quarterly firm-level variables into monthly frequency affects the results. To eliminate this possibility, Columns 3 and 4 reestimate my baseline regressions using quarterly data and yield qualitatively identical results.

5.2 Is the Proportion of Maturing Debt a Proxy for Other Firm or Bond Characteristics?

Given that my primary term of interest is the interaction between the ratio of short-term to total debt (the proportion of maturing long-term debt) and debt market illiquidity, it is possible that these variables are proxies for another factor. The first possibility is that the proportion of maturing debt may capture other contemporaneous variables. Table IX presents the results of a more explicit test of this possibility by including a number of additional interaction terms. The four added terms correspond to the interaction of equity volatility, total debt to total assets, firm size, and the years to maturity with debt market illiquidity, respectively. I expect bonds issued by firms with greater equity volatility and leverage to be more vulnerable to episodes of market illiquidity, whereas I expect bonds issued by larger firms and bonds with a longer time to maturity to be more resilient to episodes of market illiquidity.

Table IX shows that my previous findings remain relatively unchanged once the baseline regression is augmented to include all the new interaction terms. Moreover, several coefficients associated with the new interaction terms have the expected sign and are statistically and economically significant at standard levels of confidence. Firms with higher levels of equity volatility and leverage are more affected by debt market illiquidity. Furthermore, larger firms are less affected by market illiquidity.

5.3 Systemic Credit Deterioration

Given that most of the market illiquidity measures used in this article show increases during various market crises, these measures proxy general crisis periods rather than only specific debt market conditions. To disentangle whether the effect of rollover risk on corporate bond spreads is only consistent with debt market illiquidity or, more generally, with deteriorated credit conditions, I augment my baseline regression with the interaction of the ratio of short-term debt to total debt with two variables. The first variable is the 3-month Libor–OIS spread that is the difference between the London inter-bank offer rate and the overnight index swap rate. The second variable is the 3-month TED spread, which is the difference between the interest rate on inter-bank loans and the T-bill rate. It is generally understood that these spreads contain both liquidity and default premiums.

I estimate two alternative specifications. The first specification includes only the part of these measures that is unrelated to the liquidity premium.[9] The second specification includes the Libor–OIS spread and the Libor–OIS spread without extracting the liquidity premium components. Therefore, this method provides a strong robustness check. Table X presents the results of my augmented regressions. My coefficient of interest remains positive and highly significant.

9 I first regress the Libor–OIS spread and the TED spread on debt market illiquidity and then use the residual from that equation in my baseline regression. The resulting residual retains all the financial information, except market illiquidity.

Table IX. Nonlinear effects of market illiquidity

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. Market illiquidity corresponds to the gamma measure. All regressions control for bond and time fixed effects. The panel data consist of 667 corporate bonds covering the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

	(1)	(2)	(3)	(4)
Years to maturity	−86.405***	−60.240***	−92.906***	−75.602***
	(7.087)	(7.054)	(6.221)	(7.076)
Equity volatility	−1.067**	0.353	0.558	1.402**
	(0.512)	(0.551)	(0.489)	(0.550)
Operating income to sales	−66.338**	−46.106*	−58.732**	−32.717
	(28.989)	(26.968)	(27.851)	(25.515)
Total debt to asset	−220.751**	−58.767	−27.058	77.579
	(99.215)	(103.044)	(96.025)	(101.280)
Cash holdings to total debt	−10.861	−16.840	−15.759	−17.320
	(13.893)	(14.023)	(12.457)	(13.022)
Size	2.252	7.042	−18.983	−9.852
	(21.890)	(19.847)	(19.999)	(18.345)
Sovereign credit rating	−0.406	−15.877	−8.535	−24.761**
	(11.403)	(11.618)	(10.040)	(11.794)
ST debt to total debt	−24.906		−29.337	
	(33.459)		(29.821)	
Proportion LT debt maturing within the year		−53.300*		−102.933***
		(29.571)		(28.795)
Credit rating × Gamma			−0.368***	−0.318***
			(0.031)	(0.033)
ST debt to total debt × Gamma	1.016***		1.598***	
	(0.313)		(0.300)	
Proportion LT debt maturing within the year × Gamma		2.646***		3.324***
		(0.663)		(0.657)
Equity volatility × Gamma	0.021***	0.025***	0.008***	0.010***
	(0.003)	(0.004)	(0.003)	(0.004)
Total debt to asset × Gamma	0.896*	1.372***	0.336	0.499
	(0.481)	(0.491)	(0.480)	(0.469)
Size × Gamma	−0.500***	−0.438***	−0.020	−0.036
	(0.045)	(0.044)	(0.048)	(0.057)
Cash holdings to total debt × Gamma	0.018	0.202	0.019	0.026
	(0.190)	(0.214)	(0.212)	(0.217)
Years to maturity × Gamma	−0.025	−0.003	−0.031	−0.021
	(0.022)	(0.023)	(0.019)	(0.020)
Observations	20,465	15,851	20,465	15,851
Number of bonds	587	441	587	441
R^2 within	0.652	0.687	0.687	0.709
R^2 between	0.312	0.487	0.291	0.375
R^2 overall	0.391	0.536	0.391	0.475

Table X. The credit risk channel

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. Market illiquidity corresponds to the gamma measure. All regressions control for bond and time fixed effects. The panel data consist of 667 corporate bonds covering the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Years to maturity	−65.914***	−94.991***	−94.913***	−94.913***	−58.446***	−78.982***	−78.903***	−78.903***
	(6.335)	(4.801)	(4.804)	(4.804)	(5.906)	(5.813)	(5.835)	(5.835)
Equity volatility	1.745***	1.846***	1.857***	1.857***	2.141***	2.836***	2.841***	2.841***
	(0.325)	(0.346)	(0.347)	(0.347)	(0.530)	(0.477)	(0.478)	(0.478)
Operating income to sales	−30.057	−60.512**	−60.882**	−60.882**	−10.911	−30.283	−29.422	−29.422
	(29.777)	(28.570)	(28.597)	(28.597)	(27.066)	(26.143)	(26.258)	(26.258)
Total debt to asset	−33.526	2.080	−1.856	−1.856	89.396	131.992	136.932	136.932
	(105.257)	(82.364)	(82.481)	(82.481)	(108.572)	(92.969)	(92.227)	(92.227)
Cash holdings to total debt	−8.303	−14.304	−14.347	−14.347	−20.282*	−20.470*	−21.112*	−21.112*
	(10.872)	(11.396)	(11.405)	(11.405)	(11.134)	(11.899)	(11.940)	(11.940)
Size	−16.349	−18.779	−18.777	−18.777	−8.805	−9.594	−10.149	−10.149
	(23.262)	(20.361)	(20.374)	(20.374)	(20.563)	(19.146)	(19.184)	(19.184)
Sovereign credit rating	4.479	−8.712	−8.673	−8.673	−8.941	−24.930**	−23.677**	−23.677**
	(14.545)	(9.987)	(9.996)	(9.996)	(9.857)	(11.743)	(11.872)	(11.872)
ST debt to total debt	28.406	−28.517	−30.817	−41.203				
	(28.198)	(30.321)	(30.302)	(30.771)				
Proportion LT debt maturing within the year					−108.356***	−111.975***	−101.410***	−50.387
					(25.559)	(28.117)	(27.352)	(31.450)
Credit rating × Gamma	−0.254***	−0.392***	−0.392***	−0.392***	−0.248***	−0.353***	−0.352***	−0.352***
	(0.036)	(0.025)	(0.025)	(0.025)	(0.030)	(0.026)	(0.026)	(0.026)
ST debt to total debt × Gamma	1.062***	1.459***	1.784***	1.572***				
	(0.316)	(0.330)	(0.262)	(0.308)				

(continued)

Table X. (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Proportion LT debt maturing within the year × Gamma					4.016***	4.964***	3.540***	4.580***
					(0.744)	(1.228)	(0.674)	(1.049)
ST debt to total debt × Libor–OIS spread residual	0.126							
	(0.197)							
ST debt to total debt × Libor–OIS spread		0.495**						
		(0.205)						
ST debt to total debt × TED spread residual			0.335**					
			(0.147)					
ST debt to total debt × TED spread				0.335**				
				(0.147)				
Proportion LT debt maturing within the year × Libor–OIS spread residual					−3.396***			
					(1.089)			
Proportion LT debt maturing within the year × Libor–OIS spread						−2.127**		
						(0.968)		
Proportion LT debt maturing within the year × TED spread residual							−1.646**	
							(0.700)	
Proportion LT debt maturing within the year × TED spread								−1.646**
								(0.700)
Observations	15,967	20,465	20,465	20,465	11,983	15,851	15,851	15,851
Number of bonds	481	587	587	587	362	441	441	441
R^2 within	0.641	0.685	0.685	0.685	0.688	0.708	0.708	0.708
R^2 between	0.0883	0.306	0.307	0.307	0.146	0.362	0.358	0.358
R^2 overall	0.272	0.396	0.396	0.396	0.366	0.465	0.464	0.464

5.4 Instrumental Variables Generalized Method of Moments (IV-GMM) Estimation

To further control for potential endogeneity, I replicate my baseline specifications using a two-step efficient IV-GMM estimator.[10] The IV approach implemented in this article is based on two observations. First, leverage ratios and maturity debt structures appear to be stationary. Several empirical studies support the existence of a pre-established target in the leverage and short-term debt to total debt ratios (Jalilvand and Harris, 1984; Opler and Titman, 1997; Antoniou, Guney, and Paudyal, 2006; Deesomsak, Paudyal, and Pescetto, 2009). In addition, Barclay and Smith (1995) show that it is the variation between firms that provides explanatory power in regressions on the determinants of a firm's debt maturity structure.[11] The sample used in this study appears to be consistent with this observation. In fact, the statistics reported show that the ratios of short-term to total debt have been relatively stable throughout the entire study period. Second, the recent financial crisis was largely unexpected. Therefore, the ratios of short-term debt to total debt before the crisis are unlikely to have reflected the risks associated with the financial crisis. Thus, this strategy exploits the unanticipated and exogenous financial shock that abruptly disrupted market illiquidity, while the firms' maturity debt structure remained relatively fixed at least in the short term.

In view of these observations, I estimate my baseline specifications using a two-step efficient IV-GMM estimator for the period from January 2007 to June 2009. I instrument the ratio of short-term debt to total debt and its interaction with debt market illiquidity with the historical average values of the maturity debt structure and with the 3- and 6-month lags of the interaction between debt market illiquidity and those average values. The average values for the ratio of short-term debt to total debt are estimated using the period before January 2007. Therefore, their values should reflect the pre-established target in the ratios of short-term debt to total debt unrelated to the risks associated with the period from January 2007 to June 2009. Additionally, to reduce the potential endogeneity of my control variables, I use 3-month lags for all independent variables.

Table AIV in the Appendix reports the results for the second stage of the two-step efficient IV-GMM estimator for my baseline regression (Column 3 of Table III). The results remain largely unchanged relative to my previous results.[12] The table also presents the F-test and R^2 of the excluded instruments and the p-values for the Hansen's J-test of over-identifying restrictions (Baum, Schaffer, and Stillman, 2003). The F-test and R^2 of the excluded instruments indicate that the instruments and endogenous variables are correlated, even after

[10] The efficiency gains of this estimator relative to the traditional IV/2SLS estimator is derived from the use of the optimal weighting matrix, the over-identification restrictions of the model, and the relaxation of the identical and independently distributed assumptions.

[11] These authors obtain adjusted R^2 values of 0.16 and 0.26 in pooled and cross-sectional regressions with a much smaller R^2 of 0.02 in fixed effects regressions when the explanatory power of the fixed effects is excluded. The sample used in this study appears to be consistent with this observation. In fact, firm fixed effects can explain most of the variance in the ratios of short-term debt to total debt. Moreover, the statistics reported in Table II show that the ratios of short-term debt to total debt have been relatively stable throughout the entire study period.

[12] Additionally, the results from the IV-GMM estimation are robust to use alternative start dates. Specifically, I replicate this exercise for two additional start dates (July 2006 and 2007). The coefficients associated with the interaction term between the proportion of short-term debt and market illiquidity remain positive (1.796 and 1.511, respectively) and highly statistically significant.

eliminating the effects of all other exogenous variables. The J-test cannot reject the null hypothesis that all instruments are valid.

Overall, the entire set of robustness checks presented in this article suggests that the main results in this article are unlikely to be influenced by endogeneity bias.

6. Conclusion

The recent financial crisis of 2008–09 has highlighted the importance of rollover risk as a significant factor to consider in the pricing of corporate bonds. Consistent with the predictions of recent structural credit risk models, this article demonstrates that the effect of debt market illiquidity on corporate bond spreads is exacerbated by a higher proportion of short-term debt through a rollover risk channel. This effect is robust when controlling for the standard determinants of corporate bond spreads, internal liquidity, and the potential heterogeneous effects of debt market illiquidity on corporate bond spreads. Moreover, the effect is robust to alternative measures of debt market illiquidity; to the inclusion of bond, rating, and time fixed effects; and to potential endogeneity bias.

Rollover risk is able to explain an important proportion of the divergence of corporate bonds across firms and sectors during and before the financial crisis of 2008–09. Thus, this article contributes to the empirical literature on the modeling of corporate bond spreads surrounding periods of market illiquidity. Although the effect of debt market illiquidity on corporate bonds spreads through rollover risk appears important, this channel has been ignored in prior empirical studies.

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Appendix

A. OAS Analysis Computation

The OAS is the constant spread that must be added to the Treasury spot rate to make the price of the risk-free bond identical to the observed market price of the corporate bond. Therefore, to compute OASs, Bloomberg Professional first generates a "benchmark spot curve." This Appendix explains how Bloomberg Professional generates this "benchmark spot curve" and computes OASs for callable and noncallable bonds.

A.1 Benchmarck Spot Curve

Bloomberg Professional follows five steps to generate the "benchmark spot curve": (i) the 6-month spot rate is defined as being equivalent to the benchmark 6-month rate; (ii) a 1-year benchmark bond containing a 6-month coupon payment and a 1-year coupon and principal payment is considered; (iii) the 6-month coupon payment of the 1-year benchmark issue is discounted to present value using the 6-month spot rate from (i); (iv) the present value of the 6-month coupon payment in (iii) is then subtracted from the market price of the 1-year cash flow to solve for the appropriate discount rate, which becomes the 1-year spot rate; and (v) spot rates for successive terms are solved for in a similar way, generating a spot curve based on the underlying benchmark yield curve. The result of these successive calculations is a series of discount factors unique to each term of a bond's cash flows.

A.2 OAS for Noncallable Bonds

The OAS analysis for noncallable bonds utilizes the "benchmark spot curve" to value a bond by breaking up its component cash flows and valuing them using the appropriate discount factor for each cash flow term. Once the spot rates for the benchmark curve are calculated, the OAS of noncallable bonds is simply calculated as the constant spread that must be added to the spot interest rate to make the price of the risk-free bond identical to the observed market price of the corporate bond. Thus, the OAS of a noncallable bond is analogous to the Z-spread (i.e., Zero-volatility spread).

A.3 OAS for Callable Bonds

The OAS analysis for callable bonds is more complex. The OAS analysis conducted by Bloomberg uses a one-factor, arbitrage-free binomial tree of normally distributed short rates to generate a distribution of millions of different interest rate scenarios that are driven by the volatility input for the interest rate. Then, the bond's call schedule is examined and the cash flows that depend on the level of interest rates are estimated. The interest rate paths are used to discount the cash flows from the bonds to arrive at their present values. These present values are averaged to obtain the theoretical price of the bond. The OAS is the constant spread over the underlying Treasury term structure across each path that makes the theoretical value of the bond equal to the market price of the bond.

B. Debt Market Illiquidity Measures

B.1 The Gamma Measure

The gamma measure is the negative value of the autocovariance of price changes. The construction of this measure is based on the fact that illiquidity arises from market frictions and its transitory effect on the markets. Given that transitory price movements produce negative, serially correlated price changes, the gamma measure creates a meaningful measure of debt market illiquidity that captures the effect of illiquidity on prices. This articleuses the aggregated gamma measure that is obtained by aggregating the gamma measure across individual bonds. This measure from Bao, Pan, and Wang (2011) is constructed using information from the US secondary corporate bond markets from the TRACE dataset.

B.2 The Noise Measure

The noise measure is the aggregation of the price deviations across all bonds. These deviations are constructed by calculating the root mean squared distance between the market yields and the yields from a smooth zero coupon yield curve. The primary concept behind this measure is that the lack of arbitrage capital reduces the power of arbitrage and that assets can be traded at prices that deviate from their fundamental values. Therefore, this "noise" in prices contains important information regarding the amount of liquidity in the aggregate market. This measure is adopted from Hu, Pan, and Wang (2013), who analyze "noise" in the prices of US Treasury bonds.

B.3 The On/Off-the-run US Treasury Spread

The on/off-the-run US Treasury spread is the spread between the yield of on-the-run and off-the-run US Treasury bonds. Although the issuer of both types of bonds is the same, on-the-run bonds generally trade at a higher price than similar off-the-run bonds because of the greater liquidity and specialness of on-the-run bonds in the repo markets. This specialness arises from the fact that on-the-run Treasury bond holders are frequently able to pledge these bonds as collateral and borrow in the repo market at considerably lower interest rates than those of similar loans collateralized by off-the-run Treasury bonds (Sundaresan and Wang, 2009). I compute the on/off-the-run US Treasury spread using 10-year bonds, given that the spread tends to be small and noisy at smaller maturities. The data sources used in the construction of this spread are from Gürkaynak et al. (2007) and the Board of Governors of the Federal Reserve System.

B.4 The KfW Spread

The KfW spread is the spread between KfW bonds and German governmental bonds. As KfW bonds are bonds supported by an *explicit* guarantee from the German federal government, the KfW spread represents the liquidity premium that investors are willing to pay for the greater liquidity of federal government bonds compared with that of KfW bonds. The KfW spread is denominated in euros and is computed using two-year bonds. This spread is adopted from Schwarz (2014).

Table AI. Correlation between alternative debt market illiquidity measures

This table presents the correlation matrix of five debt market illiquidity measures: the gamma measure, the noise measure, the on/off-the-run Treasury spread, the supranational AAA spread, and the KfW spread.

	Gamma	Noise	On/off-the-run Treasury spread	KfW spread
Gamma	1.00			
Noise	0.95	1.00		
On/off-the-run Treasury spread	0.95	0.94	1.00	
KfW spread	0.94	0.94	0.94	1.00

Table AII. Description of variables

This table describes the variables used in the empirical model, including the variables' names, descriptions, units, and sources. ST = short-term.

Name	Description	Unit	Source
Bond spread	Option-adjusted spread	Basis points	Bloomberg
Years to maturity	Years to maturity	Years	Bloomberg
Issue size	Amount issued	US$ (in *log*)	Bloomberg
Coupon rate	Coupon bond	Basis points	Bloomberg
Equity volatity	Volatility is the standard deviation of the day-to-day logarithmic price changes. On previous day 180-day price volatility equals the annualized standard deviation of relative price change of the most recent trading days' closing price, expressed in a percentage for the day before the current.	Percent	Bloomberg
Credit rating	S&P's firm rating, long-term debt, foreign currency	(1 = D, . . . , 21 = AAA)	S&P
Operating income to sales	Operating income divided by net sales.	Ratio	Bloomberg
ST debt to total debt	Short-term debt divided by total debt.	Ratio	Bloomberg
Total debt to assets	Total debt divided by total assets.	Ratio	Bloomberg
Cash holdings to total debt	Cash holdings divided by total debt.	Ratio	Bloomberg
Size	Total assets	Millions of US$ (in *log*)	Bloomberg
Sovereign credit rating	S&P's sovereign rating, long term debt, foreign currency	(1 = D, . . . , 21 = AAA)	S&P
Gamma measure		Basis points	

(continued)

Table AII. (continued)

Name	Description	Unit	Source
	Negative of the autocovariance of price changes		Bao, Pan, and Wang (2011)
Noise measure	Root mean squared distance between the market yields and the yields from a smooth zero-coupon yield curve.	Basis points	Hu, Pan, and Wang (2013)
On/Off-the-run Treasury spread	Difference between the yield to matutity of 10 years off-the-run Treasury bonds and on-the-run Treasury bonds.	Basis points	Board of Governors of the Federal Reserve System
Supranational AAA spread	Difference between the Supranational AAA 1-3 years yield index and the Treasury 1–3 years yield index	Basis points	DataStream
KfW spread	Difference between 2 years KfW bonds and German federal government bonds.	Basis points	Schwarz (2014)
Libor–OIS spread	Spread between the 3-month OIS rates and LIBOR rates	Basis points	Bloomberg
Ted spread	Difference between the 3-month US Treasury bill rate and the 3-month LIBOR	Basis points	Bloomberg

Table AIII. The direct effect of debt market illiquidity

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. All regressions control for bond and rating fixed effects. The sample covers the period from January 2004 to June 2009. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term; LT = long-term.

Market Illiquidity	Noise		On-/off-the-run spread		KfW spread	
	(1)	(2)	(3)	(4)	(5)	(6)
Years to maturity	−12.342***	−6.542*	−14.577***	−11.658***	−45.922***	−35.892***
	(3.170)	(3.403)	(3.124)	(3.479)	(10.688)	(12.795)
Equity volatility	3.076***	4.135***	2.813***	3.632***	2.999***	3.729***
	(0.309)	(0.420)	(0.304)	(0.401)	(0.364)	(0.483)
Operating income to sales	−61.757**	−30.067	−61.704**	−32.000	−86.004***	−61.337**
	(30.203)	(27.673)	(29.467)	(26.599)	(29.126)	(26.568)
Total debt to asset	30.045	149.751	20.600	136.213	−192.528	−21.632
	(84.084)	(94.726)	(81.194)	(89.758)	(159.394)	(169.667)
Cash holdings to total debt	−18.513	−17.006	−19.462	−19.326	−68.159***	−63.878***
	(11.991)	(12.396)	(11.936)	(12.314)	(19.815)	(21.141)
Size	−59.031***	−36.001*	−49.224**	−34.471*	−131.190***	−76.808**
	(20.498)	(19.420)	(19.763)	(18.888)	(38.327)	(37.039)
Sovereign credit rating	−9.535	−23.774**	−10.608	−28.921***	−59.233***	−69.112***
	(9.857)	(11.803)	(10.293)	(10.545)	(22.300)	(22.611)
10-year US treasury rate	−0.709***	−0.756***	−0.702***	−0.762***	−0.463***	−0.630***
	(0.054)	(0.063)	(0.053)	(0.062)	(0.073)	(0.078)
Slope US treasury rate	0.006	−0.036	−0.552***	−0.560***	−0.200**	−0.284***
	(0.030)	(0.036)	(0.043)	(0.049)	(0.082)	(0.097)
ST debt to total debt	−8.520		−35.981		−47.494	
	(30.879)		(30.792)		(59.753)	
Proportion LT debt maturing within the year		−104.180***		−135.883***		−154.987**
		(30.033)		(34.076)		(61.187)
Market illiquidity	96.413***	83.962***	23.459***	20.953***	22.292***	20.092***
	(5.172)	(5.436)	(1.080)	(1.159)	(1.121)	(1.170)
Credit rating × Market illiquidity	−5.970***	−5.291***	−1.350***	−1.226***	−1.350***	−1.235***
	(0.393)	(0.401)	(0.081)	(0.086)	(0.085)	(0.086)
ST debt to total debt × Market illiquidity	23.196***		5.158***		5.654***	
	(4.038)		(0.871)		(0.935)	
Proportion LT debt maturing within the year × Market illiquidity		52.632***		11.426***		11.715***
		(9.894)		(2.485)		(2.035)
Observations	20,465	15,851	20,315	15,733	11,875	8,991
Number of bonds	587	441	587	441	562	419
R^2 within	0.659	0.684	0.656	0.683	0.667	0.692
R^2 between	0.699	0.762	0.697	0.752	0.520	0.580
R^2 overall	0.617	0.665	0.626	0.652	0.444	0.504

Table AIV. Instrumental variable-GMM estimation

This table presents estimates from a panel regression of corporate option-adjusted spreads against the variables listed below. Market illiquidity corresponds to the gamma measure. All regressions control for industry, rating, and time fixed effects. Each equation is estimated by IV-GMM. Short-term debt to total debt and rollover losses are instrumented with firm fixed effects from a regression of short-term debt to total debt on firm dummies and with the 3- and 6-month lags of the interaction between debt market illiquidity and the same firm fixed effects. These firm fixed effects are estimated from the period between January 2004 and December 2006. All independent variables are lagged three months. Robust standard errors are clustered at the bond level and are shown in parentheses below each coefficient estimate. *P*-values for the Hansen's J-test of over-identifying restrictions are reported. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. ST = short-term.

	(1)
Years to maturity	5.651***
	(0.896)
Amount issued	4.550***
	(1.260)
Coupon rate	0.157***
	(0.017)
Equity volatility	2.676***
	(0.243)
Operating income to sales	−39.585**
	(15.657)
Total debt to asset	72.213***
	(17.165)
Cash holdings to total debt	−10.313
	(7.469)
Size	0.209
	(2.486)
Sovereign credit rating	−2.500***
	(0.969)
ST debt to total debt	43.057
	(31.531)
Credit rating × Gamma	−0.272***
	(0.015)
ST debt to total debt × Gamma	1.811***
	(0.303)
Observations	10,840
Adjusted R^2	0.669
F test of excluded instruments	491.210
Partial R^2 of excluded instruments	0.170
Hansen's J-test p-value	0.684