

Rolling over Corporate Bonds: How Market Liquidity affects Credit Risk

FLORIAN NAGLER*

FIRST VERSION: FEBRUARY 10, 2014

THIS VERSION: AUGUST 31, 2014

Abstract

Structural credit risk models following He and Xiong (2012) argue that market liquidity affects credit risk via the rollover channel. This paper explores this relation in the US corporate bond market based on a complete set of transactions data over the period from 2005 to 2011, for a representative sample of firms with large exposures to corporate bond financing. A detailed and unique analysis of bond rollover policies and the underlying market liquidity conditions is provided. In order to test to what extent market liquidity affects credit risk via the corporate bond rollover channel, a quasi natural experiment by exploiting the exogenous variation in liquidity arising from the Lehman bankruptcy is employed. The results reveal that, (i) market liquidity indeed affects credit risk via rollover with a transaction cost shock a la Lehman of 100bp being associated with an overall average treatment effect of 185bp, (ii) the impact being increasing in the rollover rate, and (iii) being observable across the entire term-structure of yield spreads. Furthermore, a study of the joint cross-section of yield spreads, various commonly employed liquidity measures and rollover rates is provided, confirming the nature of the obtained results.

JEL-Classification: G12, G32

Keywords: liquidity, credit risk, corporate bonds, rollover

*VGSF (Vienna Graduate School of Finance), Welthandelsplatz 1, Building D4, 4th floor, 1020 Vienna, Austria; email: florian.nagler@vgsf.ac.at

I gratefully acknowledge financial support from the *UniCredit Leopold Gratz Foundation* and the *WU Gutmann Center*. I would like to thank Nils Friewald, Rainer Jankowitsch, Alexander Mürmann, Thomas Rauter, Marti G. Subrahmanyam, Sarah Qian Wang, Josef Zechner as well as participants at the 2013 VGSF conference and participants at the National University of Singapore (NUS) - Risk Management Institute (RMI): 8th Annual Risk Management conference for helpful comments and suggestions. Any remaining errors are my own.

1 Introduction

Credit risk and market liquidity are important factors of corporate bond yield spreads, which are a measure of debt funding costs. Given deterioration in liquidity, the bond rollover channel is of fundamental relevance: When a firm needs to roll over some bonds, hence, replaces maturing by newly issuing bonds, it is directly exposed to the liquidity in the market. As a consequence, potential rollover losses arising from an illiquid market are realized. The financial crisis highlighted the importance of the rollover channel. Thus, it is crucial to understand the empirical asset pricing implications induced by this channel and to directly address the question of how financial market frictions, i.e. market liquidity, quantitatively affect debt funding costs via bond rollover.

Classical structural credit risk models, e.g. Leland (1994b) or Leland and Toft (1996), assume that corporate bond markets are perfectly liquid. Hence, in these models, market liquidity does not influence a firm's credit risk via the rollover channel. As a result, in the literature that followed, credit risk and market liquidity have long been analyzed separately, i.e., treated independently of each other. However, apparently, when market liquidity deteriorates and imposes a wedge between fundamental and market values, firms' suffer losses from rolling over bonds at reduced prices, directly increasing their funding costs. As a consequence, structural credit risk models following He and Xiong (2012) argue that market liquidity and credit risk are intertwined through the rollover channel. This paper explores this relation by providing detailed empirical evidence on, and, quantitatively assessing, the link between market liquidity and credit risk via the corporate bond rollover channel. Specifically, this study examines corporate bond rollover policies of a representative sample of firms consisting of S&P 500 constituents, which have large exposures to the bond market, and provides a link of the resulting policies to the underlying market liquidity conditions, based on a complete set of transaction data over the period from 2005 to 2011 in the US corporate bond market.

Many credit risk instruments, such as bonds and credit default swaps (CDS), trade over-the-counter (OTC). As a consequence, empirical research linking market liquidity to credit risk is challenging, as transaction data for these instruments cannot be observed directly from a central database. In contrast, the market for US corporate bonds is an ideal laboratory for this study, since detailed data on prices and volumes are entirely available from 2005 onwards in the Trade Reporting and Compliance Engine (*TRACE*) database, maintained by the Financial Regulatory

Authority (*FINRA*). This setup allows to comprehensively link firms' bond financing policies to market conditions, and consequently, permits to address in detail the question of how corporate bond market liquidity affects credit risk via the rollover channel.

I make four contributions in this paper relative to the existing literature. First, I introduce a tractable structural credit risk model building on the framework provided by Leland (1994a) and incorporate ingredients from He and Xiong (2012). This permits to capture the underlying economic mechanism linking liquidity to credit risk through bond rollover, resulting as deterioration in liquidity increases rollover losses and, thus, destroys equityholders incentive to keep the firm solvent, in an intuitive manner. Moreover, the model provides guidance for the subsequent empirical tests, and hence, allows to closely relate them to the presented framework.

Second, I provide a detailed analysis of the debt capital structures and corporate bond rollover policies of S&P 500 constituents, excluding financials and utilities. This study is important in the first place, as it allows to understand the underlying corporate bond financing decisions from which particular market liquidity needs due to bond rollover emerge. In turn, this study permits to jointly examine the interaction of market liquidity, bond rollover and credit risk.

Third, in order to test whether deterioration in market liquidity indeed affects credit risk via the bond rollover channel, I exploit the exogenous variation in liquidity arising from the *Lehman* bankruptcy, combined with ex-ante heterogeneity in bond maturity, as a natural experiment. In particular, following the approach taken by Almeida et al. (2012), I perform a matched difference-in-differences analysis by ex-ante identifying firms which need to roll over a large fraction of their bonds directly following the bankruptcy filing. The preceding descriptive analysis suggests the *Lehman* bankruptcy to constitute an ideal exogenous shock for such an experiment, as *Lehman* represented one of the largest dealers in the US corporate bond market, with its filing for protection under Chapter 11 on September 15 in 2008 and the subsequent cease of operations inducing a sharp shock to bond market liquidity: Overall transaction costs roughly tripped shortly following the bankruptcy filing.

Fourth, I provide a study of the *joint* cross-section of firms' corporate bond yield spreads, various commonly employed measures of bond liquidity and rollover rates to disentangle the direct and indirect contribution of liquidity, via the bond rollover channel, on yield spreads. In order to attain some generality, this analysis is based on the entire cross-section of outstanding bonds per firm in a particular point in time. This allows to examine the effect of market liquidity on credit

risk via rollover in a thorough manner, i.e. for a complete sample of bonds, and thus provides the opportunity to comprehensively test the effects under consideration.

The analysis yields several distinct sets of findings. First, S&P 500 constituents represent approximately 40% of the overall amount outstanding in US corporate bond market, over the considered period, with the average aggregate amount outstanding being around \$2,000 billion. Going forward, when examining the individual debt capital structures, the results reveal bonds to represent the major source of external debt financing with roughly 70% of the total debt of these firms being represented by bonds, highlighting the importance of corporate bond market conditions for firms' external debt funding costs. This fraction seems to be relatively persistent over time within firms, as well as across various industries. Consequently, when studying the bond rollover patterns of these corporates, the analysis provides strong evidence of an actual pursued rollover policy: As these firms are rather sticky with respect to their bond financing, maturing bonds are largely replaced (rolled over) by newly issued bonds, with this pattern also being evident in illiquid periods. Given this strong contemporaneous relation of bond redemption and issuance, firm specific rollover rates in a given time period based on the fraction of maturing to overall bond amount outstanding are estimated. The results show that, conditionally on any bond maturing, roughly 13% of the overall amount outstanding of a particular firm needs to be rolled over, suggesting that firms spread out their rollover needs across time.

Second, when studying yield spreads and market liquidity in the US corporate bond market, the analysis reveals a sharp increase in spreads by 400 basis points (bp) following the *Lehman* bankruptcy. Examining both, transaction costs as measured by the price dispersion and Roll measure as well as market depth measured by the Amihud measure, the analysis suggests that the *Lehman* bankruptcy filing induced a sudden shock to corporate bond market liquidity. Specifically, average transaction costs increased by a factor of three from 50bp up to 150bp, with average price impacts based on trading \$1 million also increasing from 30bp up to 60bp, within a few days following the bankruptcy filing. Consequently, in the subsequent empirical tests, this sharp and abrupt deterioration in market liquidity constitutes an ideal laboratory to test how rather exogenous changes in liquidity impact a firms' credit risk via the bond rollover channel.

Third, when performing the difference-in-differences analysis by exploiting the bankruptcy as a natural experiment, the results provide strong evidence that deterioration in market liquidity indeed affects credit risk via the bond rollover channel. In particular, the findings demonstrate

that, when appropriately comparing yield spreads of firms which need to roll over a large fraction of their bonds to firms which do not need to roll over following the *Lehman* bankruptcy, the former experience significantly higher yield spread increases compared to the latter. Overall, this average treatment effect (ATE) amounts to approximately 185bp, and is increasing in the fraction of bond financing that needs to be rolled over. Furthermore, when studying the term-structure of yield spreads, this effect remains observable on bonds with various time to maturities including short-term (1 to 5 years maturity), medium-term (5 to 15 years maturity) and long-term (more than 15 years maturity). Interestingly, the ATE in the case of long-term bonds is higher compared to the ATE of short-term bonds.

Fourth, by performing a cross-sectional analysis the results obtained in the difference-in-differences analysis are confirmed. In particular, when studying the direct and indirect relation, via bond rollover, of various commonly employed liquidity measures (price dispersion, Amihud and Roll measure) to the level of yield spreads in a panel data analysis, the findings provide interesting insights: The direct (purely liquidity driven) contribution of these measures seems to exhibit a one-to-one relation to the level of yield spreads, e.g., an increase in transaction costs by 100bp is associated with an increase in yield spreads by around 130bp. Additionally, the indirect impact of these measures via the bond rollover channel, measured via an interaction term, confirms the quantitative nature of the results obtained in the difference-in-differences analysis. In turn, this suggests that these commonly employed liquidity measures might absorb some cross-sectional variation in credit risk, particularly the part which is attributable to bond rollover.

In summary, I provide a comprehensive analysis going beyond the results that have been presented in the prior literature, by studying in detail the corporate bond financing policies of S&P 500 constituents. Moreover, I construct empirical tests and setups closely related to the presented framework. This allows to examine the effect of corporate bond market liquidity on credit risk via the rollover channel in a very thorough manner. The paper is organized as follows: Section 2 reviews the literature. Section 3 presents a stylized model and derives the hypotheses being tested. Section 4 provides details on the data used in the analysis. Section 5 introduces the methodology and provides information on the measurement of the variables. Section 6 presents a study of corporate bond financing policies including rollover, overall corporate bond market conditions and delivers summary statistics on the data. Section 7 presents the difference-in-differences analysis, while Section 8 provides a cross-sectional analysis. Section 9 concludes.

2 Literature Review

This paper contributes to the literature on understanding the determinants and components of corporate bond yield spreads, which can be divided into theoretical models such as structural credit risk models, as well as into empirical studies which either directly calibrate (structurally estimate) theoretical models, or provide cross-sectional analyses by relating credit and liquidity risk factors to corporate bond yield spreads.

In structural credit risk models starting with Black and Scholes (1973) and Merton (1974), the default risk, and thus yield spread, of a firm is driven by the process generating its unlevered asset value. Consequently, this implies that the default risk of the firm is directly linked to the volatility of the process generating its asset value. In particular, a firm defaults when the asset value is lower than the value of its liabilities at maturity. If default occurs, bondholders take over the firm and receive the residual market value of its assets. The basic structural credit risk models following Black and Scholes (1973) and Merton (1974) are further extended by several authors adopting the endogenous default notion of Black and Cox (1976), Fischer et al. (1989) or Leland (1994b). These contributions include, e.g., Longstaff and Schwartz (1995), Leland and Toft (1996), Anderson and Sundaresan (1996), Mella-Barral and Perraudin (1997), Collin-Dufresne et al. (2001), Goldstein et al. (2001), and Acharya et al. (2006). In these models, the asset value at which default is triggered is an endogenous choice variable of equityholders, and thus, chosen optimally as to maximize the value of their claim. Interestingly, most of these models assume perfectly liquid credit markets, and thus do not discuss the implications of market liquidity frictions on corporate bond yield spreads.

Specifically, the above mentioned studies have in common that they disregard the potential interplay between market liquidity and credit risk via the corporate bond rollover channel. Recent theoretical contributions explicitly address this link: He and Xiong (2012) model credit spreads of finite maturity debt and conclude that market liquidity conditions enter equityholders default decision. This effect arises as deterioration in market liquidity increases rollover losses, and thus, destroy equityholders incentive to keep the firm solvent. Furthermore, He and Milbradt (2013) model the implications of an illiquid secondary market of defaulted bonds. They show that this assumption can generate an illiquidity loop, where equityholders default decision interacts through the endogenous secondary market liquidity via the bond rollover channel.

In the conducted empirical studies, it has been well documented that existing structural credit risk models (see, e.g., Huang and Huang (2012)) cannot fully explain observed yield spreads satisfactorily, suggesting a *credit spread puzzle*. Therefore, e.g., Chen et al. (2013a) propose a decomposition scheme to disentangle credit spreads into liquidity and default premium. They calibrate, within a framework of a structural credit risk model, historical moments of default probabilities and empirical measures of bond liquidity obtained from the prior literature, and embed countercyclical macroeconomic fundamentals as well as procyclical liquidity frictions.

Given the proposed credit spread puzzle, several other empirical studies examine illiquidity effects in the corporate bond market. Generally, they find that illiquidity is an important factor determining yield spreads. Important contributions in this field include, e.g., Chen et al. (2007), Edwards et al. (2007), Bao et al. (2011), Friewald et al. (2012) or Dick-Nielsen et al. (2012), with all these studies exploring the cross-sectional properties of liquidity risk and its relation to corporate bond yield spreads.

Other papers examine the implications and management of corporate debt maturity, e.g., Chen et al. (2013b) study the effect of systematic risk on debt maturity management and find that firms with higher systematic risk, i.e. higher betas, will choose longer debt maturity profiles. They conclude that maturity management is especially important for high-beta and high-leverage firms in diminishing the impact of a shock that shuts down long-term refinancing. Furthermore, Choi et al. (2013) study how firms spread out their debt maturity across time, which they refer to as “granularity of corporate debt”, in order to avoid having to roll over a large fraction of their debt in one given point in time. They find that corporate debt maturities are more dispersed for larger and more mature firms, for firms with better investment opportunities or with higher leverage ratios and they establish that the dispersion of debt maturities moves over time towards target levels. Gopalan et al. (2014) examine whether a firm’s debt maturity structure affects its credit quality (credit ratings), and conclude that rating agencies do evaluate rollover risk, and that, firms with greater exposure to rollover risk have lower credit quality.

This study extends the existing literature in new and important directions and provides detailed empirical evidence, for a representative sample of firms, on how market liquidity affects credit risk via the corporate bond rollover channel. Firms underlying rollover policies are linked to prevailing corporate bond market conditions, which allows to address the question under consideration in a very comprehensive and thorough manner.

3 Research Questions and Hypotheses

This section utilizes a stylized structural credit risk model in which equityholders default decision is linked to market liquidity via the corporate bond rollover channel. The presented model allows to derive the hypotheses being tested and provides intuition and guidance for the empirical analysis. Thus, it allows to link the subsequent empirical tests to the presented framework, and consequently, to capture the underlying economic mechanism in a coherent manner. Furthermore, the model provides some insights into the functional relation between the particular effects under consideration.

3.1 Stylized Model Endogenizing Rollover Losses

Following Leland (1994a), Leland and Toft (1996) and He and Xiong (2012) a firm that commits to a stationary debt structure with aggregate coupon C and aggregate principal P is considered. In every instant of time a fraction m of the aggregate principal P matures and needs to be rolled over, with m having the interpretation of a rollover rate which is modeled as the intensity of a Poisson occurrence. Thus, in expectation, in every instant of time a total amount of mP needs to be rolled over and is replaced by identical bonds, implying both equal coupon and principal. Coupon payments are tax-deductible at rate τ and default induces costs of α . Agents are risk-neutral and the firms unlevered asset value follows

$$dV_t = (r - \delta)V_t dt + \sigma V_t dW_t \quad (1)$$

where r is the riskless interest rate, δ the cash-payout rate to all claimholders on the underlying asset value V , and σ the constant volatility of the diffusion process.

First, focusing on the bond valuation: As in He and Xiong (2012), bondholders are exposed to liquidity shocks which arrive according to a Poisson occurrence at intensity ξ . If bondholders are forced to sell their holdings in the secondary market, a certain fraction k of the current market value of the bond is lost. Consequently, if forced to exit the bond market, bondholders only recover the fraction $(1 - k)$ of the bond's fundamental value. Thus, bondholders valuation fulfills a standard PDE augmented by loss of market value due to illiquidity, given by ξk .

$$rD = (r - \delta)VD_V + \frac{1}{2}\sigma^2 V^2 D_{VV} + C + m(P - D) - \xi k D \quad (2)$$

The solution to this PDE, with the detailed derivation presented in the Appendix, is obtained by imposing standard boundary conditions on the bond value for some arbitrary default boundary V_B (asset value at which default is triggered), and is given by

$$D(V, m, \xi k) = \frac{C + mP}{r + m + \xi k} + \left[(1 - \alpha)V_B - \frac{C + mP}{r + m + \xi k} \right] \left(\frac{V}{V_B} \right)^{-\beta_2} \quad (3)$$

with $\beta_2 > 0$ being the positive root of the fundamental quadratic. It follows directly that illiquidity ξk enters the overall discount rate $(r + m + \xi k)$ of the bond's cashflows. The first term in this equation represents the price of this bond in the absence of default risk, while the second part represents the default premium, with

$$PD = \left(\frac{V}{V_B} \right)^{-\beta_2} \quad (4)$$

having the interpretation of a default probability - for any given asset value V an increasing default boundary V_B results in an increased probability of default. Consequently, in order to link market liquidity to credit risk, equityholders endogenously chosen default boundary needs to depend on the illiquidity parameter ξk . Indeed, this will be the case as deteriorating market liquidity makes it increasingly costly for equityholders to roll over maturing bonds. The yield y of this bond is the average expected rate of return represented by

$$yD(V, m, \xi k) = C + m[P - D(V, m, \xi k)] \quad (5)$$

with the yield spread given by the differential of the yield y relative to the risk-free rate r . Illiquidity directly influences the yield spread of this bond, with the general property that increases in illiquidity lead to increases in the yield spread.

Given bondholders solution, the valuation of equity also fulfills a standard PDE given by

$$rE = (r - \delta)VE_V + \frac{1}{2}\sigma^2V^2E_{VV} + \delta V - (1 - \tau)C + m(D - P) \quad (6)$$

where $m(D - P)$ is the net gain/loss occurring from rolling over the bonds at current market prices, evident for any non-zero rollover rate m . Thus, if bond market liquidity deteriorates as represented by an increase in ξk , and suppresses the market value of the underlying bond, rolling over becomes increasingly costly to equityholders as they have to absorb any rollover losses. This effect arises as

the rollover gain/loss directly influences the remaining overall payout to equityholders, implying that their valuation is entirely linked to changes in liquidity through the bond rollover channel. In turn, this will affect equityholders decision at which asset value default is triggered, and hence, the credit risk of the firm. In particular, equityholders endogenously default with the optimal default boundary V_B given by the standard smooth pasting condition.

$$\left. \frac{\partial E(V, m, \xi k)}{\partial V} \right|_{V=V_B} = 0 \quad (7)$$

In general, as motivated by the previous discussion, the optimal default boundary exhibits the property that it is increasing in illiquidity. This immediately implies that changes in liquidity do not only affect the overall discount rate of the bond's cashflows, but also the probability of default, and hence credit risk. The detailed derivation and solution is presented in the Appendix.

In order to capture the intuition on the underlying economic mechanism and to derive the hypotheses being tested, this model is calibrated to various rollover rates employing the baseline parameters used in He and Xiong (2012).¹ In Figure 1, six panels are displayed which present the obtained results from the various calibrations. All panels are with respect to liquidity, represented by transaction costs in basis points. Panel A gives the relation of liquidity to the optimal default boundary for different rollover rates, i.e. w.l.o.g., for $m = 0$, $m = 10\%$ and $m = 20\%$, respectively. In the case when no rollover takes place, i.e. $m = 0$, the default boundary and hence the implied default probability are invariant to changes in liquidity. However, in the other two cases with a non-zero rollover rate deteriorating liquidity, as represented by an increase in transaction costs, also leads to an increase in the default boundary. Thus, it follows:

Hypothesis 1: *All else equal, deterioration in market liquidity affects a firm's credit risk via the corporate bond rollover channel.*

Furthermore, Panel A also indicates that the sensitivity of the optimal default boundary with respect to liquidity is increasing in the rollover rate. Given these different sensitivities with respect to liquidity, this has interesting implications for the resulting changes in the probability of default:

¹These parameters are provided in Table 1 in He and Xiong (2012) and are: $r = 8\%$, $\tau = 27\%$, $\sigma = 23\%$, $\alpha = 40\%$, $\delta = 2\%$, $k = 1\%$, $\xi = 1$ and $V = 100$. Note that, in this paper the term ξk has the interpretation of transaction costs, i.e., the initial transaction costs are 100bp. Also following He and Xiong (2012), throughout all calibrations, the coupon C and principal P are always chosen such that the bond is issued at par with an initial yield spread of 330bp.

Panel B gives the relation of the corresponding changes in the probability of default induced by particular changes in liquidity. Specifically, for any given change in liquidity the resulting change in the probability of default is higher for the 20% rollover rate compared to the 10% rollover rate:

Hypothesis 2: *All else equal, given a particular deterioration in market liquidity, the resulting impact on a firm's credit risk via the rollover channel is increasing in the rollover rate.*

Given the presented hypotheses regarding the effect of liquidity via rollover on the probability of default, and hence credit risk, it is of interest to study the resulting yield spreads: Panel C displays the relation of the yield spread to liquidity in the case of a 10% rollover rate. The general property is that deteriorating liquidity increases the yield spread. Here, as motivated by the presented model, two effects are at work: First, changes in liquidity directly enter the discount rate ($r + m + \xi k$) of the bond's cashflows, and thus the yield spread. This is referred to as the direct effect of liquidity. Second, as discussed above, changes in liquidity also affect the probability of default through the rollover channel. This is referred to as the indirect effect of liquidity. In order to disentangle the direct effect from the indirect effect of liquidity, Panel D shows the microstructure of the yield spread composition as represented by the liquidity premium and default premium. In accordance with the discussion above, the default premium is increasing in transaction costs. The liquidity premium increases linearly with transaction costs, resulting in an implied slope of one. Consequently, the direct effect of liquidity on the yield spread is represented by a one-to-one relation. A parallel reasoning is observable when examining the microstructure of the two effects in the case of a 20% rollover rate given in Panels E and F, thus:

Hypothesis 3: *All else equal, the direct effect of liquidity on the level of yield spreads is represented by a one-to-one relation.*

4 Data

This paper relies on several data sources that are combined to analyze whether corporate bond market liquidity affects credit risk via the corporate bond rollover channel. The sample covers the period from the beginning of 2005 to the end of 2011. It contains all constituents of the S&P 500 index as of the beginning of 2005, in order to eliminate potential survivorship bias, excluding

financials and utilities. This results in 429 firms which are analyzed over the entire period. For each firm *all* outstanding bonds over the *entire* period and their respective histories of amount outstandings are obtained from the *Mergent Fixed Income Securities Database* (Mergent FISD), resulting in a total number of 13,402 bonds. Mergent FISD contains detailed information on the nature of the bond indenture including, e.g., the amount issued, maturity, coupon, as well as bond rating information, and its history, of the three major rating agencies *Fitch*, *Moody's* and *Standard and Poor's*.

Transaction information including prices and volumes of the underlying bonds are obtained from the *TRACE* database maintained by the Financial Industry Regulatory Authority (*FINRA*). Reporting of all transactions to *TRACE* within a time frame of 15 minutes is obligatory for broker-dealers in the US corporate bond market.² Reporting follows a set of rules approved by the Securities and Exchange Commission (*SEC*). In general, such a database is rather unique for an OTC market. This is the case as, in almost all other cases, price information must usually be obtained either from an individual dealer's trading book, which typically provides only a very limited view on the market, or by using quotations of bid-ask prices. Standard filters in order to exclude potential errors in *TRACE* are implemented.³

Furthermore, the balance sheet and income statement information of the underlying firms are obtained from *COMPUSTAT*. The entire history of the term-structure of US Treasury yields over the period from 2005 to 2011 is obtained from *Bloomberg*, which is used to proxy for the risk-free rate in the yield spread calculation.

The final available data set is comprehensive as it contains the *complete* list and entire history of all corporate bonds of S&P 500 constituents, including available transaction data. Hence, this allows to study the interaction of bond financing policies and market conditions in a very general manner. Furthermore, various different aspects linking market liquidity and credit risk via the bond rollover channel can be addressed. In summary, the merged data set covers the period from 2005 to 2011, contains 429 firms and more than 13,000 bonds which account for approximately 22 million transactions with an aggregate volume of \$7,100 billion.

²The volume reported to *TRACE* is capped at \$1 million for high-yield and unrated bonds, and at \$5 million for investment-grade bonds. The exact trade volume is only released by *FINRA* after an 18-month delay.

³Dick-Nielsen (2009) provides an extensive description of possible reporting errors, and their implications for liquidity analysis. Such errors include (i) trade corrections within the same day, (ii) trade cancellations within the same day, and (iii) reversals across days, i.e., due to a mistake that was not detected on the trading day itself. Furthermore, price filters are implemented, eliminating potentially erroneous reported prices.

5 Methodology

This section provides information on the measurement and construction of the key variables of interest employed in the analysis. These include the calculation of yield spreads, the various liquidity measures, the rollover rate and the measurement of credit risk. All other main variables used in this study, such as trading activity variables, bond characteristics and firm fundamentals are defined in Table 1. All variables are discussed in the descriptive analysis in Section 6.

5.1 Corporate Bond Yield Spreads

Corporate bond yield spreads are represented by the yield differential relative to that of the Treasury yield curve, which serves as a risk-free benchmark. This benchmark is defined as the yield of a risk-free, zero-coupon bond, with a maturity equal to the duration of the corporate bond. This duration is calculated based on the reported yield in the *TRACE* database and the corporate bond's cash flow structure.

5.2 Liquidity Measures

Price Dispersion Measure. Similarly to Friewald et al. (2012) or Jankowitsch et al. (2014), the price dispersion measure, $d_{ij,s}$, of bond i of firm j on day s is defined as

$$d_{ij,s} = \sqrt{\frac{1}{\sum_{k_{ij,s}} v_{k_{ij,s}}} \cdot \sum_{k_{ij,s}} \left(\frac{p_{k_{ij,s}}}{m_{ij,s}} - 1 \right)^2 \cdot v_{k_{ij,s}}} \quad (8)$$

where $m_{ij,s}$ is the mean transaction price representing the fair value of the bond, and $p_{ij,s}$ ($v_{k_{ij,s}}$) are the individual trade prices (volumes). This (volume-weighted) volatility of individual trades around the fair value permits to directly estimate transaction costs based on transaction data. Market microstructure models provide the intuition for this measure: A low dispersion of traded prices around the market-wide valuation indicates that the bond can be bought or sold close to its fair value, hence, at lower transaction costs, which is indicative of a more liquid instrument.

Amihud Measure. The Amihud measure of bond i of firm j on day s given $N_{ij,s}$ observed returns r indexed by $k_{ij,s}$, with volume $v_{k_{ij,s}}$, is defined as

$$\text{Amihud}_{ij,s} = \frac{1}{N_{ij,s}} \sum_{k_{ij,s}} \frac{|r_{k_{ij,s}}|}{v_{k_{ij,s}}} \quad (9)$$

Based on Kyle (1985), and originally designed for limit order markets, this measure assesses the price impact of the traded volume, and hence the depth of the market. Intuitively, an instrument is considered illiquid, if a low transaction volume induces relatively large price changes.

Roll Measure. The Roll measure of bond i of firm j on day s given the natural logarithm of price $p_{ij,s}$ is defined as

$$\text{Roll}_{ij,s} = 2\sqrt{-\text{Cov}(\Delta p_{ij,s}, \Delta p_{ij,s-1})} \quad (10)$$

This measure, based on Roll (1984), has been extensively used to study liquidity effects in the US corporate bond market (see, e.g., Bao et al. (2011), Friewald et al. (2012)) and serves as a proxy for the round-trip costs. The Roll measure is computed based on the daily volume-weighted bond prices, where a rolling window of 60 days is employed with the requirement that at least eight observations are available in order to determine the covariance.

5.3 Rollover Rate

The rollover rate is defined as the fraction of the amount outstanding of maturing bonds to the overall amount outstanding, over a given period Δt , of a particular firm. Sections 6.1 and 6.2 further elaborate on the definition and justification of this measure by examining in detail the importance of corporate bond financing, as well as by providing an analysis of the corporate bond rollover policies of the underlying firms used in this study. The analysis suggests that the proposed measure allows to capture various aspects linking market liquidity and credit risk via the rollover channel in a reasonable manner.

5.4 Credit Risk

Credit risk is measured based on average bond ratings of the three major rating agencies *Fitch*, *Moody's*, and *Standard and Poor's*. Ratings rank the obligor according to creditworthiness (AAA, AA, ..., C, D), with the agencies assessing different dimensions of credit risk. This also includes refinancing risk, i.e., the risk of having to roll over a large portion of bonds during an illiquid period. These ratings are mapped to natural numbers, i.e., $AAA = 1$, $AA+ = 2$, ..., $D = 21$.

6 Descriptive Analysis

This section provides a study of the corporate bond financing policies of S&P 500 constituents (excluding financials and utilities), and examines the evolution of yield spreads and liquidity in the US corporate bond market over the period from 2005 to 2011. Furthermore, summary statistics on the overall available dataset are presented.

6.1 Corporate Bond Financing

In order to highlight the dimension of bond financing of all S&P 500 constituents, the relation of the underlying bonds to the overall US corporate bond market is considered. In particular, the aggregate average amount outstanding over the period from 2005 to 2011 amounts to around \$2,000 billion, which represents roughly 40% of the overall US corporate bond market. This aggregate amount outstanding was slightly growing from \$1,900 billion in 2005 up to \$2,200 billion in 2011. The aggregate average issuance size in a given year was roughly \$375 billion, while the aggregate average amount redeemed was around \$300 billion. Analyzing the individual underlying bonds: On average a total number of 7,650 bonds were outstanding per year with an average amount of \$250 million. All these statistics emphasize the scale of corporate bond financing of S&P 500 constituents, and suggest the representative nature of the sample.

Turning to the study on the relation of bonds to the firms' individual debt capital structures. Figure 2 reveals interesting insights. Panel A displays the distribution of the fractions of bonds to total book debt. The median (mean) fraction is around 74% (69%), indicating that bonds constitute the major source of debt financing of these corporations. This fact emphasizes the general exposure of debt financing to corporate bond market conditions, including liquidity. Additional evidence on the importance of corporate bond financing is given in Panel B, Figure 2, which displays the time-series of these fractions over the sample period. Generally, one can see that these corporations are very persistent in their debt capital structures with respect to corporate bond financing, with the mean fraction moving between 65% and 80%. The graph also displays the quantiles (25th and 75th) of these fractions. On average, the debt capital structure of a firm in the 25th quantile still exhibits around 55% of holdings in bonds, with this fraction varying from 48% in 2008 to around 62% in 2011. Considering the debt capital structure of a firm in the 75th quantile reveals that on average over 90% of its debt is due to bonds, indicating that for a

relatively large portion of firms bonds constitute the most prominent source of debt financing.

Given this suggested overall importance of bond financing of S&P 500 constituents, it is relevant and interesting to study the debt capital structures across industries. Panel A, in Table 2, summarizes the proportions of book debt which are due to corporate bonds across various industries. In particular, the largest fraction is given in the manufacturing industry with a median (mean) of 77% (71%) and mining industry with a median (mean) of 76% (74%), the lowest in retail trade with a median (mean) of 65% (50%). In order to get some intuition on the variation within industries, an examination of the interquartile distances (25th to 75th quantile) provides further insights. Overall, this interquartile distance across the considered industries is around 30%, and generally ranges from proportions of 50% or 60% up to 80% or 90%. In summary, these statistics indicate that corporate bonds constitute for the vast majority of firms the most important debt financing source, with this importance being evident across all considered industries.

The overall relevance of bond financing makes it necessary to study characteristics of the underlying bonds on the firm level in greater detail. These include the number of bonds, amount issued, maturity at issuance, coupon and the credit risk measure. Panel B, in Table 2, gives the summary statistics on the number of bonds outstanding per firm in a particular year, across the various industries. Considering the overall sample the median firm has 8 bonds outstanding. However, there is some variation across industries. For example, the median firm in the industry transportation has 23 bonds outstanding, while the median firm in the service industry has only 4 bonds outstanding. In all the other considered industries, the numbers correspond reasonably well to the median of the overall sample. Moreover, Panel C gives the corresponding amount outstanding per bond. The median amount outstanding per bond varies from around \$65 million in the manufacturing industry to \$400 million in the mining industry. There exists also considerable variation within industries, as represented by the interquartile distance, which is generally around \$300 to \$400 million. Considering the particular range of the distances, the analysis reveals that, e.g., in the manufacturing industry the range is from \$5 to \$350 million, while in the mining industry it is from \$250 to \$650 million. A further important dimension of the underlying bonds are the maturities at issuance, given in Panel D. In general, the maturity patterns are very similar throughout all the considered industries, with median maturities being around 10 years, and rather large interquartile distances which typically range from 5 to 20 years, indicating that bonds of all maturities are common across the various industries. Moreover, Panel E shows the distributions

of the coupon levels of the bonds. Again, these distributions are very similar across the different industries, with coupons being at a median value of 6% of face value, and interquartile distances being very similar, which typically range from values of around 5% to 7% of face value. Finally, Panel F gives the credit risk measure of the bonds as represented by the mean rating across the three major rating agencies *Fitch*, *Moody's* and *Standard and Poor's*. Lowest rated are bonds in the construction industry with a median rating of BB+ (11 representing speculative grade), highest rated are bonds in the manufacturing industry with a median rating of A (6.75 representing investment grade). Interestingly, interquartile distances differ considerably across industries with, e.g., the distance in construction being 3 (ranging from 10 to 13, which is BBB- to BB), while in the service industry the distance is 7 (ranging from 6 to 13, which is A to BB-).

6.2 Corporate Bond Redemption and Issuance

Given the persistent pattern in the proportion of bond financing, as discussed in the previous section, it is relevant to study the relation of the amount of maturing to issuing bonds of the individual firms in greater detail. In particular, this analysis of the underlying bond rollover policies is of general interest, as it sheds light onto the question of whether rollover per se is an issue to study in the first place. This might not be the case, e.g., if bond financing is entirely linked to investment with bond maturity largely matching asset maturity, then studying the implications of market liquidity via rollover might not be of first-order importance.

The relation of bond redemption and issuance is given in Figure 3, which displays seven different panels. Each panel represents a scatterplot, which illustrate the relation of bond amount redeemed to amount issued per firm in a particular year of the sample period. Although some slight dispersion is evident, a clear pattern can be identified which indicates that the firms pursue an actual rollover policy, i.e., maturing bonds are replaced by newly issued bonds of similar sizes. In order to elaborate on the relevance of the underlying economic mechanism concerning the relation of maturing to issuing bonds on the individual firm level, the following illustrative task might provide further insights: If these graphs were to be augmented by simple OLS-estimates, then the obtained R^2 would vary between values of 66% to 78%, with the estimates of the coefficients being between 0.9 and 1.05 across the various panels. This indicates a rather strong contemporaneous relation of bond redemption and issuance, and might suggest that the firms are, on average, forced to pursue an active rollover policy. This might be the case as the graphs demonstrate this

rollover pattern also to be evident in illiquid periods. In turn, this emphasizes the importance of an analysis of how market liquidity affects credit risk via the rollover channel. Interestingly, the analysis also reveals the heterogeneity across firms in the amount redeemed (issued), ranging from less than \$10 million to over \$2 billion. In general, firms are not active in the corporate bond market on a yearly basis, and hence, redeeming and consequently issuing bonds. Specifically, out of the full sample, on average, approximately 200 firms are active in a particular year. When a firm is actually exposed to the market, the average amount redeemed is \$370 million, while the average amount issued is around \$410 million.

In summary, the analysis on the relation of bond redemption and issuance provides strong evidence that these firms seem to pursue an actual rollover policy, with maturing bonds being replaced by bonds of similar sizes. In turn, this finding suggests that it might be reasonable to assume that the fraction of the amount outstanding of maturing bonds to the overall amount outstanding per firm, hence the rollover rate, is an adequate measure allowing to capture the impact of market liquidity on credit risk via the rollover channel. Figure 4 gives the histograms of these rollover rates. Again, seven different panels are shown with each panel representing the distribution of rollover rates in a particular year. One can see, as already discussed above, that in a given year the majority of firms do not need to roll over any of their bonds, as indicated by the peak around zero. The histograms look basically identical throughout the entire period, hence, also in years of illiquidity. Given that a firm needs to redeem some of its bonds, the average rollover rate is given by 15%, with standard deviations being somewhere around 24%, indicating some dispersions. The distributions of rollover rates also highlight that firms might try to avoid having all of their bonds maturing at one particular point in time, as is also discussed in Choi et al. (2013). They find that firms might try to spread out bond maturity profiles across time in order to mitigate exposure to rollover risk. Again, based on this discussion, in the subsequent analyses the proposed empirical measure of the rollover rate will be used to test whether market liquidity indeed affects a firm's credit risk via the corporate bond rollover channel.

6.3 Corporate Bond Yield Spreads and Market Liquidity

The previous sections delivered insights into the scale and policies of corporate bond financing of S&P 500 constituents. Consequently, it is of interest to examine the underlying price and liquidity dynamics in the US corporate bond market. Thus, this section examines aggregate yield

spreads as well as the evolution of liquidity as represented by the three different measures (price dispersion, Amihud, Roll) over the period from 2005 to 2011.

Figure 5 displays the time-series of yield spreads (Panel A), and the various liquidity measures given by the price dispersion measure (Panel B), Amihud measure (Panel C) and Roll measure (Panel D). First, examining prices in the US corporate bond market: Average yield spreads have been rather volatile over this period, with being roughly 200bp in the beginning of 2005 and around 400bp at the end of 2011. The lowest yield spread level was given in the middle of 2007 with a value of 50bp, while the highest was given directly following the *Lehman* bankruptcy filing (September 15, 2008), when yield spreads abruptly increased up to 700bp. In this respect, a comparison of yield spreads in the beginning of 2008 to the end of 2008 reveals the magnitude of the increases in funding costs to which firms' were exposed to: In particular, over the year of 2008, yield spreads doubled from a level of 300 to 600bp. Here, several effects including overall deterioration in market liquidity, credit risk as well as interactions of these factors, e.g., market liquidity induced changes in credit risk via the rollover channel, might contribute to this pattern. Consequently, in order to be able to disentangle and relate the underlying effects to the level of yield spreads, it is relevant to study the evolution of aggregate market liquidity.

Turning to this study of the evolution of liquidity in the US corporate bond market: Panel B presents the price dispersion measure which permits to estimate realized transaction costs based on transaction data. In the period from the beginning of 2005 to the end of 2007 average transaction costs were between 40 and 50bp, which is line with the estimates provided by, e.g., Friewald et al. (2012). However, the *Lehman* bankruptcy in 2008 constituted a shock to aggregate market liquidity: Transaction costs increased by a factor of three, up to a level of 150bp, within a few days following the filing. Thus, this sudden and sharp nature of the increase in transaction costs, and hence deterioration in liquidity, might indicate a strong element of surprise with its overall magnitude not being anticipated by the market. This level of transaction costs remained relatively high, in comparison to the pre-*Lehman* period, at around 60 to 80bp over the entire year 2009. The Amihud measure, in Panel C, which can be interpreted as a measure of market depth, also emphasizes the strong deterioration in market liquidity induced by the *Lehman* bankruptcy. Specifically, the price impact of trading \$1 million was around 20bp over the period from 2005 to 2007. However, this price impact also tripled up to 60bp following the *Lehman* bankruptcy, with the depth of the market remaining quite thin at values between 30 to 40bp in 2009. Following

2009, market depth dropped back to “normal” levels. Turning to the Roll measure, given in Panel D, which also serves as a measure of realized transaction costs similar to the price dispersion measure, the obtained evolution of the suggested liquidity dynamics is very similar compared to the other two measures. The resulting estimates of transaction costs are again around 40 to 50bp for the period up until the *Lehman* bankruptcy. Again, the Roll measure highlights the sudden loss in market liquidity directly following the bankruptcy filing, with realized transaction costs increasing by up to a factor of three.

In summary, the results present throughout various measures, the aggregate liquidity dynamics in the US corporate bond market. Overall, all measures indicate that liquidity abruptly deteriorated directly following the *Lehman* bankruptcy, with transaction costs increasing by a factor of three. Consequently, it is reasonable to assume that this sudden and sharp deterioration in liquidity strongly indicates an element of surprise, and moreover, suggests the unexpected nature of its severity. Thus, this period following the *Lehman* bankruptcy represents an interesting phase to exploit rather exogenous variation in liquidity, and to directly address several aspects of how financial market frictions act on firms’ funding costs. Specifically, in the subsequent difference-in-differences analysis, the *Lehman*-bankruptcy constitutes an ideal natural experiment to explore and quantitatively assess the impact of market liquidity on credit risk via the bond rollover channel.

6.4 Summary Statistics of Full Sample

This section presents, for the sake of completeness, the summary statistics of the variables defined in Table 1 for the full panel, hence contains the entire time-series and cross-section of each bond/year observation over the period from 2005 to 2011. Table 3 gives the summary statistics of these variables. The variable yield spread is the end-of-year estimate (average yield spread in the month of December) of the considered bonds, with an average value of around 300bp. The standard deviation of 310bp suggests substantial variation to be explained across various dimensions. These yield spreads are computed as the yield differential relative to that of a duration matched Treasury yield (with an average value of 320bp). Dispersion, Amihud and Roll are the liquidity measures of the underlying bonds, averaged across the daily estimates of the respective measure in a given year. The detailed aggregate dynamics of these measures are discussed in Section 6.3. As far as the rollover rate is concerned, with Section 6.2 providing a comprehensive study on the pursued rollover policies on the individual firm level, in the full panel the average rollover rate is 13%

exhibiting a standard deviation of 14%. Credit risk is the average end-of-year bond rating across the three major rating agencies *Fitch*, *Moody's* and *Standard and Poor's*. In the full panel, the average value is around 7.8, which corresponds to a BBB+ rating with an interquartile distance of around 4 notches (ranging from 5.75 to 10), which represents a shift from A to BBB– in terms of rating classes. Also the standard deviation of the credit risk measure is around 4.

Focusing on the bond specific trading activity variables (again averaged across the daily values in a given year), with volume giving the traded volume on a daily basis and trades representing the number of trades per trade day, in Table 3. The mean values of these variables are around \$1.5 million for the volume respectively 4 for the trades variable. These numbers are in line with various liquidity studies, e.g., Friewald et al. (2012). Days gives the number of active trading days in a given year which is around 76, with some dispersion as indicated by the standard deviation of 77. As far as the bond characteristics are concerned, discussed in detail in Section 6.1, the average coupon in the full panel is 5.7% of face value, the average time to maturity is around 10 years and the average amount outstanding is \$365 million.

Finally, turning to the characteristics of the firm, the average cash to asset ratio is 6% (standard deviation is also around 6%) , while the average leverage ratio as defined by the fraction of total book debt to the sum of total book debt and market capitalization of equity is 38%, with a standard deviation of 23%. A detailed description on the role of bond holdings in the individual debt capital structures was already provided in Section 6.1, in the panel the mean fraction of total book debt that is due to corporate bonds is 77%, with a standard deviation of 25%, confirming the overall importance of bond financing for these corporates. The fraction of long-term debt expiring within a year to total long-term debt is 10%, on average. Granularity, as a measure of bond maturity dispersion is on average 2.47, which is somewhat higher compared to the 1.9 estimate provided by Choi et al. (2013), maybe indicating that S&P 500 constituents manage corporate maturity dispersion to a greater extent. Profitability, as given by the net income to total assets ratio is around 4%, while Q (fraction of the sum of total book debt and market capitalization of equity to total assets) is around 38% on average, with a standard deviation of 18%. The ratios of intangibility and investment to total assets are 17% respectively 5%, with standard deviations of 25% respectively 6%. The retained earnings to total assets ratio is 15%. The average equity beta is 1.1 with a standard deviation of 0.34, and the average firm size measure represented by the natural logarithm of total assets is 25 with a standard deviation of 1.5.

7 Difference-in-Differences Analysis

The previous sections discussed the underlying corporate bond financing policies of S&P 500 constituents and presented the aggregate dynamics of yield spreads and liquidity in the US corporate bond market. Focusing on the posed hypotheses, this section describes the difference-in-differences approach taken to examine to what extent a shock to market liquidity affects a firm's credit risk via the bond rollover channel. In order to address this question a quasi natural experiment is conducted. Specifically, in this experiment, the exogenous variation in market liquidity arising from the *Lehman* bankruptcy (September 15, 2008) in combination with ex-ante heterogeneity in bond maturity, consequently, firms' individual rollover needs in the period from the bankruptcy filing to the end of 2008, is exploited.

In particular, yield spreads of outstanding bonds directly following the *Lehman* bankruptcy of firms which have to roll over a large fraction of their bonds (treated firms) to firms which do not have to roll over any of their bonds (control firms) are compared. Yield spreads across the entire term-structure are considered. In order to address potential endogeneity issues, the approach taken by Almeida et al. (2012) is adopted and a matched difference-in-differences estimator is employed. In this methodology, the control group is selected by performing a nearest neighbourhood matching procedure and is represented by the most suitable subset of the non-treatment group.

In this study, matching is performed based on various characteristics of the bonds as well as of the underlying firms at the end of 2007. Motivated by the previous discussions in Section 6, it is reasonable to assume that at the end of 2007 firms did not anticipate the severity of the market liquidity shock induced by the *Lehman* bankruptcy. This is important, as it rules out strategic behavior, and hence, addresses potential endogeneity. In Table 4, the set of variables on which bonds of treated and control firms are matched is displayed.⁴ In general, such a matching procedure guarantees the ex-ante homogeneity of treatment and control group, and allows to pin down the effect of treatment relative to an otherwise identical group. Hence, before treatment occurs, the underlying bonds of treated and control firms must be guaranteed to be identical across various dimensions. Specifically, in this respect, in order to test to what extent market liquidity affects a firm's credit risk via the bond rollover channel, two dimensions are of particular importance: First, it must be guaranteed that the underlying bonds of the treated and control

⁴Matching is done without replacement and a one-to-four match is performed, i.e., for each treated observation at least four control observations are available.

firms are ex-ante equally liquid. This is achieved by employing the liquidity measures and trading activity variables in the matching procedure. Second, it must be guaranteed that the underlying bonds of the two groups are ex-ante rated equally and thus carry the same credit risk, as it is perceived by the rating agencies. Additionally, treated and control firms must exhibit very similar asset as well as liability structures. Given that these criteria are all fulfilled, the subsequent analysis allows to adequately explore the effect of a shock to market liquidity on credit risk via the corporate bond rollover channel.⁵

In order to study the effect involving different rollover rates, three thresholds of treatment are considered: Firms are treated if they need to roll over at least 10%, 15% or 20% of their bond financing in the period from the *Lehman* bankruptcy to the end of 2008, hence, these firms are directly hit by the liquidity shock. For each threshold of treatment, yield spreads of outstanding bonds of treated respectively control firms exhibiting various time to maturities *around the time* of the bankruptcy filing are compared. These include long-term bonds with a time to maturity of more than 15 years, medium-term bonds with a time to maturity between 5 and 15 years as well as short-term bonds with a time to maturity between 1 and 5 years. This allows to consider the treatment effect across the entire term-structure of yield spreads.

Table 4 displays the matching variables and presents the performance of the nearest neighbourhood matching procedure. In particular, this performance is assessed by comparing the distributional differences of treatment and non-treatment group in the considered matching variables before the procedure is performed, and, the distributional differences of treatment and control group after the procedure is performed. This comparison is based on the Kolmogorov-Smirnov (K-S) test. For any given rollover rate (Panels A to C in Table 4), matching is performed separately for all considered maturities (Columns 1 to 3) of the underlying bonds of the respective treatment group. Moreover, for each particular rollover rate, matching is also performed by pooling the bonds with the various maturities (Column 4). The p -values of the K-S test indicate that after the matching procedure is performed no significant differences between treatment and control groups across all considered criteria and dimensions are evident, consequently, treatment and control groups can be considered as being homogeneous.

In order to get some intuition on the evolution of yield spreads of treatment and control groups

⁵Note that an important additional assumption necessary to hold is that treatment and control group exhibit parallel trends in the dependent as well as among the matching variables. All of these criteria are fulfilled, thus, the detailed results of this verification are not presented in the interest of conserving space.

around the date of the *Lehman* bankruptcy, Figure 6 displays the underlying yield spread dynamics of these two groups in the time period from the beginning of 2007 to the end of 2009. In this figure, three distinct panels are shown with each corresponding to one of the three considered rollover rates. The presented time-series of yield spreads are the averages across the entire term-structure of treated and control firms, hence, correspond to the pooled samples as matched in Column 4, in Table 4. Panel A displays the dynamics in the case where treatment is defined by a rollover rate of 10%. In the beginning of 2008, yield spreads of the treatment and control group were basically equal at a level of 220bp. Moreover, the presented graph reveals that yield spreads of the two groups share basically identical trends towards the *Lehman* bankruptcy. However, following the *Lehman* bankruptcy, these yield spreads start to diverge: In particular, although the yield spread of the control group also rises up to a level of 520bp, the yield spread of the treatment group experiences a much more pronounced increase up to a level of 620bp, resulting in a yield spread differential of around 100bp by the end of 2008. Consequently, these yield spread dynamics provide evidence that the common exogenous shock to market liquidity induced an increase in credit risk of the treatment group relative to the control group.

Panels B and C in Figure 6 display the dynamics of yield spreads in the case where treatment is defined by a rollover rate of 15% respectively 20%. In both cases, very similar patterns compared to previously emerge, with yield spreads of the two groups sharing identical dynamics before the *Lehman* bankruptcy. However, with parallel reasoning compared to the 10% rollover rate, following the bankruptcy, yield spreads of treatment and control groups again diverge. This divergence is more pronounced in the case of the 20% rollover rate compared to the 15% rollover rate (and 10% rollover rate), i.e., the yield spread differential of treatment and control groups by the end of 2008 amounts to 190bp for the 15% rollover rate respectively 280bp for the 20% rollover rate.

Apparently, across all three considered rollover rates, the market liquidity shock arising from the bankruptcy filing of *Lehman* induced more pronounced increases in yield spreads of the treatment groups relative to the control groups. The observed effect is economically large and seems to be increasing in the rollover rate. Consequently, these findings provide evidence that the deterioration in market liquidity affected the credit risk of the treatment groups relative to the control groups via the corporate bond rollover channel.

Given the presented dynamics of yield spreads, it is of interest to test whether the observed differences in yield spreads following the *Lehman* bankruptcy between treatment and control

groups are statistically significant as well. In order to provide a formal test on whether a shock to market liquidity affects credit risk via the rollover channel, the yield spread changes of treatment and control groups are compared by employing the following difference-in-differences specification,

$$\Delta y_{ij} = \alpha + \beta \cdot \text{Treat}_{ij} + \epsilon_{ij} \quad (11)$$

where y_{ij} is the yield spread change of bond i of firm j , given by the differential of the average yield spread in December 2007 relative to the average yield spread in December 2008, and, Treat_{ij} is an indicator variable signaling whether treatment occurred or not. Thus, the coefficient β captures the average treatment effect (ATE). Table 5 presents the results, where the ATE is given for the three different rollover rates (10%, 15% and 20%) displayed in lines (a) to (c) as well as for the three different maturities (long-term, medium-term, short-term) given in Columns 1 to 3. Moreover, Column 4 gives the *pooled* ATE as obtained by comparing yield spreads of treatment and control groups as matched in Column 4, in Table 4. Hence, this represents the ATE given a particular rollover rate across the entire term-structure of yield spreads.

First, studying the pooled treatment effect as given in Table 5 (Column 4), the results of the previous descriptive analysis are confirmed. In particular, the findings reveal the following insights: In the case of the 10% rollover rate the pooled ATE is 102bp. Moreover, the obtained pooled ATE are increasing in the rollover rate, thus, confirming the posed hypothesis. Specifically, in the case of the 15% rollover rate the ATE is 185bp, while in the case of the 20% rollover rate the ATE is given by 278bp, with the resulting differences being highly significant.

Second, turning to the analysis of the term-structure of yield spreads in Columns 1 to 3, the difference-in-differences analysis reveals that the ATE in the case of long-term bonds is larger compared to the ATE in the case of short-term bonds.⁶ Moreover, this effect is present across all three considered rollover rates. Although the obtained ATE across the various maturities are statistically significant, they are somewhat weaker in the case of long-term bonds compared to short-term bonds. However, the resulting ATE are economically large, e.g., in the case of a rollover rate of 15% the ATE for short-term bonds is around 191bp, for medium-term bonds the ATE is 216bp, while for long-term bonds the ATE is given by 276bp.

⁶It should be noted again, that for each maturity/rollover rate combination given in Table 5, the matching procedure is rerun (with the results of the matching procedure given in Table 4). Thus, the ATE in the case of, e.g. long-term bonds, results from comparing yield spreads of long-term bonds of the treatment group relative to long-term bonds of an equivalent control group.

In summary, the presented results of the difference-in-differences analysis provide strong evidence that deterioration in market liquidity affects credit risk via the corporate bond rollover channel. The observed effect is increasing in the rollover rate, i.e., given a particular shock to market liquidity, yield spreads of the treatment group increase stronger relative to yield spreads of an equivalent control group if a larger fraction of bond financing needs to be rolled over. This effect can be observed consistently across the entire term-structure of yield spreads, with long-term bonds generally exhibiting higher ATE compared to short-term bonds.

8 Cross-Sectional Analysis

The difference-in-differences analysis provides strong evidence that deterioration in market liquidity affects credit risk via the corporate bond rollover channel. Consequently, in order to verify the internal consistency of the previously obtained results, it is also of interest to study the joint cross-section of yield spreads and various commonly employed measures of bond liquidity (price dispersion, Amihud, Roll), rollover rates and credit risk. Moreover, related to the posed hypothesis, providing such an analysis allows to disentangle the direct effect of liquidity, on yield spreads, from the indirect effect of liquidity on credit risk via the rollover channel.

In particular, the cross-sectional variation in the level of end-of-year t corporate bond yield spreads is explained. The main explanatory variables of interest are represented by: the direct effect of liquidity measures over the previous year Δt , and, the indirect effect of liquidity measures through the rollover rate of the previous year Δt , which is measured via an interaction term. The interpretation of the interaction term is similar to the average treatment effect (ATE) of the difference-in-differences analysis. Furthermore, another important variable is the measure for credit risk, in the beginning of the year, given by the average bond ratings of the three major rating agencies *Fitch*, *Moody's* and *Standard and Poor's*. Hence, this allows to compare expected versus unexpected changes in credit risk. In what follows, variants of the following regression specification are tested, where i is the bond-index, j the firm-index and t the time-index

$$\begin{aligned}
 y_{ij,t} = & \alpha + \beta_1 \cdot \mathbf{Liquidity}_{ij,\Delta t} + \beta_2 \cdot (\mathbf{Liquidity}_{ij,\Delta t} \cdot \mathbf{Rollover Rate}_{j,\Delta t}) & (12) \\
 & + \beta_3 \cdot \mathbf{Rollover Rate}_{j,\Delta t} + \beta_4 \cdot \mathbf{Credit Risk}_{j,t-1} \\
 & + \beta_5 \cdot \mathbf{Controls}_{ij,t-1} + FE + \epsilon_{ij,t}
 \end{aligned}$$

with *Controls* capturing the vector of control variables which are defined in Table 1 and *FE* represents combinations of firm, year or industry fixed effects.⁷ In this setup, β_1 measures the direct effect of liquidity on yield spreads, while β_2 measures the indirect effect of liquidity on yield spreads via the rollover channel.

This specification combines the entire time-series and cross-section of yield spreads and is estimated by employing OLS regressions, adjusting the standard errors for the existence of clusters on the firm level as described in Williams (2000) and Petersen (2009). This approach addresses the issue that, in a particular year, a firm may have several bonds outstanding, and that all these bonds will show up as separate observations in the data.

8.1 Cross-Section of Corporate Bond Yield Spreads

In order to examine how various liquidity measures are related to the cross-section of yield spreads through the corporate bond rollover channel, the results of each of the three liquidity measures are analyzed in turn, as given by the price dispersion measure (Table 6), Amihud measure (Table 7) and Roll measure (Table 8). Furthermore, a study of the complete model (Table 9), where all three measures are employed is discussed.⁸

Table 6 displays five different models, where variants of Equation 12 are tested employing the price dispersion measure as a liquidity metric. In particular, Model 1 only controls for the price dispersion measure and credit risk, Model 2 additionally includes the interaction term of the price dispersion measure with the rollover rate, as well as the rollover rate on a stand-alone basis. Furthermore, Model 3 includes industry and year fixed effects, while Model 4 includes firm and year fixed effects. Finally, Model 5 displays the complete specification of Equation 12 augmented by firm and year fixed effects. This step-wise model procedure allows to compare the adjusted R^2 and to study the behaviour of the coefficients across the different specifications.

Focusing on the results: When comparing Model 1 (without interaction term and rollover rate) to Model 2, the results demonstrate the increase in adjusted R^2 (from 33% to 37%) originating from the inclusion of these two variables. This might indicate that some non-negligible part of the cross-sectional variation in end-of-year yield spreads is explained by the effect of liquidity

⁷Note that, when employed, these fixed effects are represented by dummy variables throughout the various specifications.

⁸Note that, the Internet Appendix provided in this paper also presents results by employing regression specifications in changes, hence in first-differences of Equation 12. The qualitative nature of the results is confirmed, consequently, in the interest of conserving space the results are not discussed and described in detail.

through the rollover rate. Interestingly, with the inclusion of the interaction term, the stand-alone coefficient of the price dispersion measure drops from 3.5 to 2.5 between these two models, with the coefficient of the interaction term exhibiting a positive, statistically significant, sign. Thus, when assigning an underlying economic interpretation to this comparison, the findings suggest that the price dispersion measure, as a liquidity metric capturing transaction costs, might absorb some cross-sectional variation in credit risk, particularly the part which is attributable to rollover. Furthermore, in Model 2 the stand-alone coefficient of the rollover rate is positively significant, indicating that in this pooled specification, without any employed fixed effects, a high rollover rate per se is associated with higher end-of-year yield spreads. Focusing on Model 3, where also industry and year fixed effects are included, the magnitudes of the coefficients of the individual variables change slightly, however, the qualitative and economic interpretations are similar. An important additional insight is provided by Model 4, which represents a specification augmented by firm and year fixed effects. In this model, the stand-alone coefficient of the rollover rate turns insignificant, and hence, the rollover rate does not provide any explanatory power for the cross-section of yield spreads. This has interesting implications as it suggests that the variation of the rollover rate per se does not exhibit any association with the cross-section of yield spreads. Rather, this variation in the rollover rate itself might already be captured by the credit risk variable. Consequently, the only contribution of the rollover rate on the level of yield spreads is indirectly given via the interaction term with the price dispersion measure, which still exhibits a positive and significant coefficient. Finally considering Model 5, which additionally includes all other control variables, the qualitative nature of the discussed results remains basically identical.

Focusing on the Amihud measure in Table 7, the same step-wise procedure as discussed when exploring the price dispersion measure is applied. Again, the results show the increase in adjusted R^2 when comparing Model 1 to Model 2 from 34% to 37%. Thus, similarly to the previous findings, the interaction term (Amihud measure with rollover rate) and the rollover rate provide some explanatory power. Moreover, in the same spirit as above, with the inclusion of the interaction term in Model 2 the coefficient of the Amihud measure drops from 0.7 to 0.3. Again, this suggests that the Amihud measure, as an alternative liquidity metric assessing market depth, might absorb some cross-sectional variation in credit risk, which is attributable to rollover. Throughout Models 3 to 5, the results remain very robust, with the interaction term exhibiting a positive and significant coefficient, while the stand-alone coefficient of the rollover rate is statistically insignificant.

Completing the set of liquidity metrics, Table 8 provides the results in the case of the Roll measure. Overall, the nature of the previously discussed effects is again evident: First, the interaction term of the Roll measure with the rollover rate, and the rollover rate per se, are able to capture some additional variation. Second, the overall magnitude of the stand-alone coefficient of the Roll measure is diminished when including the interaction term, indicating that a similar argument as for the other two measures might apply. Third, the interaction term again exhibits a positive and significant coefficient throughout the various specifications, while the stand-alone coefficient of the rollover rate turns insignificant when employing firm fixed effects.

Having examined the individual relation of liquidity measures to the cross-section of yield spreads, the subsequent discussion focuses on the complete model as given in Equation 12. Table 9 displays four different regression specifications where Equation 12 is tested including the complete set of control variables as well as firm and year fixed effects. For the sake of completeness, in Models 1 to 3 each of the three liquidity measures are employed in turn with the price dispersion measure given in Model 1, Amihud measure in Model 2 and Roll measure in Model 3 (corresponding to Models 5 in the respective Tables 6 to 8). Finally, Model 4 contains the complete specification including all three liquidity measures and their interactions with the rollover rate. Again, this step-wise procedure allows to compare the explanatory power and to explore the interplay of the individual coefficients across the models. Comparing the adjusted R^2 reveals that the models employing the price dispersion respectively Roll measure show basically identical explanatory power of 61%, while the adjusted R^2 in the case of the Amihud measure is 64%. Overall, the complete specification in Model 4 exhibits an adjusted R^2 of 65%.

Turning to Model 4 and the interpretation of the individual effects, the results reveal interesting insights into the cross-sectional determinants of corporate bond yield spreads. Before quantifying the cross-sectional relation between yield spreads, liquidity measures and rollover rates the discussion focuses on the effects of the various control variables. In particular, the credit risk measure indicates that a one-standard deviation downgrade is associated with a 160bp increase in yield spreads. Increased trading activity, as represented by trades or the number of active trading days in a given year, corresponds to lower yield spread levels in general. Moreover, firm specific characteristics of the underlying bonds are linked to the cross-section of yield spreads, with rather long-term bonds exhibiting higher yield spreads and larger amount outstandings being associated with lower yield spreads. The former effect may be driven by institutional investors preferring

to hold long-term bonds, while the latter effect may be liquidity driven, as trading a particular volume within a larger bond issue is easier (see also Friewald et al. (2012)). The economic effects as assessed by a one standard deviation change are also non-negligible, being 23bp for the maturity variable respectively 40bp for the amount outstanding.

Among the group of firm fundamentals interesting economic insights emerge for the cash to assets ratio, debt granularity measure, equity beta and the size proxy. Yield spreads of a firm holding a larger fraction of their assets in cash are lower on average, with the economic significance being that a one standard deviation change corresponds to a 35bp yield spread differential. Yield spreads of firms exhibiting more granular maturity profiles, as discussed in Choi et al. (2013), are lower on average, possibly indicating the lower overall rollover risk associated with debt maturity dispersion or a liquidity effect in general. Moreover, the results demonstrate a cross-sectional link between firms' equity beta and yield spreads, with higher betas corresponding to higher yield spreads. In particular, a one standard deviation change in the beta is associated with a 76bp yield spread differential. Furthermore larger firms, as measured by the size variable given as the natural logarithm of total assets, exhibit lower levels of yield spreads with a one standard deviation change in size being associated with a yield spread differential of 106bp.

Focusing now on the cross-sectional relation of yield spreads, the various liquidity measures, rollover rates and their interactions: First, in this complete model specification among the set of liquidity measures two are significant and are related to the cross-section of corporate bond yield spreads, i.e., the price dispersion and the Amihud measure. The coefficient of the price dispersion measure is around 1.3. Thus, an increase in transaction costs by 100bp is associated with a 130bp yield spread differential. Consequently, this indicates that changes in overall transaction costs are roughly transmitted via a one-to-one relation to the level of yield spreads. A similar effect with parallel reasoning is uncovered when studying the effect of the Amihud measure. Hence, these results provide evidence that the overall cross-sectional link of liquidity and yield spreads is represented by a one-to-one relation, supporting the posed hypothesis.

Second, studying the interaction terms of the three liquidity measures with the rollover rate: The analysis demonstrates that again the two interaction terms including the price dispersion and the Amihud measure are related to the cross-section of corporate bond yield spreads, exhibiting positive coefficients. In general, the underlying economic interpretation of the interaction term is similar to the average treatment effect (ATE), given in the difference-in-differences analysis,

and captures the indirect effect of liquidity through the rollover channel on yield spreads. Thus, it is important to compare the quantitative insights gained from the two distinct sets of analyses (difference-in-differences and cross-sectional analysis), in order to obtain some intuition and to verify the internal consistency of the obtained results. In general, these comparisons provide interesting implications: Specifically, in the difference-in-differences analysis the resulting pooled ATE in the case of a rollover rate of 10% was roughly 100bp, while in the case of a rollover rate of 15% (20%) the ATE was around 185bp (280bp). Now, if one were to assume a similar level of overall transaction costs of around 150bp, as was prevailing following the bankruptcy filing of *Lehman*, then the coefficient of the interaction term of, e.g., the price dispersion measure with the rollover rate reveals interesting economic insights in the cross-sectional analysis: Given this level of transaction costs of 150bp, a rollover rate of 10% is associated with an additional yield spread differential of 115bp, while in the case of a rollover rate of 15% (20%) this yield spread differential amounts to around 175bp (230bp). As a consequence, the comparison of the findings, related to the quantitative and economic implications of the effect of market liquidity on credit risk via the rollover channel, verify the consistency of the obtained results across the two sets of analyses.

In summary, the cross-sectional analysis also provides strong evidence that market liquidity affects credit risk via the rollover channel, with the quantitative implications of the effect being consistent compared to those obtained in the difference-in-differences analysis. Additionally, the microstructure of the findings reveals that commonly employed liquidity measures used to explain the cross-section of corporate bond yield spreads seem to absorb some cross-sectional variation in credit risk, specifically the part which is attributable to rollover.

9 Conclusion

Credit risk and market liquidity are important components determining corporate bond yield spreads, a direct measure of firms' debt funding costs. When firms replace maturing bonds by issuing new bonds, hence, engage in bond rollover, deteriorating market liquidity results in rollover losses. In turn, through this rollover channel, models following He and Xiong (2012) argue that market liquidity affects credit risk. As a consequence, it is crucial to understand and quantify the empirical asset pricing implications induced by the rollover channel and to comprehensively address the question of how market liquidity affects credit risk via corporate bond rollover.

This paper provides a detailed study of bond financing policies of S&P 500 constituents (excluding financials and utilities) in the US corporate bond market, based on a complete set of transactions data covering the period from 2005 to 2011. As a consequence, this allows to jointly examine corporate bond rollover decisions with prevailing market liquidity conditions, and thus, to closely link market liquidity and credit risk via the rollover channel.

An analysis of the debt capital structures reveals that these firms have large exposures to the bond market, with roughly 70% of their debt holdings being in bonds. Moreover, they are very persistent with respect to their bond financing, with the findings providing strong evidence that these corporates pursue an actual bond rollover policy, implying that maturing bonds are replaced by newly issued bonds. Interestingly, this pattern is also observable in periods of market illiquidity. Consequently, these corporates are an important subject matter to study how market liquidity affects credit risk via bond rollover.

In order to test whether corporate bond market liquidity indeed affects credit risk via the rollover channel, a quasi natural experiment by exploiting the exogenous variation in liquidity arising from the *Lehman* bankruptcy is employed. In this difference-in-differences analysis, the results demonstrate a clear impact of market liquidity on credit risk via the rollover channel. In particular, a transaction cost shock a la *Lehman* of 100bp is associated with an overall average treatment effect of 185bp. In general, the resulting impact on credit risk is increasing in the rollover rate, i.e., the fraction of bond financing that needs to be rolled over. Additionally, this effect is observable across the entire term-structure of yield spreads.

Furthermore, an analysis of the joint cross-section of yield spreads, various commonly employed bond liquidity measures and rollover rates is provided. A comparison of the difference-in-differences analysis to the cross-sectional study confirms the quantitative nature of the obtained results, verifying the consistency of the findings across the two analyses. In particular, the results suggest that these liquidity measures might absorb cross-sectional variation in credit risk, specifically the part which is attributable to bond rollover. Moreover, the findings suggest that overall changes in liquidity are represented by a one-to-one relation to the level of yield spreads, e.g., an increase in transaction costs by 100bp is associated with a yield spread differential of 130bp.

In summary, this paper provides a unique study of corporate bond rollover policies for a representative sample of firms, and offers detailed insights into the effects of market liquidity on credit risk via the corporate bond rollover channel.

A Appendix

Bond Valuation

Following Leland (1994b), the tax shield and bankruptcy costs are given by

$$TS(V) = \frac{\tau C}{r} \left[1 - \left(\frac{V}{V_B} \right)^{-\beta_0} \right] \quad (13)$$

$$BC(V) = \alpha V_B \left(\frac{V}{V_B} \right)^{-\beta_0} \quad (14)$$

with β_0 being the positive root of the fundamental quadratic

$$\beta_0 = \frac{(r - \delta - \frac{1}{2}\sigma^2) + \sqrt{(r - \delta - \frac{1}{2}\sigma^2)^2 + 2\sigma^2 r}}{\sigma^2} > 0 \quad (15)$$

The valuation equation given in (2) has a particular and a general solution satisfying,

$$D(V, m, \xi k) = \frac{C + mP}{r + m + \xi k} + AV^{\beta_1} + BV^{-\beta_2} \quad (16)$$

with β_1 and β_2 being the roots of the fundamental quadratic given by

$$\beta_1 = \frac{(r - \delta - \frac{1}{2}\sigma^2) - \sqrt{(r - \delta - \frac{1}{2}\sigma^2)^2 + 2\sigma^2(r + m + \xi k)}}{\sigma^2} > 1 \quad (17)$$

$$\beta_2 = \frac{(r - \delta - \frac{1}{2}\sigma^2) + \sqrt{(r - \delta - \frac{1}{2}\sigma^2)^2 + 2\sigma^2(r + m + \xi k)}}{\sigma^2} > 0 \quad (18)$$

The two boundary conditions imposed on debt value are

$$D(V_B, m, \xi k) = (1 - \alpha)V_B \quad (19)$$

and

$$\lim_{V \rightarrow \infty} D(V, m, \xi k) = \frac{C + mP}{r + m + \xi k} \quad (20)$$

These conditions imply $A = 0$ in order to exclude bubbles, and (3) follows with B given by

$$B = \left[(1 - \alpha)V_B - \frac{C + mP}{r + m + \xi k} \right] \left(\frac{1}{V_B} \right)^{-\beta_2} \quad (21)$$

Equity Valuation

As illiquidity decreases the overall value of the firm, the valuation following Leland (1994b), where equity value is given as the differential of firm value to debt value cannot directly be applied. Rather, the valuation must be augmented by the loss in firm value which arises due to the illiquidity. Thus, equity value is given by

$$E(V, m, \xi k) = v(V) - D(V, m, \xi k) + \frac{\xi k}{m + \xi k} [D(V, m, \xi k) - D(V, 0, 0)] \quad (22)$$

with firm value $v(V)$ given as in Leland (1994b), defined by the unlevered asset value plus the tax shield minus the bankruptcy costs

$$v(V) = V + TS(V) - BC(V) \quad (23)$$

Note that the formula for equity in the case of $m = 0$ (when the firm does not need to roll over bonds) equals Leland (1994b), while if $\xi k = 0$ (bonds are perfectly liquid) this formula equals Leland (1994a). Equityholders optimal default boundary is given by the smooth pasting condition in Equation 7 which results in

$$V_B = \frac{\frac{(C+mP)\xi k}{m+\xi k} \left[\frac{\beta_0}{r} - \frac{\beta_2}{r+m+\xi k} \right] + \frac{C+mP}{r+m+\xi k} \beta_2 - \frac{\tau C}{r} \beta_0}{\frac{(1-\alpha)\xi k}{m+\xi k} (\beta_0 - \beta_2) + \beta_0 \alpha + (1-\alpha)\beta_2 + 1} \quad (24)$$

Figure 1: Model Implications

This figure gives the results of the model calibration. The model is calibrated based on parameters provided by He and Xiong (2012) and are: $r = 8\%$, $\tau = 27\%$, $\sigma = 23\%$, $\alpha = 40\%$, $\delta = 2\%$, $k = 1\%$, $\xi = 1$ and $V = 100$. All panels are with respect to transaction costs, with the baseline value given by 100bp. The parameter m represents the rollover rate ($m = 0$, $m = 10\%$, $m = 20\%$). Throughout all calibrations, the coupon C and principal P are always chosen in such a way that the bond is issued at par and has an initial yield spread of 330bp. Panel A gives the relation between liquidity and the default boundary, while Panel B presents the relation between changes in liquidity and changes in the probability of default. Panel C gives the yield spread in the case of a rollover rate of $m = 10\%$, and Panel D gives the corresponding spread composition (default and liquidity premium). Panel E gives the yield spread in the case of a rollover rate of $m = 20\%$, and Panel F the corresponding spread composition.

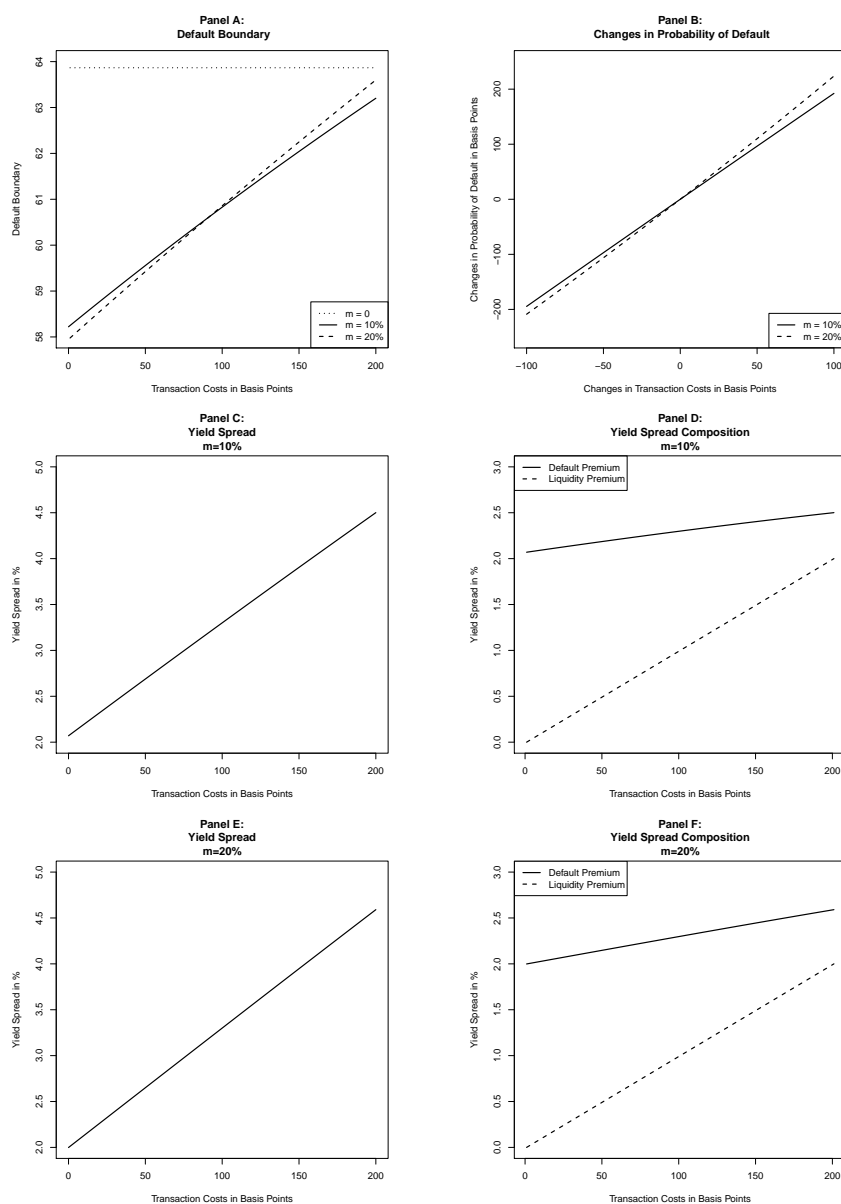


Figure 2: Corporate Bond Financing

This figure displays the distribution of the debt capital structures of S&P 500 constituents with respect to their corporate bond financing. Panel A gives the distribution (firm-year observations) of the fractions of total book debt which are due to corporate bonds. Panel B gives the time-series of these fractions and reports the 25% quantile, the mean and the 75% quantile. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

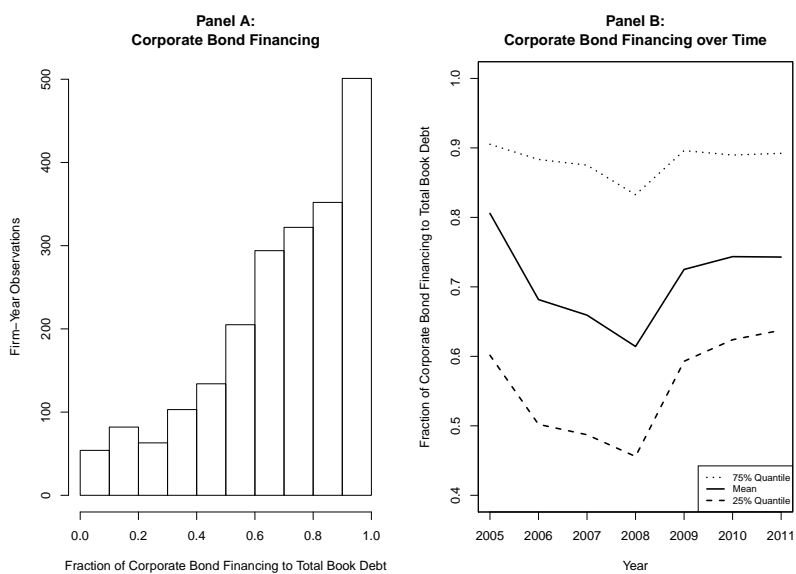


Figure 3: Corporate Bond Redemption and Issuance

This figure displays the relation of bond redemption (amount outstanding of maturing bonds) to overall issuance amount in a given year. Each dot represents a firm observation, and each of the Panels A to G correspond to a particular year. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPSTAT*.

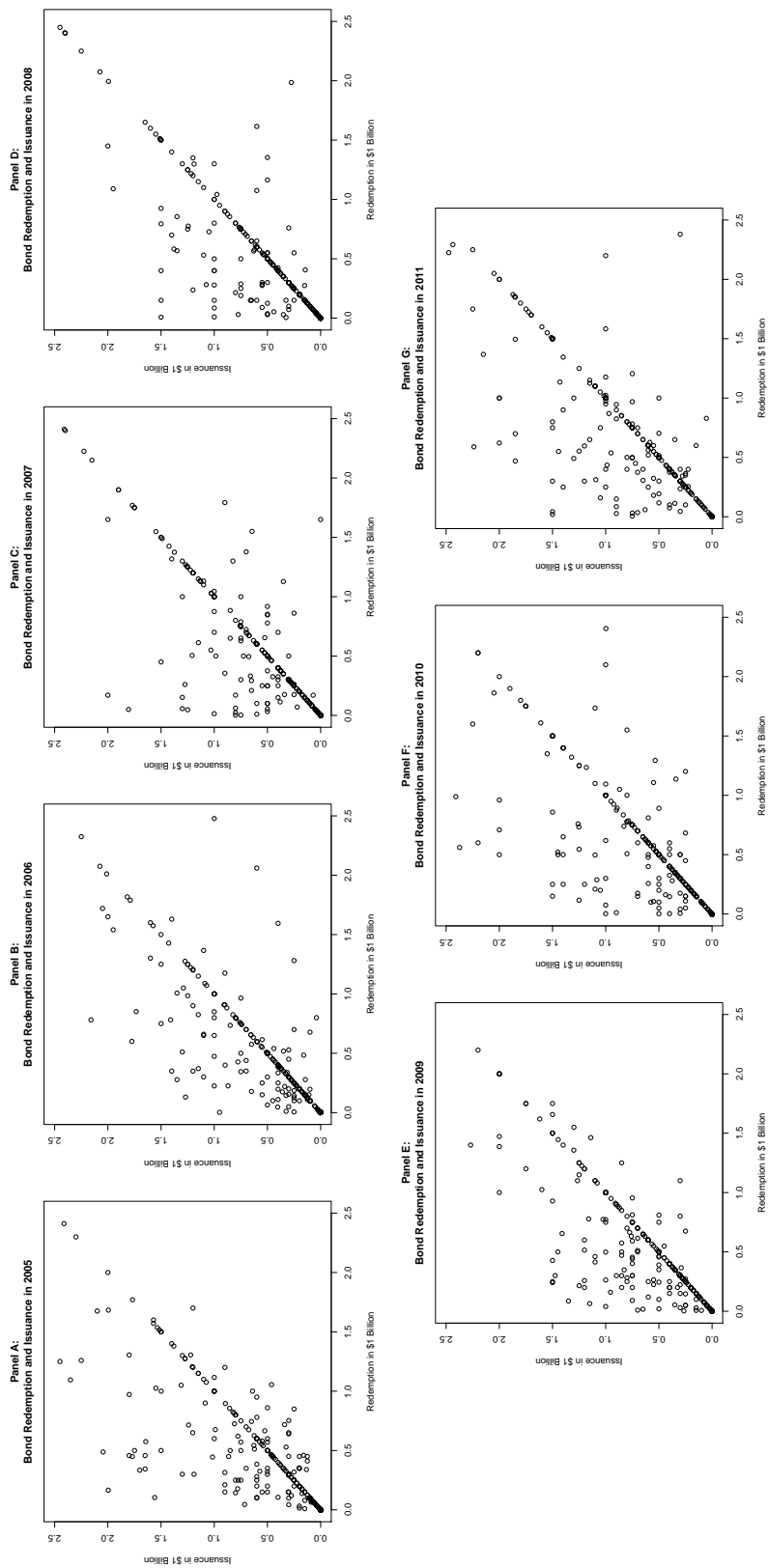


Figure 4: Rollover Rates

This figure displays the distribution of the rollover rates (fraction of amount of maturing bonds to overall amount outstanding) in a given year. In each of the Panels A to G the distribution of rollover rates across firms in a particular year is shown. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACER* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

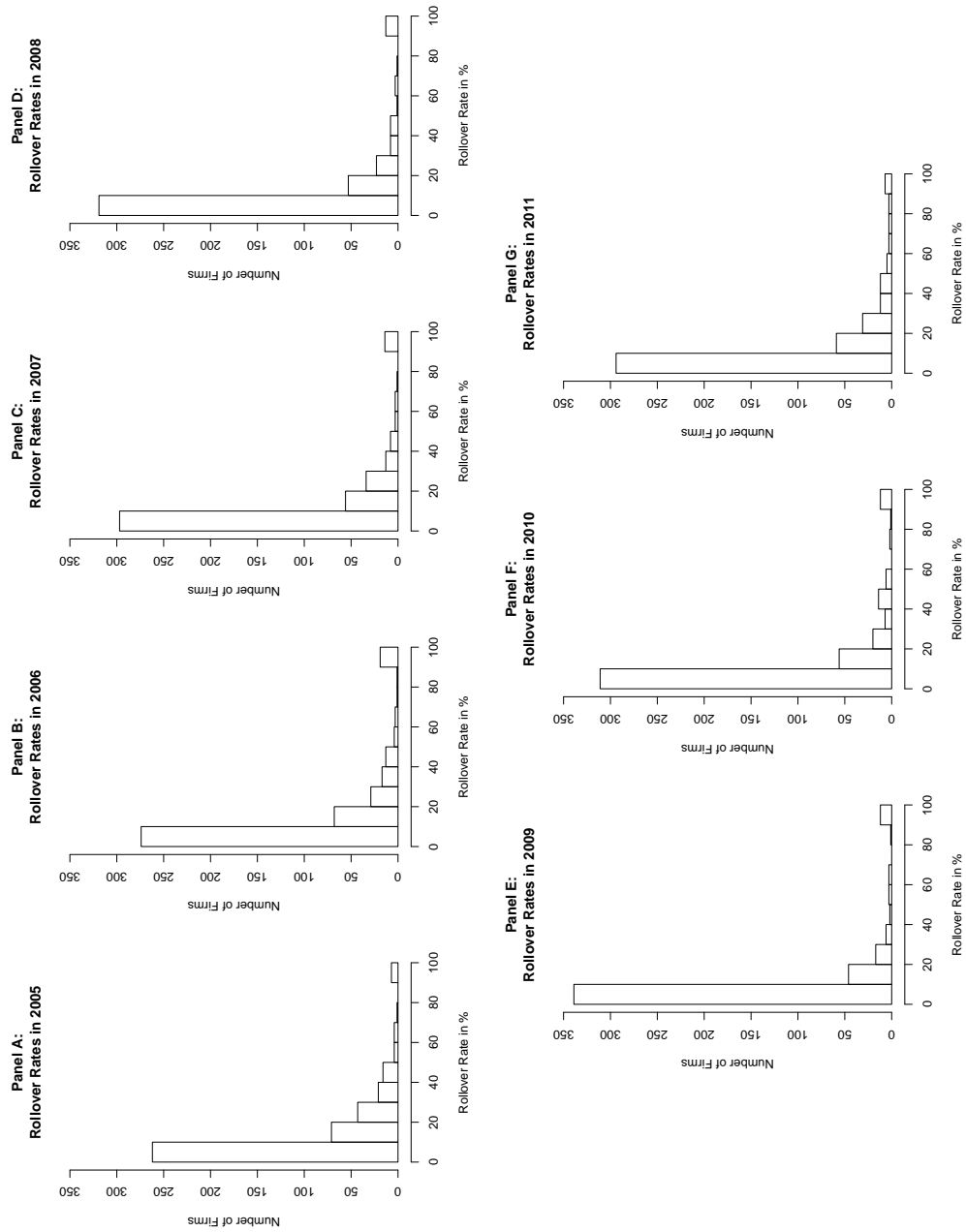


Figure 5: Yield Spreads and Market Liquidity in the US Corporate Bond Market

This figure displays the time-series of average yield spreads and market liquidity as represented by the various liquidity measures (price dispersion measure, Amihud measure, Roll measure). Panel A gives the time-series of yield spreads, Panel B the price dispersion measure, Panel C the Amihud measure and Panel D the Roll measure. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13, 402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7, 100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

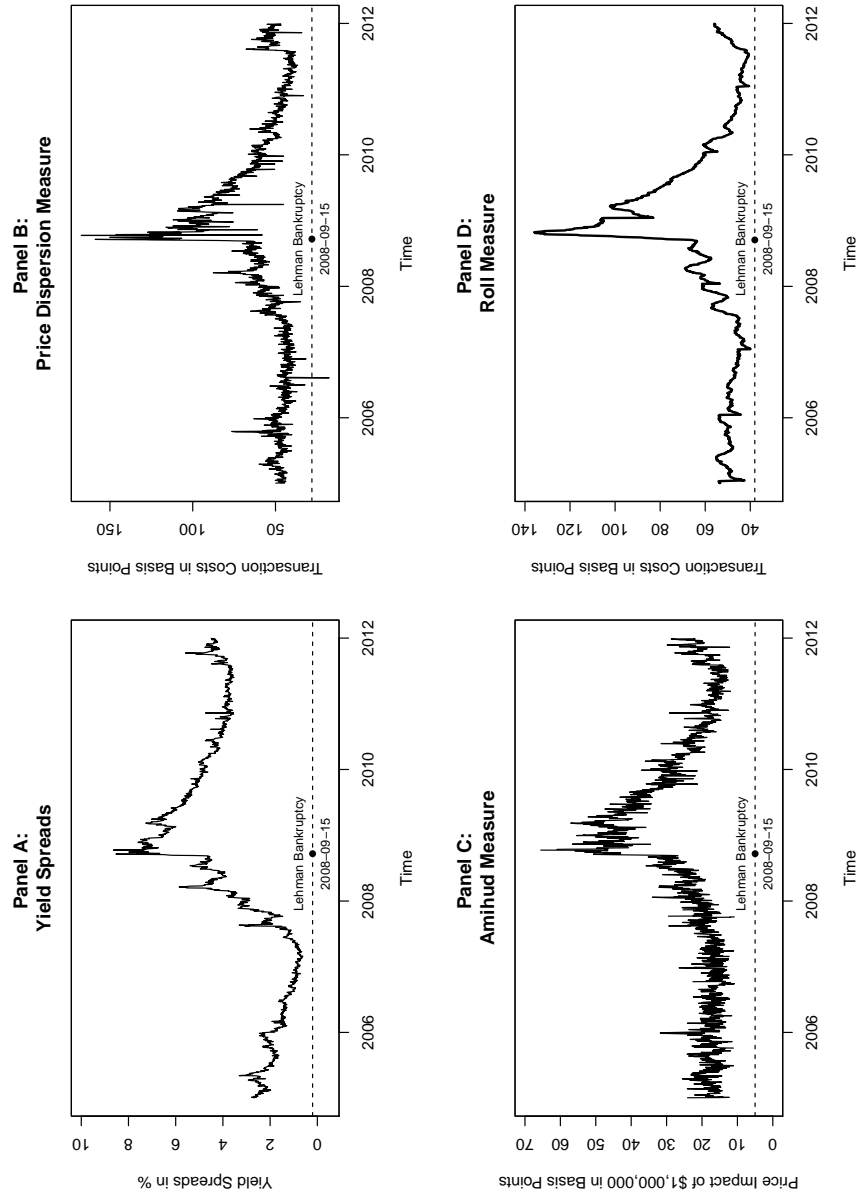


Figure 6: Corporate Bond Yield Spreads of Treatment and Control Groups

This figure displays average yield spreads of the treatment and control groups used in the difference-in-differences analysis. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period following the *Lehman* bankruptcy to the end of 2008. The figure displays the yield spreads of three different treatment groups as determined by the rollover rates given in Panels A to C ($> 10\%$, $> 15\%$ and $> 20\%$), and their corresponding control groups. The displayed yield spreads represent the average yield spreads of the firms across the entire term-structure including long-term bonds (more than 15 years), medium-term bonds (between 5 to 15 years) and short-term bonds (between 1 to 5 years maturity). The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

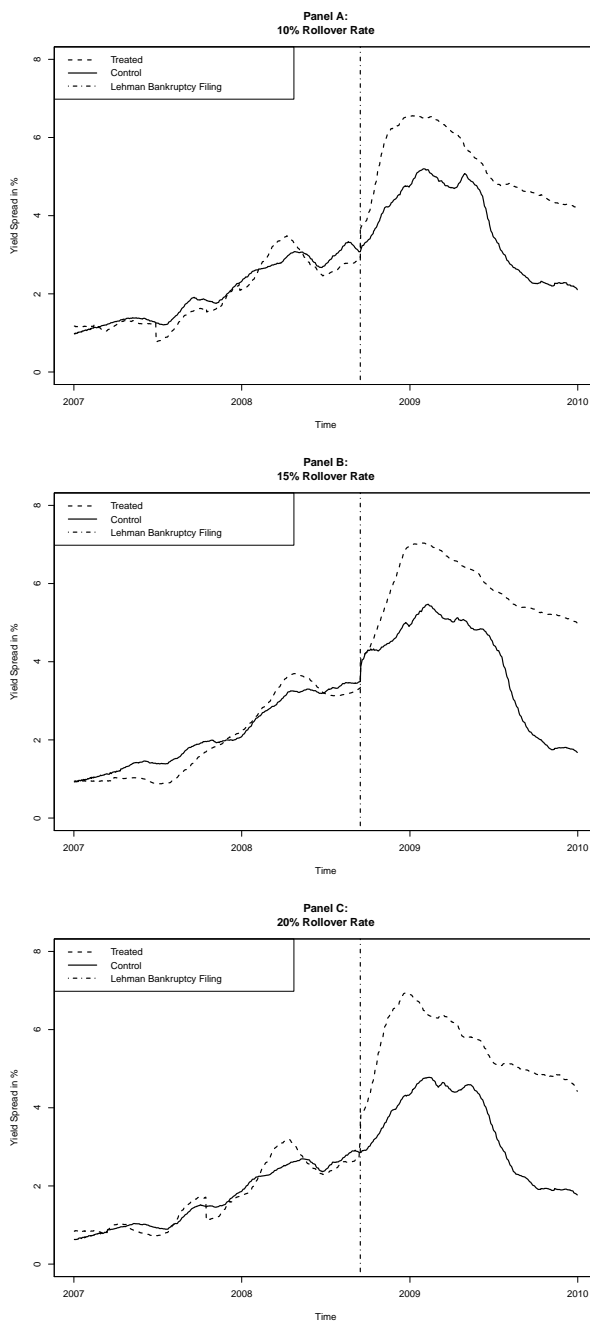


Table 1: Definition of Variables

This table provides the definitions of the variables used in the analysis, including yield spreads, liquidity measures (dispersion, Amihud, Roll), rollover rate, credit risk, trading activity variables (volume, trades, days), bond characteristics (coupon, maturity, amount outstanding) and firm fundamentals (cash, leverage, bond financing, long-term debt 1Y, granularity, profitability, Q, intangibility, investment, retained earnings, β , size, industry). The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

Variable	Definition
Yield spread	Yield differential relative to a risk-free benchmark (US Treasury yield), given as a percentage
Yield	Corporate bond yield provided by <i>TRACE</i> , given as a percentage
US Treasury yield	Duration matched yield used as risk-free benchmark, given as a percentage
Dispersion	Price dispersion measure based on Jankowitsch et al. (2011), given as a percentage
Amihud	Amihud measure based on Amihud (2002), given as a price change in percentage terms, based on \$1 million of volume
Roll	Roll measure based on Roll (1984), given as a percentage
Rollover rate	Amount outstanding of maturing bonds / overall bond amount outstanding
Credit risk	Average bond rating (mapped to natural numbers, e.g. $AAA = 1$, $AA+ = 2$, \dots , $D = 21$) of the three major rating agencies (<i>Fitch</i> , <i>Moody's</i> , <i>Standard and Poor's</i>)
Volume	Average daily traded volume per trade day, given in \$1 million
Trades	Average number of trades per trade day
Days	Number of active trading days in a given year
Coupon	Coupon of a bond in percent of face value
Maturity	Maturity of a bond measured in years
Amount outstanding	Amount outstanding of a bond given in \$1 million
Cash	ch / at
Leverage	$(dlc+dltt) / (dlc+dltt + shrout \cdot prc)$
Bond financing	$(\text{overall bond amount outstanding}) / (dlc + dltt)$
Long-term debt 1Y	$dd1 / (dlc + dltt)$
Granularity	Based on measure <i>Gran1</i> in Choi et al. (2013)
Profitability	ni / at
Q	$(dlc+dltt + shrout \cdot prc) / at$
Intangibility	$intan / at$
Investment	$capx / at$
Retained earnings	re / at
β	equity beta
Size	natural logarithm of total assets (at)
Industry	2-digit SIC code

Table 2: Corporate Bond Financing

This table summarizes the information on the scale of corporate bond financing with respect to the individual debt capital structures of the firms in the sample, and on their underlying corporate bonds. For each variable the 25% quantile ($Q_{0.25}$), median, mean, 75% quantile ($Q_{0.75}$) and standard deviation (SD) across various industries are reported. Panel A provides information on the fraction of corporate bond financing to total book debt per firm, Panel B on the number of bonds outstanding per firm in a given year. Panel C gives the statistics on the amount issued of the individual bonds, while Panel D gives the corresponding time to maturities at issuance. Panel E summarizes the coupon levels of the bonds, and Panel F the credit risk measure of the bonds as represented by the average bond rating across the three major rating agencies (*Fitch*, *Moody's*, *Standard and Poor's*). Amount issued is given in \$1 million, maturity is given in years and the coupon in percent of face value. The bond ratings are mapped to natural numbers, e.g. AAA = 1, AA+ = 2, ..., D = 21. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fized Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

Industry	Panel A: Bond Financing				Panel B: Bonds Outstanding				Panel C: Amount Issued					
	$Q_{0.25}$	Median	Mean	SD	$Q_{0.25}$	Median	Mean	SD	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	
Mining	0.64	0.76	0.74	0.91	4	7	8	11	7	250.00	400.00	519.50	650.00	453.12
Construction	0.65	0.75	0.66	0.88	4	7	8	11	7	193.80	250.00	256.80	300.00	118.23
Manufacturing	0.56	0.77	0.71	0.92	2	5	15	11	63	5.31	64.66	325.70	350.00	2063.34
Transportation	0.56	0.68	0.68	0.85	13	23	31	39	28	48.00	200.00	319.70	400.00	410.96
Wholesale Trade	0.51	0.70	0.65	0.90	4	7	8	10	5	129.90	225.00	245.00	350.00	164.77
Retail Trade	0.49	0.65	0.50	0.89	2	5	11	14	13	100.00	300.00	606.20	500.00	2552.59
Services	0.47	0.73	0.68	0.88	1	4	5	7	8	200.00	375.00	497.50	625.00	469.94

Industry	Panel D: Maturity at Issuance				Panel E: Coupon				Panel F: Credit Risk					
	$Q_{0.25}$	Median	Mean	SD	$Q_{0.25}$	Median	Mean	SD	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	
Mining	9.54	10.04	15.20	19.84	13.63	5.11	6.50	6.09	7.38	2.14	7.00	9.00	11.00	2.39
Construction	5.24	9.66	9.77	10.04	10.60	5.25	6.19	6.48	7.78	2.19	10.00	11.00	13.00	2.03
Manufacturing	5.01	8.04	10.98	14.00	10.13	4.20	5.50	5.36	6.66	2.05	5.67	6.75	7.96	3.10
Transportation	9.21	10.33	15.85	21.03	11.66	5.60	6.65	6.57	7.62	1.91	6.15	8.17	9.67	3.91
Wholesale Trade	7.03	10.00	12.09	15.05	11.44	5.53	6.56	6.34	7.50	1.67	8.50	9.14	9.85	2.81
Retail Trade	7.04	10.03	13.95	20.01	10.06	5.38	6.50	6.23	7.38	1.92	6.14	9.33	11.33	3.64
Services	5.06	8.36	11.03	14.06	10.66	3.50	5.75	5.46	7.38	2.73	5.83	8.78	9.51	4.27

Table 3: Summary Statistics of Full Sample

This table provides the summary statistics of the variables (as discussed in Sections 5 and 6.4, as well as defined in Table 1) used in the analysis for the full available sample, hence for each bond/year observation. For each variable the 25% quantile ($Q_{0.25}$), median, mean, 75% quantile ($Q_{0.75}$), standard deviation (SD) and number of observations (N) are reported. Yields, given as a percentage, are the end-of-year estimate (average yields in the month of December) of the underlying bonds, the liquidity measures (dispersion, Amihud, Roll) correspond to the yearly averages of these measures of the individual bonds. Dispersion and Roll are measured as a percentage, the Amihud measure represents a price change in percentage terms, based on \$1 million of volume. Rollover rate is given as a fraction, and credit risk is represented by the average bond rating (mapped to natural numbers, e.g. $AAA = 1$, $AA+ = 2$, ..., $D = 21$) across the three major rating agencies (*Fitch*, *Moody's*, *Standard and Poor's*). Volume is given in \$1 million, trades is the average number of trades per trade day and days is the average number of active trading days in a year. Coupon is given as a percent of face value, maturity in years and amount outstanding in \$1 million. Cash, leverage, bond financing, long-term debt 1Y, profitability, Q, intangibility, investment and retained earnings are given as fractions. Size is the natural logarithm of total assets. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

Variable	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	N
Yield spread	1.26	2.52	3.06	3.96	3.10	40,480
Yield	4.64	5.61	6.06	6.47	3.84	40,480
Treasury yield	1.66	3.90	3.20	4.63	1.71	40,480
Dispersion	0.22	0.39	0.48	0.65	0.38	41,446
Amihud	0.17	0.20	0.24	0.27	0.19	41,056
Roll	0.46	0.50	0.57	0.61	0.30	37,882
Rollover rate	0.04	0.10	0.13	0.19	0.14	93,814
Credit risk	5.75	7.50	7.84	10.00	4.09	92,586
Volume	0.06	0.55	1.50	1.82	3.03	42,345
Trades	2.00	2.56	4.18	3.75	9.81	42,345
Days	14.00	46.00	76.15	123.00	76.39	42,345
Coupon	4.50	5.78	5.70	7.00	2.13	93,758
Maturity	2.67	6.33	9.94	14.10	10.98	46,057
Amount outstanding	80.00	231.10	365.10	400.00	1627.51	59,500
Cash	0.02	0.05	0.06	0.09	0.06	91,267
Leverage	0.19	0.37	0.38	0.58	0.23	93,199
Bond financing	0.62	0.79	0.77	0.94	0.25	92,888
Long-term debt 1Y	0.04	0.10	0.10	0.15	0.08	89,186
Granularity	1.60	2.10	2.47	3.06	1.76	93,814
Profitability	0.02	0.04	0.04	0.06	0.07	93,285
Q	0.24	0.36	0.38	0.54	0.18	86,548
Intangibility	0.04	0.10	0.17	0.25	0.18	90,376
Investment	0.02	0.04	0.05	0.06	0.04	93,094
Retained earnings	0.07	0.16	0.15	0.28	0.60	92,850
β	0.84	1.06	1.10	1.36	0.34	93,814
Size	23.54	24.41	24.54	25.38	1.48	93,285

Table 4: Nearest Neighborhood Matching

This table provides the p -values of the Kolmogorov-Smirnov test, which allows to compare the distributional differences between treatment and non-treatment groups before the nearest neighborhood matching is performed and the distributional differences between the treatment and control groups after matching is performed. The variables used in the matching procedure are given in the table. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period following the *Lehman* bankruptcy to the end of 2008. Three rollover rates, given in Panels A to C ($> 10\%$, $> 15\%$ and $> 20\%$), are considered. For each rollover rate, matching is performed separately for various maturities of the underlying bonds including long-term (more than 15 years), medium-term (between 5 to 15 years) and short-term (between 1 to 5 years maturity). Furthermore, for each of the rollover rates, also a pooled matching is performed by including bonds over the entire term-structure. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*.

	Long-Term		Medium-Term		Short-Term		Pooled	
	Before	After	Before	After	Before	After	Before	After
Panel A: 10% Rollover Rate								
Dispersion	0.11	0.52	0.08	0.71	0.02	0.25	0.01	0.72
Amihud	0.03	0.27	0.16	0.93	0.05	0.94	0.02	0.15
Roll	0.00	0.39	0.00	0.26	0.00	0.31	0.00	0.25
Credit risk	0.50	1.00	0.32	1.00	0.21	1.00	0.01	1.00
Volume	0.00	0.13	0.00	0.56	0.00	0.76	0.00	0.77
Trades	0.03	0.22	0.10	0.78	0.01	0.26	0.00	0.18
Days	0.16	0.15	0.37	0.95	0.41	0.55	0.31	0.29
Coupon	0.17	1.00	0.11	0.73	0.36	1.00	0.05	0.93
Maturity	0.00	0.10	0.01	0.98	0.00	0.81	0.00	0.46
Amount outstanding	0.27	0.63	0.41	0.98	0.56	0.80	0.29	0.97
Cash	0.00	0.25	0.03	0.62	0.02	0.21	0.00	0.40
Leverage	0.45	0.47	0.66	0.69	0.03	0.76	0.00	0.71
Bond financing	0.00	0.17	0.00	0.29	0.01	0.55	0.00	0.19
Long-term debt 1Y	0.09	0.35	0.22	0.11	0.01	0.13	0.00	0.19
Granularity	0.23	0.97	0.94	0.97	0.02	0.95	0.01	0.99
Profitability	0.20	0.92	0.00	0.99	0.77	0.99	0.01	1.00
Q	0.10	0.42	0.04	0.79	0.03	0.73	0.00	0.21
Intangibility	0.24	0.93	0.33	0.92	0.11	0.43	0.01	0.69
Investment	0.33	0.83	0.30	0.66	0.06	0.92	0.01	0.94
Retained earnings	0.15	0.57	0.02	0.16	0.00	0.57	0.00	0.63
β	0.01	0.23	0.00	0.86	0.00	0.18	0.00	0.32
Size	0.92	0.52	0.33	0.20	0.06	0.98	0.12	0.61
Industry	0.41	0.97	0.25	0.97	0.32	0.16	0.05	0.39
Panel B: 15% Rollover Rate								
Dispersion	0.06	0.46	0.08	0.29	0.05	0.21	0.05	0.56
Amihud	0.05	0.68	0.44	0.59	0.05	0.50	0.01	0.89
Roll	0.02	0.55	0.07	0.82	0.81	0.71	0.12	0.59
Credit risk	0.06	0.99	0.02	0.79	0.02	0.99	0.00	1.00
Volume	0.01	0.90	0.01	0.71	0.00	0.21	0.00	0.54
Trades	0.01	0.77	0.00	0.82	0.01	0.46	0.00	0.29
Days	0.01	0.32	0.00	0.17	0.06	0.52	0.00	0.50
Coupon	0.19	0.78	0.11	0.79	0.45	0.78	0.05	0.91
Maturity	0.34	0.34	0.05	0.54	0.46	0.31	0.25	0.27
Amount outstanding	0.00	0.92	0.01	0.67	0.01	0.88	0.00	0.86
Cash	0.00	0.10	0.00	1.00	0.00	0.65	0.00	0.24
Leverage	0.13	0.73	0.03	0.38	0.03	0.82	0.00	0.75
Bond financing	0.00	0.45	0.00	0.93	0.00	0.85	0.00	0.17
Long-term debt 1Y	0.01	0.95	0.01	0.37	0.00	0.72	0.00	0.26
Granularity	0.01	1.00	0.02	0.77	0.00	0.97	0.00	0.62
Profitability	0.02	0.81	0.00	0.98	0.01	0.98	0.00	0.93
Q	0.08	0.52	0.35	0.10	0.01	0.44	0.00	0.32
Intangibility	0.22	0.99	0.05	0.39	0.14	0.44	0.00	0.76
Investment	0.08	0.59	0.20	0.87	0.59	0.29	0.00	0.69
Retained earnings	0.04	0.76	0.01	0.39	0.01	0.50	0.00	0.90
β	0.01	0.28	0.00	0.66	0.00	0.11	0.00	0.36
Size	0.04	0.56	0.02	0.35	0.00	0.30	0.00	0.19
Industry	0.05	1.00	0.02	1.00	0.08	0.99	0.00	1.00
Panel C: 20% Rollover Rate								
Dispersion	0.05	0.14	0.07	0.39	0.06	0.99	0.02	0.90
Amihud	0.74	0.56	0.42	0.88	0.88	0.57	0.57	0.54
Roll	0.04	0.28	0.12	0.91	0.07	0.68	0.03	0.40
Credit risk	0.38	1.00	0.44	1.00	0.78	1.00	0.03	1.00
Volume	0.20	0.88	0.19	0.58	0.05	0.98	0.08	0.47
Trades	0.07	0.62	0.08	0.89	0.00	0.74	0.00	0.70
Days	0.18	0.17	0.20	0.43	0.05	0.51	0.28	0.55
Coupon	0.25	0.55	0.18	0.79	0.36	0.98	0.04	0.91
Maturity	0.02	0.43	0.02	0.87	0.01	0.98	0.00	0.82
Amount outstanding	0.04	0.53	0.22	0.90	0.09	0.79	0.03	0.90
Cash	0.00	0.24	0.00	0.17	0.00	0.12	0.00	0.10
Leverage	0.01	0.34	0.02	0.88	0.00	0.61	0.00	0.63
Bond financing	0.00	0.85	0.00	0.20	0.00	0.52	0.00	0.14
Long-term debt 1Y	0.00	0.45	0.00	0.38	0.00	0.68	0.00	0.22
Granularity	0.00	0.88	0.05	0.81	0.00	0.99	0.00	0.32
Profitability	0.06	0.64	0.19	0.72	0.03	0.90	0.00	0.96
Q	0.66	0.94	0.52	0.72	0.34	0.65	0.07	0.22
Intangibility	0.22	0.94	0.54	0.84	0.06	0.49	0.00	0.28
Investment	0.03	0.63	0.01	0.54	0.01	0.85	0.00	0.77
Retained earnings	0.02	0.64	0.02	0.80	0.00	0.32	0.00	0.65
β	0.01	0.29	0.00	0.89	0.01	0.22	0.00	0.35
Size	0.01	0.34	0.05	0.72	0.00	0.35	0.00	0.14
Industry	0.02	0.76	0.77	0.78	0.92	0.99	0.57	0.69

Table 5: Matched Difference-in-Differences Analysis

This table gives the results of the matched difference-in-differences analysis. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period following the *Lehman* bankruptcy to the end of 2008. The dependent variable is the change in the yield spread over the period from the end of 2007 to the end of 2008 (average yield spread in the month of December). The explanatory variable is a dummy indicating whether treatment occurred or not. Three levels of the rollover rate for the assignment to the treatment group are considered ($> 10\%$, $> 15\%$ and $> 20\%$), with the results of the average treatment effects (ATE) for each of these rollover rates given in rows (a) to (c). In columns (1) to (3), the ATE is given for the underlying bonds exhibiting different maturities including long-term (more than 15 years), medium-term (between 5 to 15 years) and short-term (between 1 to 5 years maturity), of the treatment group relative to the control group. Moreover, column (4) gives the pooled ATE, hence across the entire term-structure of yield spreads. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Homoscedastic standard errors (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01 , ** < 0.05 , * < 0.1 .

		Average Treatment Effect (ATE)			
		(1)	(2)	(3)	(4)
	Firms Treated	Δ Yield Spread Long-Term	Δ Yield Spread Medium-Term	Δ Yield Spread Short-Term	Pooled
(a)	Rollover Rate 10%	1.9122* (1.0432)	1.0663** (0.5589)	1.1878** (0.5192)	1.0180** (0.5018)
(b)	Rollover Rate 15%	2.7582* (1.5158)	2.1651** (1.1122)	1.9133** (0.7969)	1.8493*** (0.8153)
(c)	Rollover Rate 20%	4.7416* (2.5398)	3.1759* (1.6859)	2.4468** (1.1459)	2.7785** (1.3346)

Table 6: Price Dispersion Measure

This table reports the results for the price dispersion measure. The dependent variables are the yield spreads of the individual bonds. The explanatory variables are given by the price dispersion measure of the underlying bonds, the rollover rate and the credit risk measure (as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1). Model 1 only controls for the price dispersion measure and credit risk. Model 2 includes the interaction term of the price dispersion measure with the rollover rate, and the rollover rate itself. Model 3 includes industry and year fixed effects, while Model 4 includes firm and year fixed effects. Model 5 includes the complete set of control variables as well as firm and year fixed effects. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model				
	(1)	(2)	(3)	(4)	(5)
Intercept	1.9395*** (0.0536)	1.7329*** (0.1127)	0.6411*** (0.1884)	1.2054 (0.7559)	1.4936 (0.8588)
Dispersion _{LIQ}	3.5063*** (0.0771)	2.4737*** (0.1753)	1.7124*** (0.1744)	1.6267*** (0.1388)	0.8886*** (0.1547)
Dispersion _{LIQ} * Rollover Rate		0.0741*** (0.0143)	0.0707*** (0.0141)	0.0582*** (0.0108)	0.0624*** (0.0117)
Rollover Rate		0.0227*** (0.0082)	0.0133* (0.0079)	0.0010 (0.0060)	0.0079 (0.0063)
Credit Risk	0.4224*** (0.0065)	0.4176*** (0.0064)	0.5246*** (0.0088)	0.6640*** (0.0192)	0.5292*** (0.0178)
Adjusted R^2	0.33	0.37	0.43	0.49	0.61
Observations	39,557	39,557	39,557	39,557	39,557
Industry FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Other Controls	No	No	No	No	Yes

Table 7: Amihud Measure

This table reports the results for the Amihud measure. The dependent variables are the yield spreads of the individual bonds. The explanatory variables are given by the Amihud measure of the underlying bonds, the rollover rate and the credit risk measure (as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1). Model 1 only controls for the Amihud measure and credit risk. Model 2 includes the interaction term of the Amihud measure with the rollover rate, and the rollover rate itself. Model 3 includes industry and year fixed effects, while Model 4 includes firm and year fixed effects. Model 5 includes the complete set of control variables as well as firm and year fixed effects. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model				
	(1)	(2)	(3)	(4)	(5)
Intercept	1.9240*** (0.0581)	2.0115*** (0.0910)	0.8439*** (0.1621)	0.8959 (0.6476)	1.6300 (0.9895)
Amihud _{LIQ}	0.7005*** (0.0201)	0.2596*** (0.0569)	0.1673*** (0.0524)	0.1635*** (0.0532)	0.1309*** (0.0571)
Amihud _{LIQ} * Rollover Rate		0.0302*** (0.0041)	0.0286*** (0.1621)	0.0251*** (0.0039)	0.0261*** (0.0043)
Rollover Rate		0.0093* (0.0052)	0.0013 (0.0049)	-0.0081 (0.0053)	0.0012 (0.0061)
Credit Risk	0.4251*** (0.0060)	0.4098*** (0.0058)	0.5185*** (0.0038)	0.6147*** (0.0189)	0.4783*** (0.0178)
Adjusted R^2	0.34	0.37	0.47	0.52	0.64
Observations	39,232	39,232	39,232	39,232	39,232
Industry FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Other Controls	No	No	No	No	Yes

Table 8: Roll Measure

This table reports the results for the Roll measure. The dependent variables are the yield spreads of the individual bonds. The explanatory variables are given by the Roll measure of the underlying bonds, the rollover rate and the credit risk measure (as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1). Model 1 only controls for the Roll measure and credit risk. Model 2 includes the interaction term of the Roll measure with the rollover rate, and the rollover rate itself. Model 3 includes industry and year fixed effects, while Model 4 includes firm and year fixed effects. Model 5 includes the complete set of control variables as well as firm and year fixed effects. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model				
	(1)	(2)	(3)	(4)	(5)
Intercept	1.8660*** (0.0667)	1.5301*** (0.0942)	0.0691 (0.1697)	0.1517 (0.7380)	0.9770 (0.6525)
Roll _{LIQ}	1.0130*** (0.0341)	0.6531*** (0.0611)	0.4644*** (0.0612)	0.4231*** (0.0723)	0.4065*** (0.0776)
Roll _{LIQ} * Rollover Rate		0.0270*** (0.0045)	0.0255*** (0.0044)	0.0207*** (0.0058)	0.0257*** (0.0043)
Rollover Rate		0.0348*** (0.0055)	0.0200*** (0.0054)	0.0039 (0.0070)	0.0011 (0.0055)
Credit Risk	0.4306*** (0.0069)	0.4244*** (0.0066)	0.5527*** (0.0087)	0.6915*** (0.0190)	0.5584*** (0.0184)
Adjusted R^2	0.28	0.31	0.43	0.49	0.61
Observations	36,357	36,357	36,357	36,357	36,357
Industry FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Other Controls	No	No	No	No	Yes

Table 9: Cross-Section of Corporate Bond Yield Spreads

This table reports the results for the complete regression specification. The dependent variables are the yield spreads of the individual bonds. The explanatory variables are given by the various liquidity measures (price dispersion, Amihud, Roll) of the underlying bonds, the rollover rate and the credit risk measure, as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1. All models contain firm and year fixed effects. Model 1 contains as liquidity measure only the price dispersion measure and its interaction term with the rollover rate, Model 2 the Amihud measure and Model 3 the Roll measure. Model 4 includes the complete set of liquidity measures and their interaction terms with the rollover rate. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Merger Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model			
	(1)	(2)	(3)	(4)
Intercept	1.4936 (0.8588)	1.6300 (0.9895)	0.9770 (0.6525)	0.8068 (0.5470)
Dispersion _{LIQ}	0.8886*** (0.1547)			1.3331*** (0.1722)
Amihud _{LIQ}		0.1309*** (0.0571)		0.1090** (0.0501)
Roll _{LIQ}			0.4065*** (0.0776)	0.0820 (0.0994)
Dispersion _{LIQ} * Rollover Rate	0.0624*** (0.0117)			0.0774*** (0.0127)
Amihud _{LIQ} * Rollover Rate		0.0261*** (0.0043)		0.0319*** (0.0033)
Roll _{LIQ} * Rollover Rate			0.0257*** (0.0043)	0.0013 (0.0077)
Rollover Rate	0.0079 (0.0063)	0.0012 (0.0061)	0.0011 (0.0055)	-0.0067 (0.0054)
Credit Risk	0.5292*** (0.0178)	0.4783*** (0.0178)	0.5584*** (0.0184)	0.3850*** (0.0153)
Volume	0.0007 (0.0088)	-0.0040 (0.0090)	-0.0122 (0.0100)	0.0125 (0.0098)
Trades	-0.0130*** (0.0030)	-0.0004 (0.0028)	-0.0026 (0.0029)	-0.0064** (0.0029)
Days	-0.0030*** (0.0003)	-0.0007** (0.0004)	0.0001 (0.0003)	-0.0013*** (0.0003)
Coupon	0.1674*** (0.0134)	0.1591*** (0.0133)	0.1571*** (0.0142)	0.1060*** (0.0144)
Maturity	0.0232*** (0.0017)	0.0369*** (0.0016)	0.0410*** (0.0018)	0.0212*** (0.0018)
Amount outstanding	-0.0003** (0.0002)	-0.0004** (0.0002)	-0.0003** (0.0002)	-0.0003* (0.0002)
Cash	-0.0768*** (0.0065)	-0.0659*** (0.0064)	-0.0764*** (0.0064)	-0.0577*** (0.0062)
Leverage	0.1263 (0.1052)	0.0200 (0.1065)	0.0124 (0.1286)	0.0499 (0.1149)
Bond financing	-0.0003 (0.0002)	-0.0002 (0.0002)	-0.0002 (0.0002)	-0.0002 (0.0002)
Long-term debt 1Y	0.3565 (0.3027)	0.3929 (0.2976)	0.2819 (0.3057)	0.2656 (0.3019)
Granularity	-0.3240*** (0.0301)	-0.2408*** (0.0292)	-0.3504*** (0.0252)	-0.2320*** (0.0221)
Profitability	-0.0094** (0.0044)	-0.0129*** (0.0044)	-0.0124*** (0.0044)	-0.0094** (0.0043)
Q	0.0207*** (0.0043)	0.0183*** (0.0041)	0.0263*** (0.0042)	0.0138*** (0.0041)
Intangibility	-0.0062 (0.0038)	-0.0059 (0.0040)	-0.0035 (0.0038)	-0.0025 (0.0037)
Investment	0.0015 (0.0121)	0.0050 (0.0118)	-0.0008 (0.0122)	-0.0053 (0.0119)
Retained earnings	0.0027 (0.1134)	0.0026 (0.1090)	0.0023 (0.0022)	0.0002 (0.0025)
β	2.7184*** (0.3969)	2.3769*** (0.3876)	2.9820*** (0.1134)	2.2339*** (0.0947)
Size	-0.8387*** (0.1020)	-0.8071*** (0.0997)	-0.8390*** (0.1059)	-0.7163*** (0.0983)
Adjusted R^2	0.61	0.64	0.61	0.65
Observations	39,557	39,232	36,357	35,525
Firm and Year FE	Yes	Yes	Yes	Yes

B Internet Appendix

Table 10: Changes in the Price Dispersion Measure

This table reports the results for a specification in changes (first difference) of the variables. The table analyzes changes in the price dispersion measure. The dependent variables are the changes in yield spreads of the individual bonds. The explanatory variables are given by the changes in the price dispersion measure of the underlying bonds, the rollover rate and the credit risk measure (as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1). Model 1 only controls for the changes in the price dispersion measure and credit risk. Model 2 includes the changes in the interaction term of the price dispersion measure with the rollover rate, and the changes in the rollover rate itself. Model 3 includes industry fixed effects, while Model 4 includes firm fixed effects. Model 5 includes the complete set of control variables as well as firm fixed effects. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model				
	(1)	(2)	(3)	(4)	(5)
Intercept	-0.0548*** (0.0187)	-0.0640*** (0.0182)	0.3511** (0.1446)	0.8301 (0.8857)	0.4514 (0.8939)
Δ Dispersion _{LIQ}	2.6468*** (0.0994)	1.6102*** (0.1471)	1.6035*** (0.1465)	1.4859*** (0.1341)	1.3202*** (0.1480)
Δ (Dispersion _{LIQ} * Rollover Rate)		0.0783*** (0.0113)	0.0782*** (0.0112)	0.0852*** (0.0107)	0.0901*** (0.0116)
Δ Rollover Rate		-0.0201 (0.0530)	-0.0194 (0.0530)	-0.0249 (0.0500)	-0.0255 (0.0550)
Δ Credit Risk	0.9020*** (0.0324)	0.8931*** (0.0317)	0.9012*** (0.0318)	0.9602*** (0.0332)	0.9600*** (0.0370)
Adjusted R^2	0.17	0.18	0.19	0.21	0.23
Observations	28,693	28,693	28,693	28,693	28,693
Industry FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Other Controls	No	No	No	No	Yes

Table 11: Changes in the Amihud Measure

This table reports the results for a specification in changes (first difference) of the variables. The table analyzes changes in the Amihud measure. The dependent variables are the changes in yield spreads of the individual bonds. The explanatory variables are given by the changes in the Amihud measure of the underlying bonds, the rollover rate and the credit risk measure (as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1). Model 1 only controls for the changes in the Amihud measure and credit risk. Model 2 includes the changes in the interaction term of the Amihud measure with the rollover rate, and the changes in the rollover rate itself. Model 3 includes industry fixed effects, while Model 4 includes firm fixed effects. Model 5 includes the complete set of control variables as well as firm fixed effects. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model				
	(1)	(2)	(3)	(4)	(5)
Intercept	-0.1445*** (0.0175)	-0.1460*** (0.0172)	0.2496* (0.1433)	0.5585 (0.9158)	0.2411 (0.9351)
Δ Amihud _{LIQ}	0.5016*** (0.0184)	0.3620*** (0.0571)	0.3460*** (0.0574)	0.3310*** (0.0585)	0.3710*** (0.0658)
Δ (Amihud _{LIQ} * Rollover Rate)		0.0311*** (0.0041)	0.0311*** (0.0041)	0.0307*** (0.0042)	0.0313*** (0.0045)
Δ Rollover Rate		-0.0244 (0.0570)	-0.0237 (0.0570)	-0.0252 (0.0610)	-0.0268 (0.0710)
Δ Credit Risk	0.9050*** (0.0308)	0.8560*** (0.0300)	0.8624*** (0.0301)	0.9288*** (0.0326)	0.9163*** (0.0359)
Adjusted R^2	0.21	0.26	0.26	0.29	0.31
Observations	28,454	28,454	28,454	28,454	28,454
Industry FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Other Controls	No	No	No	No	Yes

Table 12: Changes in the Roll Measure

This table reports the results for a specification in changes (first difference) of the variables. The table analyzes changes in the Roll measure. The dependent variables are the changes in yield spreads of the individual bonds. The explanatory variables are given by the changes in the Roll measure of the underlying bonds, the rollover rate and the credit risk measure (as well as other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1). Model 1 only controls for the changes in the Roll measure and credit risk. Model 2 includes the changes in the interaction term of the Roll measure with the rollover rate, and the changes in the rollover rate itself. Model 3 includes industry fixed effects, while Model 4 includes firm fixed effects. Model 5 includes the complete set of control variables as well as firm fixed effects. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model				
	(1)	(2)	(3)	(4)	(5)
Intercept	-0.1800*** (0.0192)	-0.1931*** (0.0189)	0.2193 (0.1504)	0.1892 (0.9959)	-0.2225 (1.0030)
ΔRoll_{LIQ}	0.4460*** (0.0305)	0.2268*** (0.0604)	0.2245*** (0.0600)	0.2293*** (0.0632)	0.1721** (0.0710)
$\Delta(\text{Roll}_{LIQ} * \text{Rollover Rate})$		0.0175*** (0.0051)	0.0174*** (0.005)	0.0158*** (0.0055)	0.0186*** (0.0061)
$\Delta\text{Rollover Rate}$		-0.0001 (0.0053)	0.0006 (0.0053)	0.0024 (0.0057)	0.0013 (0.0065)
$\Delta\text{Credit Risk}$	1.0051*** (0.0365)	1.0071*** (0.0361)	1.0158*** (0.0361)	1.1157*** (0.0365)	1.0994*** (0.0408)
Adjusted R^2	0.13	0.14	0.14	0.16	0.19
Observations	26,294	26,294	26,294	26,294	26,294
Industry FE	No	No	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Other Controls	No	No	No	No	Yes

Table 13: Changes in the Cross-Section of Corporate Bond Yield Spreads

This table reports the results for the changes (first difference) in the complete regression specification. The dependent variables are the changes in yield spreads of the individual bonds. The explanatory variables are given by the changes of the various liquidity measures (price dispersion, Amihud, Roll) of the underlying bonds, the rollover rate and the credit risk measure, as well as changes of other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table 1. All models contain firm fixed effects. Model 1 contains as liquidity measure only the price dispersion measure and the interaction term with the rollover rate, Model 2 the Amihud measure and Model 3 the Roll measure. Model 4 includes the complete set of liquidity measures and their interaction terms with the rollover rate. The overall available data set consists of all S&P 500 constituents (excluding financials and utilities) as of the beginning of 2005, and amounts to 429 firms accounting for 13,402 corporate bonds. The data set contains transaction data reported by *TRACE* for the period from January 2005 to December 2011, amounting to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US Treasury data were obtained from *Bloomberg*, and the corporate bond data were obtained from the *Mergent Fixed Income Securities Database*. The firm data were retrieved from *COMPUSTAT*. Clustered standard errors at the firm level (see, e.g., Petersen (2009)) are given in parentheses. Significance is indicated by: *** < 0.01, ** < 0.05, * < 0.1.

	Model			
	(1)	(2)	(3)	(4)
Intercept	0.4514 (0.8939)	0.2411 (0.9351)	-0.2225 (1.0030)	0.0746 (0.9803)
Δ Dispersion _{LIQ}	1.3202*** (0.1480)			0.9813*** (0.1674)
Δ Amihud _{LIQ}		0.3710*** (0.0658)		0.1339*** (0.0493)
Δ Roll _{LIQ}			0.1721** (0.0710)	0.2202** (0.0873)
Δ (Dispersion _{LIQ} * Rollover Rate)	0.0901*** (0.0116)			0.0920*** (0.0122)
Δ (Amihud _{LIQ} * Rollover Rate)		0.0313*** (0.0045)		0.0370*** (0.0029)
Δ (Roll _{LIQ} * Rollover Rate)			0.0186*** (0.0061)	-0.0102 (0.0069)
Δ Rollover Rate	-0.0255 (0.0550)	-0.0268 (0.0710)	0.0013 (0.0065)	-0.0221 (0.0630)
Δ Credit Risk	0.9600*** (0.0370)	0.9163*** (0.0359)	1.0994*** (0.0408)	0.6012*** (0.0320)
Δ Volume	-0.0416** (0.0192)	-0.0562*** (0.0205)	-0.0717*** (0.0227)	-0.0262 (0.0218)
Δ Trades	-0.0065 (0.0043)	0.0136*** (0.0046)	0.0154*** (0.0044)	-0.0027 (0.0042)
Δ Days	-0.0124*** (0.0008)	-0.0093*** (0.0007)	-0.0106*** (0.0008)	-0.0097*** (0.0007)
Δ Amount outstanding	-0.0002 (0.0004)	-0.0001 (0.0004)	-0.0001 (0.0004)	-0.0001 (0.0004)
Δ Cash	-0.0393*** (0.0073)	-0.0257*** (0.0073)	-0.0377*** (0.0077)	-0.0402*** (0.0072)
Δ Leverage	0.0095*** (0.0032)	0.0086*** (0.0033)	0.0123*** (0.0040)	0.0083** (0.0033)
Δ Bond financing	0.0003 (0.0003)	0.0004 (0.0004)	0.0005 (0.0004)	0.0004 (0.0003)
Δ Long-term debt 1Y	-0.0089 (0.0300)	-0.0094 (0.0300)	-0.0150 (0.0300)	-0.0075 (0.0290)
Δ Granularity	-0.2921*** (0.0223)	-0.2835*** (0.0212)	-0.3355*** (0.0254)	-0.2154*** (0.0245)
Δ Profitability	-0.0197*** (0.0051)	-0.0149*** (0.0049)	-0.0251*** (0.0052)	-0.0069 (0.0046)
Δ Q	0.0181*** (0.0060)	0.0262*** (0.0061)	0.0212*** (0.0060)	0.0181*** (0.0062)
Δ Intangibility	0.0155** (0.0070)	0.0216*** (0.0073)	0.0335*** (0.0071)	0.0134** (0.0066)
Δ Investment	0.0087 (0.0148)	0.0059 (0.0150)	0.0091 (0.0156)	0.0058 (0.0151)
Δ Retained earnings	-0.0021 (0.0039)	-0.0015 (0.0038)	-0.0014 (0.0041)	-0.0008 (0.0037)
Δ Beta	3.4037*** (0.1701)	2.8990*** (0.1570)	4.0856*** (0.1833)	2.5564*** (0.1369)
Δ Size	-0.4666** (0.1982)	-0.6897*** (0.1989)	-0.8311*** (0.1969)	-0.4472** (0.1767)
Adjusted R^2	0.23	0.31	0.19	0.23
Observations	28,693	28,454	26,294	28,693
Firm FE	Yes	Yes	Yes	Yes

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