Rolling over Corporate Bonds: How Market Liquidity affects Credit Risk

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Abstract

Does bond liquidity affect credit risk via the corporate bond rollover channel? This paper explores this relation in the US corporate bond market, based on a complete set of transactions data, for firms with large exposures to the bond market. I provide a detailed analysis of debt capital structures and corporate bond rollover policies. A quasi-natural experiment based on the Lehman bankruptcy allows to examine the asset pricing implications associated with the rollover channel. The findings demonstrate that (i) bond liquidity impacts yield spreads via exposure to bond rollover and reveal economically sizeable average treatment effects. Furthermore, the impact (ii) is increasing in the size of the rollover exposure, (iii) is observable across the entire term-structure of yield spreads and (iv) is more pronounced for credit risky firms.

JEL-Classification: G12, G32
Keywords: corporate bond liquidity, credit risk, corporate bond rollover

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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 market 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 prevailing bond 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. Therefore, 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 funding costs via exposure to bond rollover.

Traditional structural credit risk models (e.g., Fischer, Heinkel, and Zechner, 1989; Leland, 1994b; Leland and Toft, 1996) assume that credit markets are perfectly liquid. Hence, in these models market liquidity does not influence credit risk. As a result, in the empirical literature credit risk and liquidity are typically analyzed separately, i.e., treated independently of each other. However, apparently, when market liquidity deteriorates and imposes a wedge between fundamental and market values then firms are exposed to potential losses arising from rolling over bonds at reduced prices. This leads to a direct increase in debt funding costs. As a consequence, structural credit risk models following He and Xiong (2012) argue that market liquidity affects credit risk via the rollover channel. This paper comprehensively explores this relation, over the period from 2005 to 2011 in the US corporate bond market, by providing detailed empirical evidence on, and by quantifying, the asset pricing implications associated with exposure to corporate bond rollover. Specifically, for the first time, this study examines corporate bond rollover policies for a representative sample of firms consisting of S&P 500 constituents, which exhibit large exposures to the bond market. This analysis of rollover policies and the availability of a complete set of transactions data of the underlying bonds allows to precisely elaborate on the asset pricing implications related to the rollover channel.

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 link firms' bond financing policies to bond liquidity and, therefore, permits to examine in detail the asset pricing implications of liquidity associated with exposure to corporate bond rollover.

I make three contributions in this paper relative to the existing literature. First, I provide a detailed analysis of the debt capital structures and corporate bond rollover policies of S&P 500 constituents, excluding financials and utilities. Although it is a common belief as well as a standard assumption in credit risk models (e.g., He and Xiong, 2012; He and Milbradt, 2014) that firms roll over their outstanding bonds, there is no empirical evidence that systematically examines this paradigm. Therefore, such an investigation is important in the first place as it allows to understand the underlying corporate bond financing decisions from which particular exposures to bond liquidity arising from rollover emerge. In turn, this allows to examine the asset pricing interaction of bond liquidity, exposure to rollover and credit risk.

Second, in a quasi-natural experiment I provide causal evidence as well as a quantification of the pricing implications associated with the rollover channel. In particular, I exploit the exogenous variation in bond liquidity arising from the *Lehman* bankruptcy combined with ex-ante heterogeneity in bond maturity dates, hence, firms potential rollover exposures. In this respect, exposure to bond financing is particularly well suited as an identification device due to the long-term financing nature of these instruments, hence, close to bond maturity the underlying issuance decisions are results of the distant past. Thus, in the difference-in-differences analysis I identify firms which potentially need to roll over a large fraction of their bonds following the bankruptcy filing. The preceding empirical analysis of bond liquidity suggests that the *Lehman* bankruptcy constitutes an ideal exogenous shock for such an experiment. *Lehman* represented one of the largest dealers in the US corporate bond market with the filing for protection under Chapter 11, on September 15 in 2008, and the subsequent cease of operations inducing a sharp shock to corporate bond liquidity: Overall transaction costs roughly trippeled shortly following the bankruptcy filing.

Third, given the availability of transactions data, I provide a study of the *joint* cross-section of corporate bond yield spreads, various commonly employed measures of bond liquidity and rollover rates to disentangle the direct and indirect contribution of bond liquidity, via exposure to bond rollover, on yield spread changes. In this respect, the paper contributes to the understanding of the role of liquidity as a price factor in the bond market by explicitly elaborating on the interaction of liquidity effects and the underlying financial structures of issuers. 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 impact of liquidity in a thorough manner, i.e. for a complete sample of bonds and, thus, provides the opportunity to comprehensively test the economic mechanisms 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 that bonds are the major source of external debt financing with roughly 70% of the debt capital structures of these firms being represented by bonds. This clearly highlights the importance of corporate bond liquidity for firms' overall 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 rather 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 bond amount outstanding of a given firm is subject to rollover which suggests that firms spread out their rollover exposures 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 liquidity. Specifically, average transaction costs increased by a factor of three from 50 bp up to 150 bp with average price impacts based on trading $1 million also increasing from 30 bp up to 60 bp within a few days following the bankruptcy filing. Bond liquidity recovered in 2009, however, the level remained lower compared to the period before the *Lehman* bankruptcy.

Third, when performing the difference-in-differences analysis by exploiting the bankruptcy as a quasi-natural experiment the results provide strong evidence for the pricing implications associated with the bond rollover channel. In particular, the findings clearly demonstrate that by comparing yield spreads of firms which are exposed to rolling over a large fraction of their bonds to firms which are not exposed to rolling 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 195 bp and is increasing in the fraction of bond financing that needs to be rolled over. Moreover, the ATE is increasing in the ex-ante credit risk of the underlying firms. Additionally, by studying the term-structure of corporate bond yield spreads the findings remain 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) bonds. Interestingly, the ATE in the case of long-term bonds is larger compared to the ATE of short-term bonds, strengthening the notion of increased default risk.

Fourth, in the cross-sectional study the results obtained in the difference-in-differences analysis are confirmed. In particular, when studying the direct and indirect relation, via the bond rollover channel, of changes in various commonly employed liquidity measures (price dispersion, Amihud and Roll measures) to the cross-section of yield spread changes the findings provide interesting insights: The direct (purely liquidity driven) contribution of these measures confirms the overall presence of liquidity effects in the bond market. However, an economically non-negligible part of the cross-sectional variation in yield spread changes is explained by the indirect impact of bond liquidity via the corporate bond rollover channel, which is measured via interaction terms. In turn, from an economic perspective, this suggests that these commonly employed bond liquidity measures might absorb some cross-sectional variation in changes in credit risk, i.e., particularly the part which is attributable to exposure to bond rollover. Moreover, the cross-sectional study confirms the nature and quantitative magnitude of the findings obtained in the difference-in-differences analysis.

In summary, I provide a detailed analysis going beyond the results that have been presented in the prior literature by explicitly elaborating on the rollover channel associated with corporate bond financing. Specifically, I provide an in-depth study of the corporate bond financing policies of S&P 500 constituents. Morover, I construct empirical tests and setups which closely mimic the theoretical mechanism of the rollover risk paradigm. This allows to comprehensively examine the asset pricing implications related to the bond rollover channel.

2 Literature review

This paper contributes to the literature on understanding the determinants and components of corporate bond yield spreads. Traditionally, this literature can be divided into theoretical models such as structural credit risk models as well as into empirical studies, which either directly calibrate existing theoretical models to moments obtained from empirical studies, or provide cross-sectional analyses by relating credit and liquidity factors to the underlying 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 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 the assets. These traditional structural credit risk models are extended by Black and Cox (1976), Fischer, Heinkel, and Zechner (1989) or Leland (1994b) who establish the endogenous default notion.[1] In these models, the asset value at which default is triggered is an endogenous choice variable of equityholders. Interestingly, these models have in common that they disregard the potential interplay between market liquidity and credit risk, which is mainly dictated by the assumption of perfectly liquid credit markets. However, recent theoretical contributions explicitly address this link. Specifically, He and Xiong (2012) model credit spreads of finite maturity debt and conclude that market liquidity conditions enter equityholders default decision. This implication arises as deterioration in market liquidity increases rollover losses and, thus, destroys equityholders incentive to keep the firm alive. Furthermore, He and Milbradt (2014) model the implications of an illiquid market of defaulted bonds and provide an endogenous explanation for market liquidity. Moreover, Chen, Cui, He, and Milbradt (2014) propose a structural decomposition scheme to disentangle credit spreads into liquidity and default premium. They calibrate in sample historical moments of default probabilities and estimates of bond liquidity obtained from the prior literature.

Several empirical studies examine illiquidity effects in the corporate bond market. Generally, they find that liquidity is an important factor determining yield spreads. Important contributions in this field include, e.g., Schultz (2001), Chen, Lesmond, and Wei (2007), Edwards, Harris, and Piwowar (2007), Goldstein, Hotchkiss, and Sirri (2007), Bao, Pan, and

[1] Further contributions which adopt the endogenous default notion include, e.g., Longstaff and Schwartz (1995), Leland and Toft (1996), Anderson and Sundaresan (1996), Mella-Barral and Perraudin (1997), Collin-Dufresne, Goldstein, and Martin (2001), Goldstein, Ju, and Leland (2001), Ericsson and Renault (2006) or Acharya, Huang, Subrahmanyam, and Sundaram (2006).

Wang (2011), Lin, Wang, and Wu (2011), Feldhütter (2012), Friewald, Jankowitsch, and Subrahmanyam (2012), Dick-Nielsen, Feldhütter, and Lando (2012) or Acharya, Amihud, and Bharath (2013). All these studies explore the cross-sectional properties of liquidity or liquidity risk and its relation to corporate bond pricing.

Other papers examine the implications and management of corporate debt maturity. Almeida, Campello, Laranjeira, and Weisbenner (2012) show that firms which had a large fraction of long-term debt maturing during the crisis had higher investment declines. Chen, Xu, and Yang (2013) study the effect of systematic risk on debt maturity and find that firms with higher systematic risk will choose longer debt maturity profiles. Furthermore, Choi, Hackbarth, and Zechner (2015) study how firms spread out their debt maturities across time, which they refer to as granularity of corporate debt. They establish that the dispersion of debt maturities moves over time towards target levels. Gopalan, Song, and Yerramilli (2014) examine whether a firm's debt maturity structure affects its credit quality as measured by credit ratings. They show that firms with shorter debt maturities have lower credit quality.

A few empirical studies provide evidence related to rollover risk. Hu (2010) studies firms' overall debt rollover risk during the recent crisis in the CDS market and shows that firms with shorter debt maturities experienced higher CDS spreads. Since the entire analysis is based on quoted spreads rather than actual transaction data she cannot compute a comprehensive set of liquidity metrics of the underlying instruments, which ultimately disables any statements about the pricing implications of direct and indirect liquidity effects. Moreover, the analysis does not disentangle specific sources of the rollover exposure (e.g. bonds or loans) of the individual underlying instruments but rather considers a firms' overall debt structure. Valenzuela (2015) studies rollover risk in international bond markets where, again, the analysis is based on quoted spreads and market-wide liquidity indicators. Therefore, similarly as above, this analysis has the shortcoming that it lacks a clear measurement of liquidity effects on the bond level, thereby, it suffers somewhat from similar limitations regarding the identification and quantification of the pricing implications of rollover risk on the bond level. Moreover, the analysis is aggregated with respect to the debt structure composition as well, and does not consider sources of the rollover exposure. Furthermore, the analysis is mainly focused on the short-term debt channel which has the disadvantage of being an endogenous measure.

This study extends the existing literature in new and important directions by explicitly elaborating on the asset pricing implications of the rollover risk channel arising from exposure to corporate bond financing. Firms bond rollover policies are linked to individual bond liquidity, thereby, this paper voids a gap in the literature by providing a comprehensive study, based on transactions data, on the direct and indirect pricing impacts of liquidity.

3 Research questions and hypotheses

In this section, I discuss a stylized version of the model introduced by He and Xiong (2012) which allows to intuitively capture the underlying economic mechanism namely that liquidity affects credit risk via the rollover channel. Specifically, the model provides intuition and guidance for the subsequent empirical study (see Section 6) as well as for the interpretation of the results by discussing how changes in liquidity might be related to changes in yield spreads. Moreover, the framework allows to derive the hypotheses being tested and to construct empirical tests which closely mimic the theoretical pricing mechanism of the rollover risk paradigm, thereby, it alleviates potential endogeneity concerns.

3.1 Stylized model endogenizing rollover losses

Following Leland and Toft (1996) I consider a firm that commits to a stationary debt structure with aggregate coupon C and aggregate principal P. In any instant of time a fraction ϕ of the aggregate principal P matures and needs to be rolled over. Hence, in this framework, ϕ has the interpretation of a rollover rate which is modeled as the intensity of a Poisson occurence. Thus, in expectation, in any instant of time a total amount of ϕP 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, default induces costs of α and there are fractional debt issuance costs of h. Agents are risk-neutral and the value of the firm's assets follows a Geometric Brownian Motion (GBM) with drift $(r-\delta)$ and volatility σ, where r is the instantaneous riskless interest rate and δ is the instantaneous earnings yield on assets.

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 with 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 ODE augmented by loss of market value due to illiquidity given by ξk, hence,

$$rD = (r-\delta)XD_X + \frac{1}{2}\sigma^2 X^2 D_{XX} + C + \phi(P-D) - \xi k D. \tag{1}$$

Two standard boundary conditions (e.g., Leland and Toft, 1996) are imposed to solve the equation (see Appendix A for detailed derivation). First, firms with extremely profitable assets, i.e. $X=\infty$, never default which gives the default-free bond value by $p=\frac{C+\phi P}{r+\phi+\xi k}$. Hence, illiquidity ξk enters the overall discount rate $(r+\phi+\xi k)$ of the bond's cash flows. Moreover, default occurs when $X_t = X_B$ and debtholders take over the remaining assets with a value of $D(X_B)=(1-\alpha)X_B$. Under these conditions the bond value is given by

$$D(X_t) = p + \left[(1-\alpha)X_B - p\right]\pi(X_t). \tag{2}$$

The first term in this equation represents the price of the bond in the absence of default risk, while the second part is the default premium with $\pi(X_t)=\left(\frac{X_t}{X_B}\right)^{\beta_2}$ representing the default probability where $\beta_2<0$ (see Appendix A for technical details). For a given value of assets X_t an increasing default boundary X_B results in an increased probability of default. In order to link liquidity to credit risk the endogenous default boundary of equityholders needs to be positively related to the liquidity cost ξk. Indeed, this will be the case as deteriorating bond liquidity makes it increasingly costly for equityholders to roll over maturing bonds.

The yield y_t of the bond is the average expected rate of return represented by

$$y_t D(X_t) = C + \phi \left[P - D(X_t)\right] \tag{3}$$

where the yield spread Y_t is given by the differential of the yield relative to the risk-free rate, thus, $Y_t = y_t - r$. Illiquidity influences the yield spread of the bond, with the general property that an increase in illiquidity leads to an increase in the yield spread.

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

$$rE = (r - \delta)XE_X + \frac{1}{2}\sigma^2 X^2 E_{XX} + \delta X - (1 - \tau)C - h\phi P + \phi(D - P) \tag{4}$$

where $h\phi P$ are the fixed issuance costs of debt and $\phi(D - P)$ is the net gain/loss occuring from rolling over the bonds at current market prices, evident for any non-zero rollover rate ϕ. As a consequence, if bond market liquidity deteriorates as represented by an increase in ξk and suppresses the market value D of the underlying bond below the principal P, rolling over becomes increasingly costly for 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 value of the underlying assets default is triggered and, hence, the credit risk and therefore the firms' yield spread. In particular, equityholders endogenously default with the optimal default boundary X_B given by the standard smooth pasting condition (see Equation (32) in Appendix A).

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 cash flows, but also the probability of default and, hence, credit risk. 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 standard parameters used in the literature, see e.g. Leland and Toft (1996), Chen (2010), He and Xiong (2012) or Chen, Xu, and Yang (2013).[2] 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 $\phi = 0$, $\phi = 10\%$ and $\phi = 20\%$, respectively. In the case when no rollover takes place, i.e. $\phi = 0$, 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: *Corporate bond liquidity affects yield spreads via exposure to bond rollover.*

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: 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: *The impact of corporate bond liquidity on yield spreads via exposure to bond rollover is increasing in the size of the exposure.*

[2] These parameters are: $r = 5\%$, $\tau = 27\%$, $\sigma = 23\%$, $\alpha = 40\%$, $\delta = 2\%$, $k = 0.5\%$, $\xi = 1$, $h = 0.5\%$ and $X_t = 100$. Note that, in this paper the term ξk has the interpretation of transaction costs, i.e., the initial transaction costs are 50 bp. Following the common literature, 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 300 bp or 500 bp, respectively.

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 20% 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 of the bond's cash flows 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 default premium and liquidity premium. The liquidity premium increases linearly with transaction costs and, in accordance with the discussion above, the default premium is increasing in transaction costs as well.

Panel E and F present the implications for a low credit risk firm (initial yield spread of 300 bp) as well as for a high credit risk firm (initial yield spread of 500 bp). Panel E shows that for any given level of transaction costs the high credit risk firm is closer to default compared to the low credit risk firm. This has implications for the relation between changes in liquidity and changes in the probability of default as shown in Panel F for the case of a rollover rate of 20%. In particular, any given change in transaction costs is associated with a more pronounced change in the probability of default for the high credit risk firm compared to the low credit risk firm:

Hypothesis 3: *The impact of corporate bond liquidity on yield spreads via exposure to bond rollover is increasing in the initial credit risk.*

4 Data

This paper relies on several data sources that are combined to analyze the asset pricing implications of the impact of bond liquidity on credit risk via exposure to corporate bond rollover. The sample covers the period from the beginning of 2005 to the end of 2011. In order to eliminate a potential survivorship bias, the sample contains all constituents of the S&P 500 index as of the beginning of 2005, 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 corresponding histories of amount outstandings are obtained from the *Mergent Fixed Income Securities Database* (Mergent FISD). In particular, this collection results in a total number of $13,402$ corporate bonds in the final sample. 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. 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 and ask prices. Standard filters as in, e.g., Friewald, Jankowitsch, and Subrahmanyam (2012), Dick-Nielsen, Feldhütter, and Lando (2012) or Jankowitsch, Nagler, and Subrahmanyam (2014) are implemented in order to exclude potential erroneous reports in *TRACE*.[3]

[3] Dick-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 to eliminate potentially erroneous reported prices.

Furthermore, balance sheet as well as income statement information of the underlying firms are obtained from *COMPUSTAT*. The entire history of the term-structure of US swap rates over the period from 2005 to 2011 is obtained from *Bloomberg*, which is used to proxy for the risk-free rate in the calculation of corporate bond yield spreads.

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 bond liquidity in a very detailed manner. Furthermore, various different aspects related to the asset pricing implications of bond liquidity via the corporate 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. This data set allows to comprehensively study corporate bond financing policies and to elaborate on the economic pricing role of the rollover channel associated with bond financing.

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 variables used in this study, such as trading activity variables, bond characteristics and firm fundamentals are defined in Table A1 and discussed in the empirical part in Section 6.

5.1 Corporate bond yield spreads

Corporate bond yield spreads are represented by the yield differential relative to that of the swap rate curve, which serves following Feldhütter and Lando (2008) as a risk-free benchmark. This benchmark is defined as the rate of a swap where the maturity is matched to the duration of the corporate bond. This duration is calculated based on the reported yield in the *TRACE* database and the underlying corporate bond cash flow structure.

5.2 Liquidity measures

Price dispersion measure. Similarily to Friewald, Jankowitsch, and Subrahmanyam (2012) or Jankowitsch, Nagler, and Subrahmanyam (2014) the price dispersion measure $d_{ij,s}$ of bond i of firm j on day s is defined as

$$d_{ij,s} = \sqrt{\frac{1}{\sum_{k_{ij,s}} v_{k_{ij,s}}} \cdot \sum_{k_{ij,s}} \left(\frac{p_{k_{ij,s}}}{m_{ij,s}} - 1 \right)^2 \cdot v_{k_{ij,s}}} \tag{5}$$

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. The intuition for this measure is that 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 bond.

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

$$\text{Amihud}_{ij,s} = \frac{1}{N_{ij,s}} \sum_{k_{ij,s}} \frac{|r_{k_{ij,s}}|}{v_{k_{ij,s}}}. \tag{6}$$

Based on Kyle (1985), and originally designed for limit order markets, this measure assesses the price impact of the traded volume and, therefore, the depth of the market. 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

$$\text{Roll}_{ij,s} = 2\sqrt{-\text{Cov}(\Delta p_{ij,s}, \Delta p_{ij,s-1})}. \tag{7}$$

This measure, based on Roll (1984), has been extensively used to study liquidity effects in the US corporate bond market see, e.g., Bao, Pan, and Wang (2011) or Friewald, Jankowitsch, and Subrahmanyam (2012) and serves as a proxy for the round-trip costs. The measure is computed based on the daily volume-weighted 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 scope of corporate bond financing as well as by providing an analysis of the underlying corporate bond rollover policies of the firms.

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 Empirical analysis

This section presents the empirical analysis and provides a study of the corporate bond financing policies of S&P 500 constituents, examines the evolution of yield spreads and liquidity in the US corporate bond market and discusses the main results obtained in the difference-in-differences analysis as well as in the cross-sectional study.

6.1 Corporate bond financing

Since this study explicitly elaborates on rollover risk arising from corporate bond financing, I first highlight the dimension of bond financing of S&P 500 constituents and the scale of the underlying bonds relative to the overall US corporate bond market. 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 is roughly \$375 billion, while the aggregate average amount redeemed is around \$300 billion. Analyzing the individual underlying bonds: On average a total number of $7,650$ bonds are outstanding per year with an average amount of \$250 million. All these statistics emphasize the scope of corporate bond financing of S&P 500 constituents and their dependence on bond market liquidity.

Now the analysis focuses on the debt capital structure composition on the individual firm level. Specifically, Panel A in Figure 2 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 firms. Additional evidence on the importance of corporate bond financing is given in Panel B which displays the time-series of these fractions. 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 bond holdings, with this fraction varying from a minimum of 48% in 2008 to a miximum of 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. Overall, both, the level and the persistence of debt capital structures with respect to bond financing emphasize the exposure of funding costs to corporate bond market conditions and make these firms particularly well-suited to study the interaction between market liquidity, exposure to bond rollover and credit risk.

Further evidence on the importance of bond financing of S&P 500 constituents is provided by studying the debt capital structures across industries, presented in Panel A in Table 1. 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 interquantile distances (25th to 75th quantile) provides further insights. Overall, this interquantile 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 confirm the importance of bond financing across industries.

In order to understand the structure of bond financing in greater detail the discussion now focuses on the characteristics of the underlying bonds on the firm level. These characteristics include the number of bonds, amount issued, maturity at issuance, coupon and the credit risk measure. Panel B in Table 1 gives the summary statistics on the number of bonds outstanding per firm in a particular year across industries. 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 also exists considerable variation within industries as represented by the interquantile distance which is generally around \$300 to \$400 million. Here, the analysis reveals that the range of this distance in, e.g., the manufacturing industry is from \$5 to \$350 million while in the mining industry it is from \$250 to \$650 million. A further important characteristic of the underlying bonds are the maturities at issuance (see 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 interquantile distances which typically range from 5 to 20 years, indicating that bonds of all maturities are common across the various industries. The long-term nature of the maturity at issuance makes bonds particularly interesting to study rollover risk on the firm level. This is the case since arguably at a given point in time exposure to bond rollover arises from decisions in the very distant past which mitigates endogeneity concerns. Panel E shows the distributions of the coupon levels of the bonds which are very similar across industries, i.e., coupons being at a median value of 6% of face value and interquantile distances ranging from 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 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, interquantile 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 persistence in the proportion of bond financing, as discussed above, this section studies the relation of the amount of maturing to issuing bonds on the individual firm level in greater detail, thus, the discussions focuses on the observed bond rollover policies. In particular, this analysis of the underlying bond rollover policies is of general interest, as it sheds light onto the question whether bond rollover risk 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, hence, in this case rollover risk is not of first-order importance. Furthermore, although it is an accepted assumption that firms tend to roll over bonds (see e.g., He and Xiong, 2012; He and Milbradt, 2014) this paradigm has so far not been systematically analyzed.

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. 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 relation between maturing and issuing bonds on the firm level, the following illustrative example provides additional insights: If these graphs were to be augmented by OLS-estimates, then the obtained R^2 would vary between values of 66% to 78%, with the estimates of the coefficients being between 0.90 and 1.05 across the various panels. This indicates a rather strong contemporanous relation of bond redemption and issuance and strengthens the notion that bond rollover policies are commonly employed. Furthermore, the graphs also demonstrate that the rollover pattern is evident in illiquid periods as well. In turn, this emphasizes the importance of an quantification of the impact of bond market liquidity on credit risk via the bond 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, on average, approximately 200 firms are active in a particular year. Moreover, conditionally that a firm is active on 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 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 rollover rate, defined by the fraction of amount outstanding of maturing bonds to the overall amount outstanding, is an adequate measure allowing to capture the pricing impact of bond 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. Given that firms need to redeem some of their 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 (see, e.g., Choi, Hackbarth, and Zechner, 2015, for a discussion on debt maturity profiles). Based on this discussion, the proposed empirical measure of the bond rollover rate will be used in the empirical analysis to explore the asset pricing implications of the bond rollover channel for yield spreads.

6.3 Corporate yield spreads and bond liquidity dynamics

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 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) as well as of 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 200 bp in the beginning of 2005 and around 400 bp at the end of 2011. The lowest yield spread level was given in the middle of 2007 with a value of 50 bp, while the highest was given directly following the *Lehman* bankruptcy filing (September 15, 2008) when yield spreads abruptly increased up to 700 bp. 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: Over the year of 2008 yield spreads doubled from a level of 300 bp to 600 bp. Here, several effects including overall deterioration in bond liquidity and credit risk as well as interactions of these forces, e.g. liquidity induced changes in credit risk via the rollover channel, contribute to this pattern. As a consequence, in order to be able to disentangle the pricing implications on yield spreads it is relevant to study the evolution of liquidity.

Turning to this study on the dynamics of liquidity: 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 bp and 50 bp, which is in line with estimates provided by Friewald, Jankowitsch, and Subrahmanyam (2012) over this period. However, the *Lehman* bankruptcy in 2008 constituted a shock to market liquidity: Transaction costs increased by a factor of three, up to a level of 150 bp, 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. Interestingly, this level of transaction costs remained relatively high, in comparison to the pre-*Lehman* period, at around 60 bp to 80 bp 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 bond liquidity induced by the *Lehman* bankruptcy. Specifically, the price impact of trading $1 million was around 20 bp over the period from 2005 to 2007. However, this price impact also trippled up to 60 bp following the *Lehman* bankruptcy with the depth of the market remaining quite thin at values between 30 bp to 40 bp in 2009. Following 2009 the depth of the market 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 implied liquidity dynamcis is very similar compared to the other two measures. The resulting estimates of transaction costs are again around 40 bp to 50 bp for the period up until the *Lehman* bankruptcy. Again, the Roll measure highlights the sudden loss in bond liquidity directly following the bankruptcy filing, with transaction costs increasing by up to a factor of three.

In summary the results present, throughout various measures, 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 suggests the unexpected nature of its severity. Furthermore, although liquidity somewhat recovered following the *Lehman* bankruptcy it still remained relatively low in 2009 compared to the period before. Thus, the heavy dry up in liquidity associated with the bankruptcy represents an interesting exogenous variation that allows to directly address several asset pricing aspects of how liquidity frictions act on corporate yield spreads, i.e., the *Lehman* bankruptcy constitutes an ideal experiment to explore the pricing implications associated with the corporate bond rollover channel.

6.4 Summary statistics of full sample

For completeness this section presents quarterly summary statistics on the bond level for the remaining variables defined in Table A1. The statistics are presented in Table 2. First, focusing on the trading activity variables, with volume being the traded volume on a daily basis and trades representing the number of trades per trade day in a given bond. The mean values of these variables are $1.5 million for the volume and 4 for the trades variable, respectively. The variable days represents the number of active trading days per quarter which is around 18 with some dispersion as indicated by the standard deviation of 19.

Finally, turning to the firm characteristics, the average cash to asset ratio is 6% (standard deviation 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 about bond holdings in the firms' debt capital structures was already provided in Section 6.1, in the panel the average fraction of bond financing is 77% with a standard deviation of 25%, confirming the 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 2.47 on average, which is somewhat higher compared to estimates provided by Choi, Hackbarth, and Zechner (2015) which maybe indicates that S&P 500 constituents manage bond 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, investment and retained earnings to total assets are 17%, 5% and 15%, respectively, with standard deviations of 25%, 6% and 30%. The average equity beta is 1.1 with a standard deviation of 0.34, and the average firm size measure as represented by the natural logarithm of total assets is 25 with a standard deviation of 1.5.

6.5 Difference-in-differences analysis

The previous sections discussed the corporate bond financing policies of S&P 500 constituents and presented the 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 the asset pricing implications of a shock to bond liquidity via exposure to bond rollover. In order to address this question a quasi-natural experiment is conducted. Specifically, the exogenous variation in liquidity arising from the *Lehman* bankruptcy in combination with ex-ante heterogeneity in bond maturity, hence, firms individual rollover exposures in the period from the beginning of 2009 to the end of 2009 is exploited.

In particular, yield spread reactions of outstanding bonds around 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 assure homogeneity of treated and control firms a matched difference-in-differences estimator is employed. In this methodology, the control group is selected based on a nearest neighbourhood matching procedure and is represented by a subset of the non-treated group.

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 discussion in the previous sections, 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, therefore, addresses potential endogeneity issues.[4] Tables 3 to 5 display the set of variables on which bonds of treated and control firms are matched.[5] In general, such a matching procedure guarantees the ex-ante homogeneity of the treatment and control groups, 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 identical across various dimensions. Specifically, in this respect, in order to test to what extent bond 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 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 exhibit ex-ante equal credit ratings 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. Therefore, given that all these criteria are fulfilled the subsequent analysis allows

[4]Note that, the overall findings are robust to matching at the end of 2006. The results are not discussed in detail but are presented in the Internet Appendix in Table A5.

[5]Matching is done with replacement and a one-to-four match is performed, i.e., for each treated observation at least four control observations are available.

to adequately explore the asset pricing implications induced by a shock to bond liquidity via exposure to corporate bond rollover.[6]

In order to examine the effect involving different exposures to bond rollover, three thresholds for treatment are considered where the cutoffs for treatment correspond well to the descriptive analysis in Section 6.2. In particular, firms are treated if they need to roll over at least 10%, 15% or 20% of their bond financing in the period from the beginning of 2009 to the end of 2009. As a consequence, these firms are confronted with a liquidity shock which potentially affects their funding costs in the future. For each threshold of treatment, yield spreads of outstanding bonds of treated and control firms, respectively, 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 consideration allows to examine the treatment effect across the entire term-structure of corporate bond yield spreads.

Tables 3 to 5 display the matching variables and present the performance of the nearest neighbourhood matching procedure. In particular, this performance is assessed by comparing the distributional differences of treatment and control groups in the considered matching variables after the procedure is performed. This comparision is based on the Kolmogorov-Smirnov (K-S) test. For any given rollover rate (Table 3 for the 10%, Table 4 for the 15% and Table 5 for the 20% rollover rate), matching is performed separately for all considered maturities (long-term, medium-term, short-term) 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. The p-values of the K-S test indicate that after matching is performed no significant differences between treatment and control groups across all considered criteria and dimensions are evident, consequently, treatment and control

[6] An important additional assumption neccessary to hold is that the treatment and control groups exhibit parallel trends in the dependent as well as among the matching variables, for a detailed discussion see Roberts and Whited (2012). All of these criteria are fulfilled, thus, the detailed results of this verification are not presented in the interest of conserving space.

groups can be considered as being homogeneous. Moreover, Tables 3 to 5 display the means of the matching variables of treatment and control groups. Here, interesting patterns are evident. For example, as a result of the matching procedure for both, treated and control groups, the average maturity of long-term bonds is 25 years while that of medium-term bonds is 10 years and that of short-term bonds is around 3 years, respectively. In the pooled sample the average maturity is around 9 years. Furthermore, long-term bonds are less liquid compared to short-term bonds, i.e., the corresponding transaction costs are around 50 bp and 30 bp, respectively. These patterns are in accordance with previous studies (see e.g. Friewald, Jankowitsch, and Subrahmanyam, 2012; Dick-Nielsen, Feldhütter, and Lando, 2012) which document that short-term bonds are more liquid compared to long-term bonds. The average credit rating of treated and control bonds is around BBB, which indicates investment-grade status, while the average amount outstanding of the underlying bonds is $260 million.

In order to get some intuition on the evolution of yield spreads of the treatment and control groups around the date of the *Lehman* default, 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. Specifically, 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 Tables 3 to 5. Panel A in Figure 6 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 treated and control groups were basically at the same level of around 220 bp. Moreover, the presented graph reveals that yield spreads of the two groups share basically identical trends towards the *Lehman* bankruptcy. However, following the default event, the yield spreads start to diverge. Specifically, although the yield spread of the control group also rises up to a level of 520 bp, the yield spread of the treated group experiences a much more pronounced increase up to a level of 620 bp, resulting in a yield spread differential of around 100 bp by the end of 2008. Consequently, these yield spread dynamics provide evidence that the exogenous shock to liquidity induced an increase in credit risk of the treated group relative to the control group and confirm the pricing implications associated with rollover exposure.

Panels B and C display the dynamics of yield spreads in the case where treatment is defined by a rollover rate of 15% and 20%, respectively. 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 case of the 10% rollover rate, following the default, yield spreads of treated and control groups 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 treated and control groups by the end of 2008 amounts to 200 bp for the 15% rollover rate and 280 bp for the 20% rollover rate, respectively.

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

Given the presented yield spreads dynamics, it is of interest to test whether the observed differences in yield spreads following the *Lehman* bankruptcy between treated and control groups are statistically significant as well. In order to quantify the economic magnitude associated with the bond rollover channel, the underlying yield spread changes of treated and control groups are compared by employing the following difference-in-differences specification

$$\boldsymbol{\Delta y_{ij}} = \alpha + \boldsymbol{\beta} \cdot \mathbf{Treat}_{\boldsymbol{ij}} + \epsilon_{ij} \tag{8}$$

where Δy_{ij} is the yield spread change of bond i of firm j, given by the differential of the average yield spread in August 2008 relative to the average yield spread in December 2008, and, Treat_{ij}

is an indicator variable signaling whether treatment occurs or not. As a conseqence, the coefficient β captures the average treatment effect (ATE). By examining yield spread changes in a time period closely around the liquidity shock but before the bonds of the treated groups mature, this specification allows to study the asset pricing implications induced by a liquidity shock on yield spreads given exposure to corporate bond rollover. The results are given in Panel A in Table 6, where the ATE is given for the three different rollover rates (10%, 15% and 20%) 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 treated and control groups as matched in Tables 3 to 5. Therefore, 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 6 (Panel A, Column 4), the results of the previous descriptive analysis are confirmed. In particular, the findings reveal that in the case of the 10% rollover rate the pooled ATE is 99 bp. Moreover, the obtained pooled ATE is increasing in the rollover rate, thus, confirming the posed hypothesis. Specifically, in the case of the 15% rollover rate the ATE is 197 bp, while in the case of the 20% rollover rate the ATE is 278 bp with the differences being economically significant.

Second, focusing on the results on the term-structure of yield spreads in Columns 1 to 3 in Table 6 (Panel A), 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.[7] 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 191 bp, for medium-term bonds the ATE is 217 bp, while for long-term bonds the ATE is given by 256 bp. Furthermore, the highest ATE in the analysis is given for long-term bonds

[7] It should be noted again that for each maturity-rollover rate combination given in Table 6, the matching procedure is rerun (with the results of the matching procedure given in Tables 3 to 5). Thus, the ATE in the case of, e.g., long-term bonds results from comparing yield spreads of long-term bonds of the treated group relative to long-term bonds of an equivalent control group.

in the case of a rollover rate of 20% and amounts to 474 bp, which highlights the magnitude of the underlying economic pricing impact. The finding that the ATE of long-term bonds is higher compared to short-term bonds strengthens the notion that the measured economic mechanism is increased credit risk.[8]

In order to explore whether yield spreads of firms with various ex-ante levels of credit risk react differently to the liquidity shock, the entire analysis is separately performed for the sub-sample of investment-grade firms. Again, the nearest neighborhood matching procedure is performed separately for the three different rollover rates as well as for different bond maturities. Tables A2 to A4 in the Internet Appendix provide the results of the matching procedure. There are only minor differences in the statistics of the underlying matching variables. One noteable difference is given by the transaction cost metrics which indicate that investment-grade bonds are slightly more liquid compared to the full sample. Specifically, average transaction costs are around 38 bp compared to 42 bp for the full sample, respectively. Again, we observe that long-term bonds are less liquid compared to short-term bonds. Obviously, the average rating of treated and control firms is higher with a grade of around A.

The corresponding results of the difference-in-differences analysis as given by Equation (8) are presented in Panel B of Table 6. In general, the previously discussed patterns are again evident. Hence, the ATE are increasing in the rollover rate as well as in the maturity of the underlying bonds. However, one important difference is that the magnitudes of the ATE are uniformly smaller for investment-grade firms compared to the full sample. This finding strengthens the hypothesis that liquidity interacts stronger via the rollover channel with yield spreads of high credit risk firms. In particular, in quantitative terms the obtained ATE in the case of a 10% rollover rate is 72 bp (compared to 99 bp in the full sample), the ATE of the 15% rollover rate is 141 bp (compared to 197 bp) and the ATE of the 20% rollover rate

[8]In order to further elaborate on the mechanism of increased credit risk via the bond rollover channel, Table A6 in the Internet Appendix presents results of Equation (8) where the dependent variable is the bond rating change over the considered period. The table reveals that ATE are again significant, i.e., treated firms experienced higher rating downgrades following the *Lehman* bankruptcy. The ATE are again increasing in the rollover rate, e.g., for the 10% rollover rate the ATE is around 0.33 notches, while for the 20% rollover rate the ATE is 1.18 notches. Furthermore, the ATE are again increasing in the maturity of the underlying bonds.

is 191 bp (compared to 278 bp), respectively. Also in the sub-sample of investment-grade firms the highest ATE is given for long-term bonds in the case of a rollover rate of 20% and amounts to around 282 bp. Thus, even in the sub-sample of investment-grade firms the obtained economic effects are non-negligible.

In summary, the results of the difference-in-differences analysis provide strong evidence in accordance with the asset pricing implications of bond liquidity via exposure to bond rollover.[9] The observed effect is increasing in the rollover rate, i.e., given a particular shock to market liquidity, yield spreads of the treated 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. Moreover, the ATE seems to be increasing in the level of credit risk of the underlying firms.

6.6 Cross-sectional analysis

The difference-in-differences analysis provides strong evidence in accordance with the pricing implications of liquidity via the corporate bond rollover channel. As a consequence, in order to verify the internal consistency of the previously obtained results and to obtain generality, it is also of interest to study the joint cross-section of yield spreads, various commonly employed measures of bond liquidity (price dispersion, Amihud and Roll measure), rollover rates and credit risk. Moreover, related to the posed hypothesis, providing such an analysis allows to disentangle the direct effect of changes in liquidity on yield spread changes from the

[9] A further interesting question that arises is related to the speed of mean reversion in the shock, i.e., whether cross-sectional variation in the speed of mean reversion in the liquidity measures of the underlying bonds is associated with variation in the ATE. Specifically, this question is also related to the recent critique proposed by Hennessy and Strebulaev (2015) on causal inference based on (quasi-)natural experiments. In order to provide some evidence in this direction, I estimate the half-lives of the liquidity measures of the underlying bonds. The median half-life of the liquidity measures in a given bond is around 21 days. Then, I rerun Equation (8) for the subset of bonds with low reversion (long half-lives) in liquidity by splitting the sample based on the median. The results are presented in the Internet Appendix in Table A7. Consistent with the intuition that low-reversion bonds are more sensitive to a shock in liquidity, the ATE are uniformly higher in this sub-sample compared to the full sample. For instance, the ATE for the 10% rollover rate is 131 bp (compared to 99 bp in the full sample) and 362 bp (compared to 278 bp) for the 20% rollover rate.

indirect effect of changes in liquidity on changes in credit risk via the bond rollover channel.

In particular, the cross-sectional variation in quarterly corporate bond yield spread changes is explained. The main explanatory variables of interest are represented by the direct effect of changes in the liquidity measures over the quarter t and the indirect effect of changes in the liquidity measures through the 1-year ahead corporate bond rollover rate, 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 changes in credit risk which is given by the change in average bond ratings of the three major rating agencies (*Fitch*, *Moody's*, *Standard and Poor's*). Hence, this allows to compare expected versus unexpected changes in credit risk. In the subsequent analysis variants of the following regression specification are tested, where i is the bond-index, j the firm-index and t the time-index

$$\begin{aligned} \boldsymbol{\Delta y_{ij,t}} &= \alpha + \boldsymbol{\beta_1 \cdot \Delta \textbf{Liquidity}_{ij,t}} + \boldsymbol{\beta_2 \cdot \Delta \textbf{Liquidity}_{ij,t} \times \textbf{Rollover Rate}_{j,t}} \\ &+ \beta_3 \cdot \Delta \text{Credit Risk}_{j,t} + \beta_4 \cdot \text{Rollover Rate}_{j,t} \\ &+ \beta_5 \cdot \text{Controls}_{ij,t} + FE + \epsilon_{ij,t} \end{aligned} \tag{9}$$

with *Controls* capturing the vector of control variables which are defined in Table A1 in the Internet Appendix and FE represents combinations of industry, firm or year fixed effects. 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 bond rollover channel.

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

6.6.1 Cross-section of corporate bond yield spread changes

In order to examine how changes in the various liquidity measures are related to the cross-section of yield spread changes through the corporate bond rollover channel, each of the three liquidity measures are analyzed in turn, as given by the price dispersion measure (Table 7), Amihud measure (Table 8) and Roll measure (Table 9). Furthermore, the results of the complete model including all three measures are discussed in Table 10.

Table 7 displays five different models where variants of Equation (9) are tested employing the price dispersion measure as a liquidity metric. In particular, Model 1 only contains 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 (9) augmented by industry, 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, the comparison of Model 1 (without interaction term and rollover rate) to Model 2 demonstrates the increase in the adjusted R^2 from 15% to 17% originating from the inclusion of these two variables. This might indicate that some non-negligible part of the cross-sectional variation in yield spread changes is explained by the effect of changes in liquidity through the rollover rate. Interestingly, with the inclusion of the interaction term the stand-alone coefficient of the price dispersion measure drops from 2.41 to 1.49, while the coefficient of the interaction term is positive and statistically significant. Thus, when assigning an underlying economic interpretation to the comparison, this finding suggests that changes in the price dispersion measure, a liquidity metric which captures transaction costs, might absorb some cross-sectional variation in changes in credit risk, particularly the part which is attributable to bond 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 yield spread changes. 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. Furthermore, 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 is insignificant. Hence, this finding 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 spread changes. 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 spread changes is given indirectly via the interaction term with the price dispersion measure, which still exhibits a positive and significant coefficient. Finally considering Model 5, which gives the complete model specification, the qualitative nature of the discussed results remains basically identical.

Focusing on the Amihud measure in Table 8, the same step-wise procedure as discussed above in exploring the price dispersion measure is applied. Again, the results show the increase in the adjusted R^2 by comparing Model 1 to Model 2 from 20% to 23%. 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 0.51 to 0.14. Again, this suggests that changes in the Amihud measure, which is an alternative liquidity metric assessing market depth, might absorb some cross-sectional variation in changes in credit risk, particularly the part 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.

In order to finalize the set of liquidity metrics, Table 9 provides the results for the Roll measure. Overall, the patterns of the previously discussed effects are again present: 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 in yield spread changes. Second, the overall magnitude of the stand-alone coefficient of the Roll measure is diminished when including the interaction term, which indicates 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 along the various models.

Following the above discussion about the relation of the individual liquidity measures to the cross-section of yield spread changes, the subsequent analysis focuses on the interpretation and quantification of the results of the complete model specification. Again, a step-wise procedure is employed which allows to compare the explanatory power and to explore the interplay of the individual coefficients across the models. Table 10 presents the results and shows eight different model specifications in which Equation (9) is tested including the complete set of control variables as well as industry, firm and year fixed effects. Model 1 contains all liquidity measures without any interaction terms and serves as a benchmark for the interpretation of the results. In this model the adjusted R^2 is 36%. Model 2 shows the interaction term of the price dispersion measure with the rollover rate, Model 3 shows the interaction term with the Amihud measure and Model 4 shows the interaction term with the Roll measure. Finally, Model 5 includes the interaction terms of the rollover rate with all three liquidity measures. Comparing the adjusted R^2 reveals that the models employing the price dispersion and Amihud measure, respectively, show identical explanatory power of 38% while the adjusted R^2 in the case of the Roll measure is lower at a value of 37%. Moreover, employing all three interaction terms yields an adjusted R^2 of 39%. Overall, from an economic point of view, this comparison highlights the importance of the corporate bond rollover channel for the cross-section of yield spread changes.

The results of the difference-in-differences analysis suggest that the maturity of the bonds as well as the ex-ante credit risk level of the underlying firms are important for the understanding of the impact of liquidity on yield spreads via exposure to bond rollover. Therefore, in order to further elaborate on these two dimensions, Model 6 explores the variation in the interaction terms of the liquidity measures with the rollover rate by additionally interacting these terms with the maturity of the bonds. Moreover, in Model 7 the same approach is applied by interacting with the level of credit risk. In both models, the adjusted R^2 increases to 41% in the case of maturity and 46% in the case of credit risk, respectively. Consequently, this clearly demonstrates that the importance of the corporate bond rollover channel is particularly dependent on the ex-ante credit risk of the underlying firms. Hence, this finding is in support of the posed hypothesis.

Finally, Model 8 serves as a basis for the quantification of the economic magnitude associated with the corporate bond rollover channel. First, in this complete model specification, among the set of liquidity measures the price dispersion and the Amihud measure are statistically different from zero. For example, a change in transaction costs by 100 bp is associated with a 73 bp change in yield spreads. Second, by studying the interaction terms of the liquidity measures with the rollover rate the results demonstrate that again the two terms including the price dispersion and the Amihud measure are related to the cross-section of yield spread changes. The economic interpretation of the interaction term is similar to the ATE of the difference-in-differences analysis, therefore, the coefficient of the interaction term of, e.g., the price dispersion measure with the rollover rate allows for an economic quantification. Specifically, a transaction cost increase of 100 bp and a rollover rate of 10% is associated with an additional yield spread increase of 119 bp, while in the case of a rollover rate of 15% (20%) this yield spread increase amounts to 178 bp (237 bp). Moreover, these effects are increasing in the maturity and the level of credit risk. For example, in the case of a 10% rollover rate a change in transaction costs by 100 bp leads to an additional 1 bp increase in spreads per year of maturity as well as an additional increase of around 10 bp per rating notch.

In summary, the cross-sectional analysis also provides strong evidence for the pricing implications of bond liquidity via the rollover channel, with the economic impacts 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 changes corporate bond yield spreads seem to absorb some cross-sectional variation in changes in credit risk, specifically the part which is attributable to exposure to bond rollover.

7 Conclusion

Credit risk and market liquidity are important components of corporate bond yield spreads, a direct measure of firms' debt funding costs. When firms replace maturing bonds by issuing new bonds, hence, when performing bond rollover, deteriorating market liquidity results in rollover losses. In turn, via 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 this channel and to elaborate on the direct and indirect pricing effects of liquidity. This paper explicitly examines the asset pricing implications of the rollover channel arising from exposure to bond rollover, based on a complete set of transactions data in the US corporate bond market covering the period from 2005 to 2011. Specifically, this paper provides a detailed study of debt capital structures and the underlying bond financing policies of S&P 500 constituents (excluding financials and utilities). This setup allows to closely link individual bond liquidity to exposure to corporate bond rollover and, thus, to examine the direct and indirect pricing effects of liquidity.

To begin with, the analysis of the debt capital structures reveals that S&P 500 firms have large exposures to the bond market with roughly 70% of their debt holdings being in bonds. Moreover, they are persistent with respect to bond financing with the findings providing strong evidence that these corporates pursue actual bond rollover policies, implying that maturing bonds are replaced by newly issued bonds. As a result, these corporates represent ideal objects to study the interaction between liquidity and credit risk via bond rollover.

In order to identify and quantify the asset pricing implications of corporate bond liquidity via the bond 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 liquidity on yield spreads via exposure to bond rollover. In particular, a transaction cost shock in the order of magnitude as induced by the *Lehman* bankruptcy of 100 bp is associated with an overall average treatment effect of 195 bp. In general, the resulting impact of liquidity on yield spreads is increasing in the rollover exposure. Additionally, the effect is observable across the entire term-structure of yield spreads and increasing in the ex-ante level of credit risk of the firms.

Furthermore, a study of the joint cross-section of yield spread changes, 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 economic nature of the obtained results and verifies the consistency of the findings across the two analyses. In addition, regarding the pricing of liquidity, the results suggest that changes in these commonly employed liquidity measures might absorb cross-sectional variation in changes in credit risk, specifically the part which is attributable to exposure to bond rollover.

In summary, this paper provides a unique study of corporate bond rollover policies for a representative sample of firms and offers comprehensive insights into the direct and indirect asset pricing implications of corporate bond liquidity.

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A Appendix

Claim valuation

Folllowing Leland (1994b), the tax shield TS satisfies the following equation

$$TS(X) = \frac{\tau C}{r} + A_1 X^{\gamma_1} + B_2 X^{\beta_1} \tag{10}$$

with γ_1 and β_1 being the roots of the fundamental quadratic given by

$$\gamma_1 = \frac{-(r - \delta - \frac{1}{2}\sigma^2) + \sqrt{(r - \delta - \frac{1}{2}\sigma^2)^2 + 2\sigma^2 r}}{\sigma^2} \quad > \quad 0 \tag{11}$$

and

$$\beta_1 = \frac{-(r - \delta - \frac{1}{2}\sigma^2) - \sqrt{(r - \delta - \frac{1}{2}\sigma^2)^2 + 2\sigma^2 r}}{\sigma^2} \quad < \quad 0. \tag{12}$$

The two boundary conditions imposed on the tax shield are

$$\lim_{X \to X_B} \qquad TS(X_B) = 0 \tag{13}$$

and

$$\lim_{X \to \infty} \qquad TS(X) = \frac{\tau C}{r}. \tag{14}$$

These conditions imply $A_1 = 0$, in order to exclude bubbles, and A_2 is given by

$$A_2 = -\frac{\tau C}{r} \left(\frac{1}{X_B} \right)^{\beta_1}. \tag{15}$$

The bankruptcy costs BC satisfy the following equation

$$BC(X) = B_1 X^{\gamma_1} + B_2 X^{\beta_1} \tag{16}$$

with the two boundary conditions given by

$$\lim_{X \to X_B} \quad BC(X_B) = \alpha X_B \tag{17}$$

and

$$\lim_{X \to \infty} \quad BC(X) = 0. \tag{18}$$

These conditions imply $B_1 = 0$, in order to exclude bubbles, and B_2 is given by

$$B_2 = \alpha X_B \left(\frac{1}{X_B} \right)^{\beta_1}. \tag{19}$$

The debt issuance costs IC satisfy the following equation

$$IC(X) = \frac{h\phi P}{r} + C_1 X^{\gamma_1} + C_2 X^{\beta_1} \tag{20}$$

with the two boundary conditions given by

$$\lim_{X \to X_B} \quad IC(X_B) = 0 \tag{21}$$

and

$$\lim_{X \to \infty} \quad IC(X) = \frac{h\phi P}{r}. \tag{22}$$

These conditions imply $C_1 = 0$, in order to exclude bubbles, and C_2 is given by

$$C_2 = -\frac{h\phi P}{r} \left(\frac{1}{X_B} \right)^{\beta_1}. \tag{23}$$

Bond valuation

The bond valuation equation given in (1) has a particular and a general solution satisfying

$$D(X) = p + D_1 X^{\gamma_2} + D_2 X^{\beta_2} \tag{24}$$

with γ_2 and β_2 being the roots of the fundamental quadratic given by

$$\gamma_2 = \frac{-(r-\delta-\frac{1}{2}\sigma^2)+\sqrt{(r-\delta-\frac{1}{2}\sigma^2)^2+2\sigma^2(r+\phi+\xi k)}}{\sigma^2} \quad > \quad 0 \tag{25}$$

and

$$\beta_2 = \frac{(r-\delta-\frac{1}{2}\sigma^2)-\sqrt{(r-\delta-\frac{1}{2}\sigma^2)^2+2\sigma^2(r+\phi+\xi k)}}{\sigma^2} \quad < \quad 0. \tag{26}$$

The two boundary conditions imposed on the value of debt are

$$\lim_{X \to X_B} \qquad D(X_B) = (1-\alpha)X_B \tag{27}$$

and

$$\lim_{X \to \infty} \qquad D(X) = p. \tag{28}$$

These conditions imply $D_1 = 0$, in order to exclude bubbles and (2) follows, with D_2 given by

$$D_2 = [(1-\alpha)X_B - p]\left(\frac{1}{X_B}\right)^{\beta_2}. \tag{29}$$

Equity valuation

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

$$E(X_t) = F(X_t) - D(X_t, \phi, \xi k) + \frac{\xi k}{\phi + \xi k}\left[D(X_t, \phi, \xi k) - D(X_t, \phi = 0, \xi k = 0)\right] \tag{30}$$

with firm value F given by

$$F(X_t) = X_t + TS(X_t) - BC(X_t) - IC(X_t). \tag{31}$$

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

$$\left.\frac{\partial E(X_t)}{\partial X_t}\right|_{X_t = X_B} = 0 \tag{32}$$

which results in

$$X_B = \frac{\frac{(C+\phi P)\xi k}{\phi+\xi k}\left(\frac{\beta_2}{r+\phi+\xi k} - \frac{\beta_1}{r}\right) - p\beta_2 + \left(\frac{\tau C}{r} + \frac{h\phi P}{r}\right)\beta_1}{\frac{(1-\alpha)\xi k}{\phi+\xi k}(\beta_2 - \beta_1) - \beta_1\alpha - (1-\alpha)\beta_2 + 1}. \tag{33}$$

Figure 1: Model implications. This figure presents the results of the model calibration. The model is calibrated based on the following parameters: riskless rate $r = 5\%$, tax rate $\tau = 27\%$, asset volatility $\sigma = 23\%$, bankruptcy costs $\alpha = 40\%$, earnings yield on assets $\delta = 2\%$, fractional trading cost $k = 0.5\%$, liquidity shock intensity $\xi = 1$, fractional issuance cost $h = 0.5\%$ and asset value $X_t = 100$. All panels are with respect to transaction cost with the baseline value given by 50 bp. The parameter ϕ represents the rollover rate ($\phi = 0$, $\phi = 10\%$, $\phi = 20\%$). Throughout all calibrations the coupon C and principal P are chosen in such a way that the bond is issued at par and has an initial yield spread of 300 bp (500 bp). 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 $\phi = 20\%$ and Panel D gives the corresponding yield spread composition (default and liquidity premium). Panel E gives the default boundary for a high credit risk firm and a low credit risk firm with a rollover rate of $\phi = 20\%$ and initial yield spread of 500 bp and 300 bp, respectively. Panel F compares the changes in the probability of default for a high and low credit risk frim, respectively, for a rollover rate of $\phi = 20\%$.

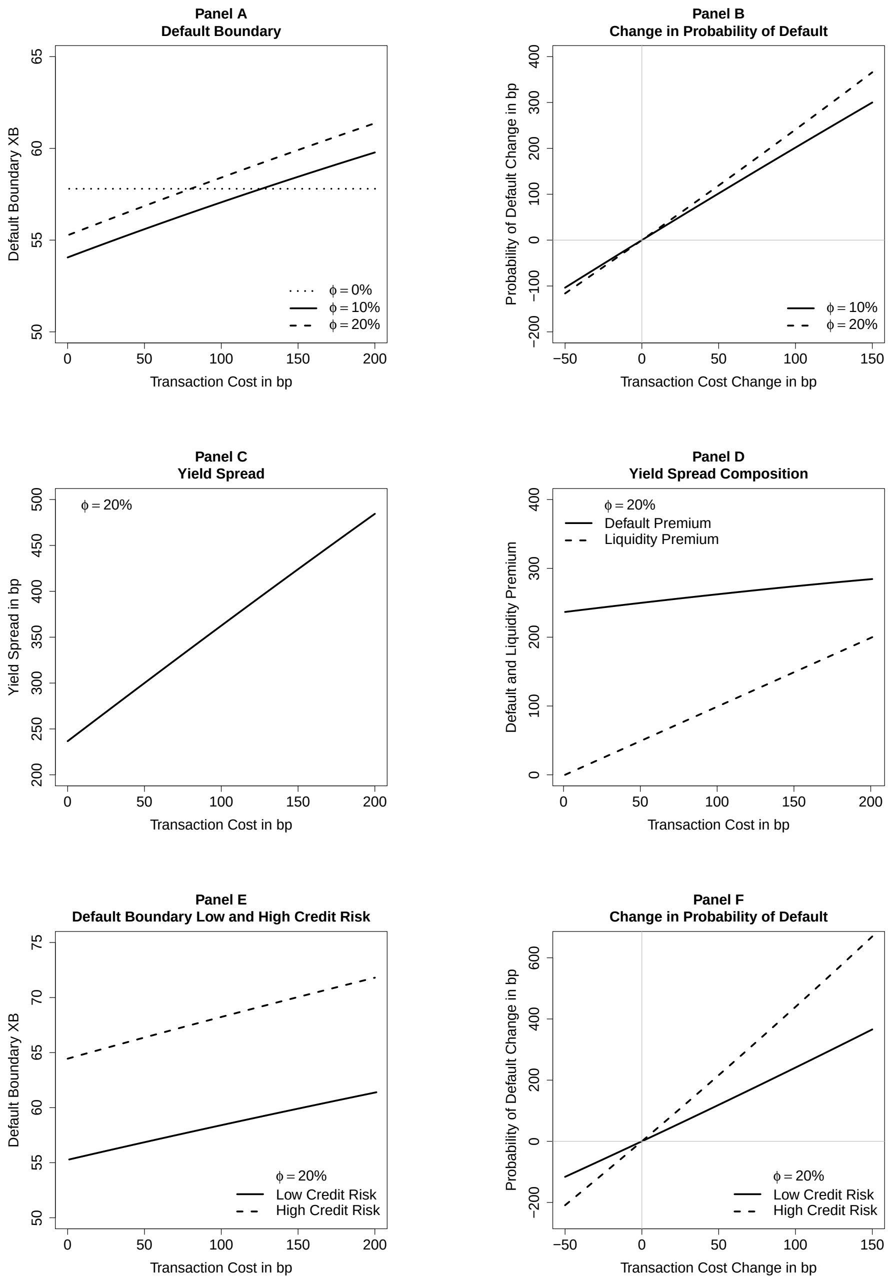

Figure 2: Corporate bond financing. This figure displays the distribution of the debt capital structures of S&P 500 constituents with respect to their corporate bond financing. Panel A gives the distribution (firm-year observations) of the fractions of book debt which are due to corporate bonds. Panel 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 and amounts to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

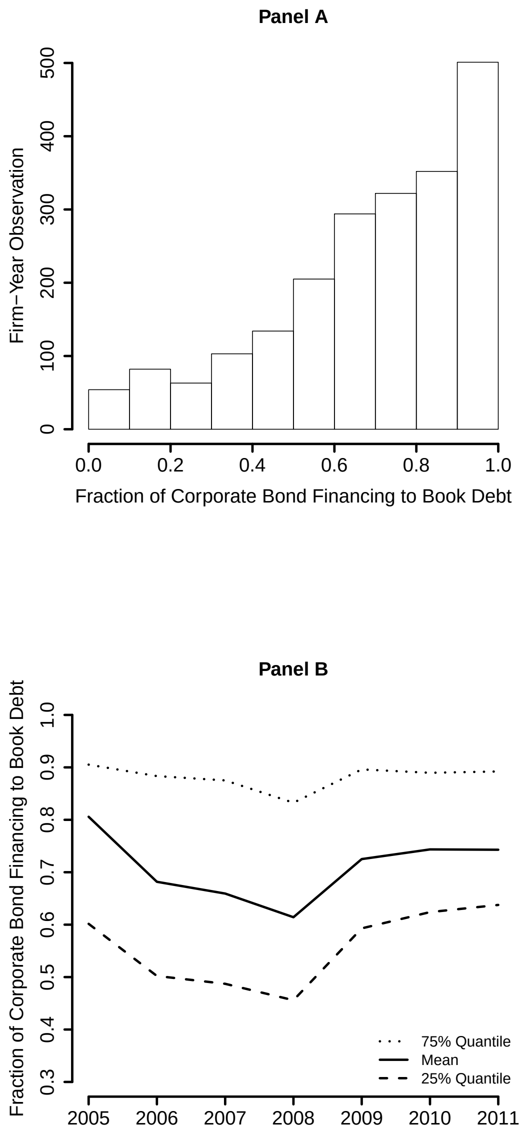

Figure 3: Corporate bond redemption and issuance. This figure displays the relation of bond redemption (amount outstanding of maturing bonds) to overall issuance amount in a given year. Each dot represents a firm observation and each of the Panels A to G correspond to a particular year. The overall available 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

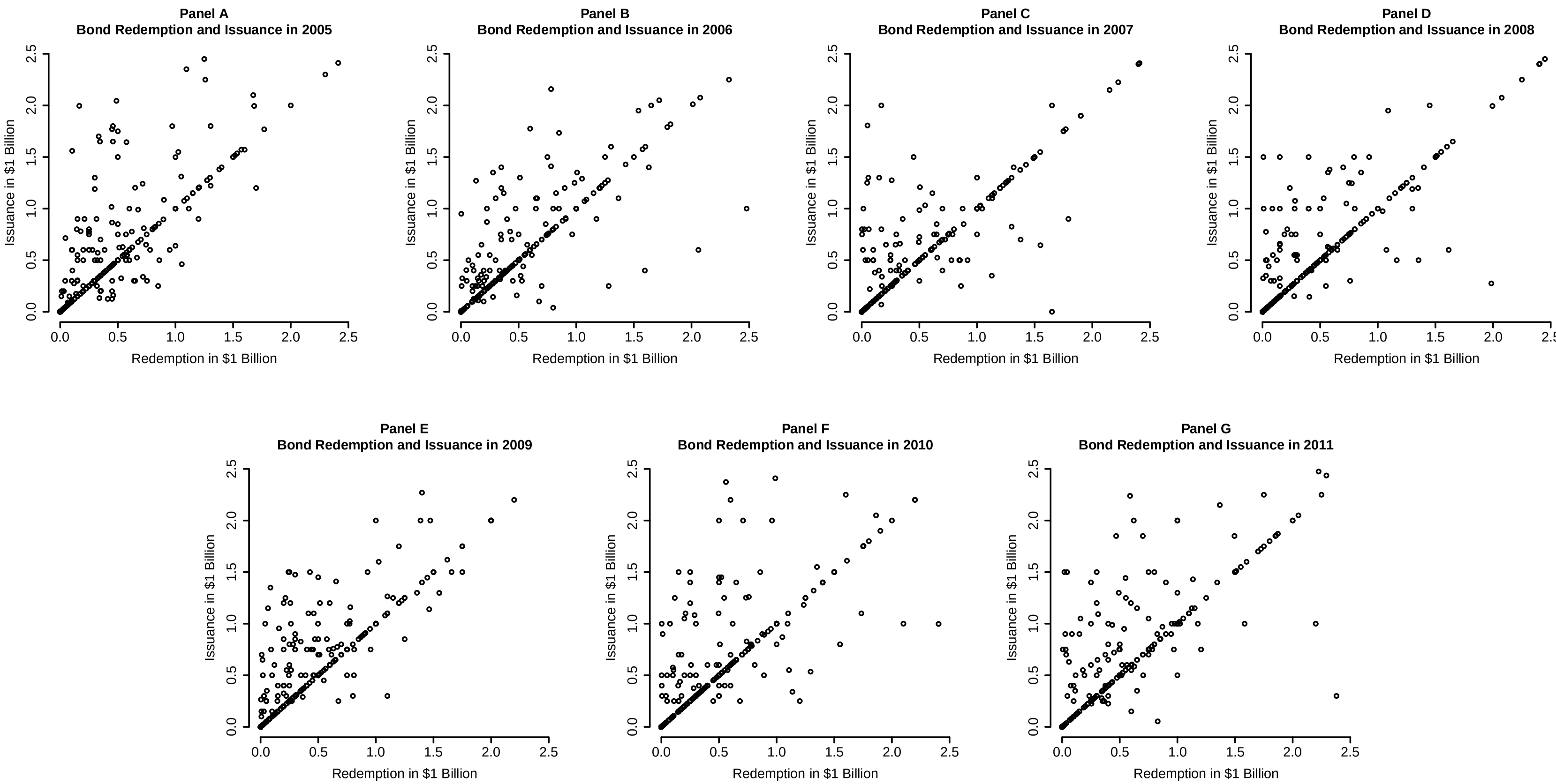

Figure 4: Rollover rate. This figure displays the distribution of the rollover rates (fraction of amount of maturing bonds to overall amount outstanding) in a given year. In each of the Panels A to G the distribution of rollover rates across firms in a particular year is shown. The overall available 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 *TRACE* for the period from January 2005 to December 2011 and amounts to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database.* The firm data are retrieved from *COMPUSTAT.*

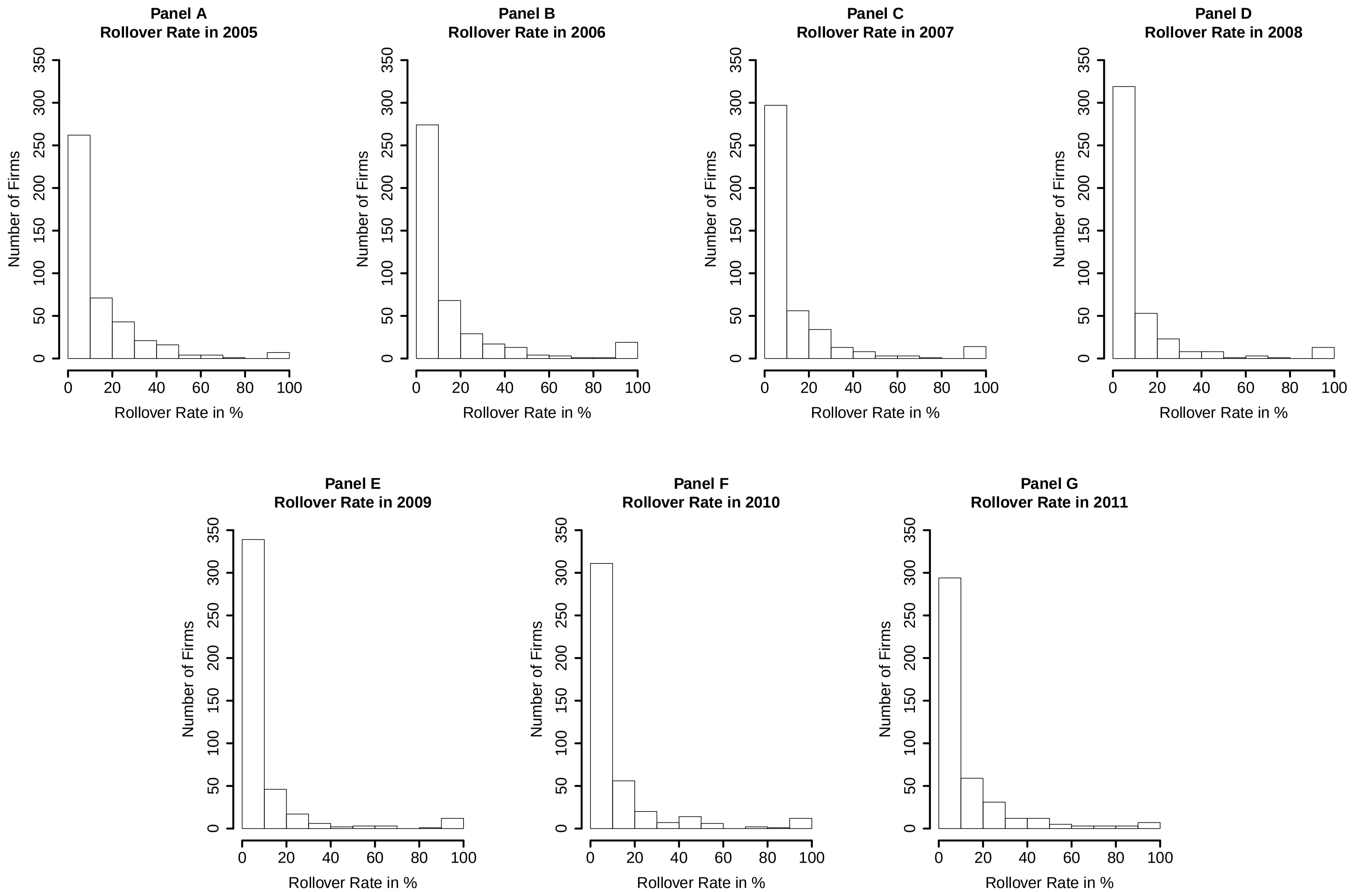

Figure 5: Yield spreads and liquidity in the US corporate bond market. This figure displays the time-series of average yield spreads and market liquidity as represented by the various liquidity metrics (price dispersion measure, Amihud measure, Roll measure). Panel A gives the time-series of yield spreads, 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

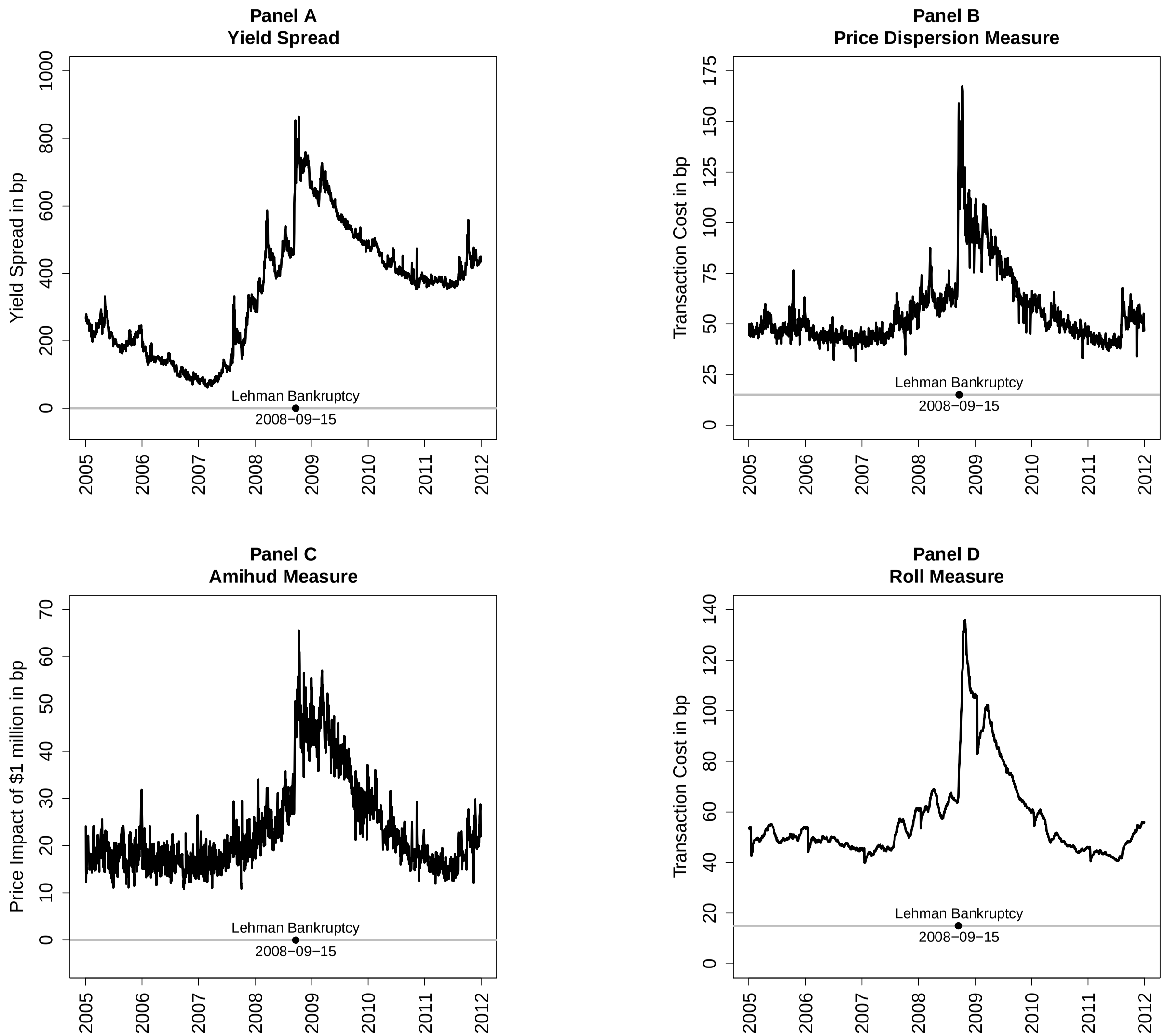

Figure 6: Corporate bond yield spreads of treatment and control groups. This figure displays average yield spreads of the treated and control groups used in the difference-in-differences analysis. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The figure displays the yield spreads of three different treatment groups as determined by the rollover rates given in Panels A to C (more than 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 and amounts to approximately 22 million transactions with an aggregate volume of $7, 100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

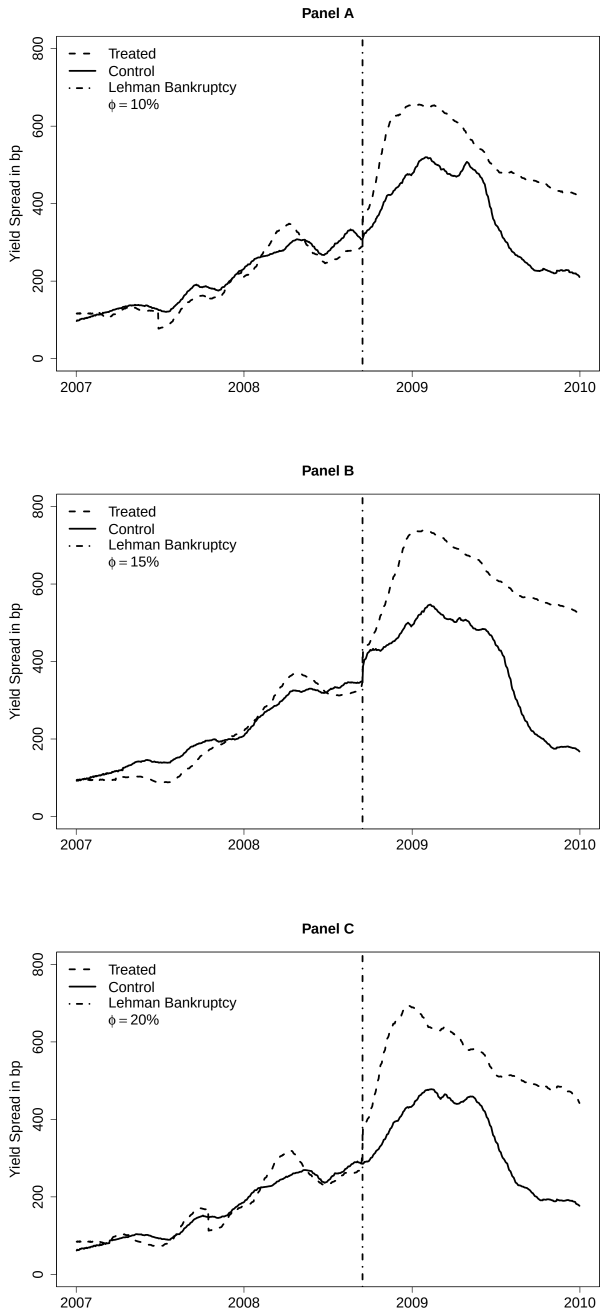

Table 1: Corporate bond financing. This table summarizes the information about the scale of corporate bond financing activities with respect to the individual debt capital structures of the firms in the sample, as well as information on their underlying corporate bonds. For each variable the 25% quantile ($Q_{0.25}$), 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Panel A					**Panel B**					**Panel C**				
	Bond Financing					**Bonds Outstanding**					**Amount Issued**				
Industry	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD
Mining	0.64	0.76	0.74	0.91	0.21	4	7	8	11	7	250.00	400.00	519.50	650.00	453.12
Construction	0.65	0.75	0.66	0.88	0.30	4	7	8	11	7	193.80	250.00	256.80	300.00	118.23
Manufacturing	0.56	0.77	0.71	0.92	0.24	2	5	15	11	63	5.31	64.66	325.70	350.00	2063.34
Transportation	0.56	0.68	0.68	0.85	0.22	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	0.27	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	0.31	2	5	11	14	13	100.00	300.00	606.20	500.00	2552.59
Services	0.47	0.73	0.68	0.88	0.26	1	4	5	7	8	200.00	375.00	497.50	625.00	469.94

	Panel D					**Panel E**					**Panel F**				
	Maturity at Issuance					**Coupon**					**Credit Risk**				
Industry	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	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	9.13	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	11.60	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	9.67	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	8.63	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	12.25	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	9.21	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	13.00	4.27

Table 2: 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 A1 in the Internet Appendix) used in the analysis for the full available sample, hence for each bond-quarter 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. Yield, given as a percentage, is the end-of-quarter estimate (average yield in last week of quarter) of the underlying bonds, the liquidity measures (dispersion, Amihud, Roll) correspond to the quarterly 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 quarter. 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	$Q_{0.25}$	Median	Mean	$Q_{0.75}$	SD	N
Yield spread	1.25	2.53	3.08	4.01	3.15	161920
Yield	4.72	5.81	5.50	6.18	3.86	161920
Swap rate	1.68	3.98	3.25	4.71	1.75	161920
Dispersion	0.44	0.50	0.56	0.61	0.38	165784
Amihud	0.17	0.20	0.23	0.27	0.19	164224
Roll	0.46	0.50	0.57	0.61	0.30	151528
Rollover rate	0.04	0.10	0.13	0.19	0.14	375256
Credit risk	5.75	7.50	7.84	10.00	4.09	370344
Volume	0.06	0.55	1.50	1.82	3.03	169380
Trades	2.00	2.56	4.18	3.75	9.81	169380
Days	3.50	11.50	18.15	30.75	19.09	169380
Coupon	4.50	5.78	5.70	7.00	2.13	375032
Maturity	2.67	6.33	9.94	14.10	10.98	184228
Amount outstanding	80.00	231.10	365.10	400.00	1627.51	238000
Cash	0.02	0.05	0.06	0.09	0.06	365068
Leverage	0.19	0.37	0.38	0.58	0.23	372796
Bond financing	0.62	0.79	0.77	0.94	0.25	371552
Long-term debt 1Y	0.04	0.10	0.10	0.15	0.08	356744
Granularity	1.60	2.10	2.47	3.06	1.76	375256
Profitability	0.02	0.04	0.04	0.06	0.07	373140
Q	0.24	0.36	0.38	0.54	0.18	346192
Intangibility	0.04	0.10	0.17	0.25	0.18	361504
Investment	0.02	0.04	0.05	0.06	0.04	372376
Retained earnings	0.07	0.16	0.15	0.28	0.30	371400
β	0.84	1.06	1.10	1.36	0.34	375256
Size	23.54	24.41	24.54	25.38	1.48	373140

Table 3: Nearest neighborhood matching for treatment group: 10 % rollover rate. This table provides summary statistics as given by the average values of the matching variables of the treatment groups (T) and the control groups (C) as well as the p-values of the Kolmogorov-Smirnov test (K-S), which allows to compare the distributional differences between treatment and control groups after the nearest neighborhood matching is performed. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The cutoff for treatment is given by a rollover rate of at least 10% resulting in 65 treated firms. 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, also a pooled matching is performed by including bonds across 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Long-Term			**Medium-Term**			**Short-Term**			**Pooled**		
	T	C	K-S	T	C	K-S	T	C	K-S	T	C	K-S
Dispersion	0.58	0.54	0.52	0.43	0.42	0.71	0.30	0.27	0.25	0.43	0.40	0.72
Amihud	0.22	0.19	0.27	0.16	0.17	0.93	0.14	0.14	0.94	0.16	0.17	0.15
Roll	0.47	0.50	0.39	0.40	0.40	0.26	0.23	0.23	0.31	0.36	0.40	0.25
Credit risk	8.56	7.74	0.99	8.08	8.32	0.98	8.22	8.03	0.95	8.29	8.02	0.92
Volume	1.46	1.45	0.13	1.45	1.43	0.56	1.42	1.39	0.76	1.44	1.42	0.77
Trades	5.00	3.56	0.22	7.27	4.50	0.78	6.55	4.25	0.26	6.26	4.24	0.18
Days	128.04	97.21	0.15	140.30	102.99	0.35	138.52	111.54	0.55	135.67	106.39	0.29
Coupon	5.70	6.00	0.99	5.73	6.03	0.73	5.88	5.82	0.99	5.78	5.86	0.93
Maturity	25.01	25.41	0.10	8.53	8.82	0.98	2.87	3.05	0.80	11.66	11.93	0.46
Amount outstanding	294.10	301.25	0.63	305.55	297.19	0.98	264.21	280.00	0.80	286.20	279.45	0.97
Cash	0.09	0.07	0.25	0.07	0.06	0.62	0.09	0.07	0.21	0.08	0.06	0.40
Leverage	0.42	0.40	0.47	0.45	0.47	0.69	0.43	0.43	0.76	0.43	0.40	0.71
Bond financing	0.69	0.66	0.17	0.65	0.63	0.29	0.69	0.68	0.76	0.68	0.66	0.19
Long-term debt 1Y	0.10	0.11	0.35	0.10	0.09	0.11	0.11	0.11	0.13	0.09	0.08	0.19
Granularity	2.01	2.01	0.97	2.11	2.15	0.97	2.40	2.37	0.95	2.28	2.27	0.99
Profitability	0.10	0.11	0.92	0.10	0.09	0.99	0.11	0.10	0.99	0.10	0.10	0.95
Q	0.36	0.35	0.42	0.29	0.28	0.79	0.29	0.25	0.73	0.31	0.33	0.21
Intangibility	0.19	0.21	0.93	0.18	0.21	0.92	0.20	0.20	0.43	0.19	0.20	0.69
Investment	0.05	0.05	0.83	0.05	0.05	0.66	0.05	0.05	0.92	0.05	0.05	0.94
Retained earnings	0.16	0.17	0.57	0.18	0.14	0.16	0.18	0.16	0.57	0.18	0.17	0.63
β	1.07	1.00	0.23	1.07	1.10	0.86	1.06	1.03	0.18	1.07	1.03	0.32
Size	23.93	23.99	0.52	23.95	23.74	0.20	23.65	23.68	0.98	23.83	23.75	0.61
Industry	4.09	3.80	0.97	4.12	3.81	0.97	3.91	3.54	0.16	4.03	3.84	0.39

Table 4: Nearest neighborhood matching for treatment group: 15 % rollover rate. This table provides summary statistics as given by the average values of the matching variables of the treatment groups (T) and the control groups (C) as well as the p-values of the Kolmogorov-Smirnov test (K-S), which allows to compare the distributional differences between treatment and control groups after the nearest neighborhood matching is performed. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The cutoff for treatment is given by a rollover rate of at least 15% resulting in 39 treated firms. 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, also a pooled matching is performed by including bonds across 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Long-Term			**Medium-Term**			**Short-Term**			**Pooled**		
	T	C	K-S	T	C	K-S	T	C	K-S	T	C	K-S
Dispersion	0.55	0.47	0.46	0.50	0.44	0.29	0.30	0.28	0.21	0.43	0.42	0.56
Amihud	0.20	0.24	0.68	0.19	0.18	0.68	0.17	0.17	0.50	0.20	0.22	0.89
Roll	0.57	0.56	0.55	0.55	0.47	0.82	0.28	0.27	0.71	0.42	0.41	0.59
Credit risk	8.90	8.62	0.99	8.38	8.07	0.79	8.75	8.25	0.95	8.70	8.59	0.99
Volume	1.45	1.46	0.90	1.44	1.46	0.71	1.42	1.39	0.21	1.44	1.44	0.54
Trades	4.64	5.25	0.77	6.75	6.58	0.82	6.05	5.03	0.46	5.98	4.93	0.29
Days	119.00	97.55	0.32	145.61	101.30	0.17	121.66	104.02	0.52	127.18	109.15	0.50
Coupon	5.69	5.42	0.78	5.89	6.16	0.79	5.89	5.91	0.78	5.74	5.90	0.91
Maturity	26.43	26.64	0.34	9.33	8.83	0.54	2.86	2.97	0.31	12.10	12.29	0.27
Amount outstanding	280.00	281.20	0.92	300.50	291.00	0.67	240.25	271.80	0.88	269.10	269.00	0.86
Cash	0.07	0.09	0.10	0.07	0.07	0.95	0.10	0.07	0.65	0.09	0.08	0.24
Leverage	0.44	0.44	0.73	0.48	0.49	0.38	0.41	0.43	0.82	0.44	0.46	0.75
Bond financing	0.72	0.68	0.45	0.66	0.65	0.93	0.70	0.67	0.85	0.69	0.67	0.17
Long-term debt 1Y	0.11	0.10	0.95	0.10	0.09	0.37	0.11	0.11	0.95	0.08	0.09	0.26
Granularity	2.10	2.11	0.97	2.00	2.05	0.77	2.40	2.37	0.97	2.31	2.27	0.62
Profitability	0.11	0.10	0.81	0.11	0.12	0.98	0.11	0.11	0.98	0.11	0.11	0.93
Q	0.36	0.35	0.52	0.33	0.28	0.10	0.29	0.25	0.44	0.29	0.28	0.93
Intangibility	0.23	0.19	0.99	0.16	0.19	0.39	0.20	0.17	0.44	0.19	0.19	0.76
Investment	0.06	0.05	0.59	0.05	0.05	0.87	0.05	0.06	0.29	0.05	0.05	0.69
Retained earnings	0.15	0.16	0.76	0.14	0.14	0.39	0.15	0.15	0.50	0.15	0.16	0.90
β	1.11	0.99	0.28	1.13	1.09	0.66	1.08	1.03	0.11	1.10	1.04	0.36
Size	23.08	23.72	0.56	23.74	23.66	0.35	23.31	23.54	0.30	23.55	23.54	0.19
Industry	3.21	3.72	0.97	3.71	3.46	0.95	3.76	3.64	0.99	3.73	3.66	0.91

Table 5: Nearest neighborhood matching for treatment group: 20 % rollover rate. This table provides summary statistics as given by the average values of the matching variables of the treatment groups (T) and the control groups (C) as well as the p-values of the Kolmogorov-Smirnov test (K-S), which allows to compare the distributional differences between treatment and control groups after the nearest neighborhood matching is performed. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The cutoff for treatment is given by a rollover rate of at least 20% resulting in 23 treated firms. 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, 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Long-Term			**Medium-Term**			**Short-Term**			**Pooled**		
	T	C	K-S	T	C	K-S	T	C	K-S	T	C	K-S
Dispersion	0.51	0.52	0.14	0.52	0.46	0.39	0.29	0.30	0.99	0.42	0.43	0.90
Amihud	0.30	0.27	0.56	0.42	0.46	0.88	0.17	0.15	0.57	0.17	0.18	0.54
Roll	0.70	0.60	0.28	0.73	0.67	0.88	0.34	0.28	0.57	0.55	0.49	0.54
Credit risk	9.23	7.74	0.95	8.50	7.86	0.92	8.76	8.48	0.99	8.87	8.15	0.94
Volume	1.42	1.44	0.88	1.41	1.39	0.58	1.38	1.39	0.98	1.40	1.41	0.47
Trades	4.91	5.17	0.62	6.47	6.58	0.89	5.64	5.82	0.74	5.56	5.51	0.70
Days	101.75	98.09	0.17	121.70	84.14	0.13	94.00	119.59	0.51	103.11	110.44	0.55
Coupon	4.86	5.09	0.55	5.88	6.75	0.79	5.70	5.97	0.98	5.44	5.89	0.91
Maturity	28.43	29.07	0.43	10.02	10.35	0.87	2.71	2.92	0.98	13.73	14.76	0.82
Amount outstanding	239.00	249.50	0.53	271.20	322.00	0.90	215.50	248.45	0.79	237.00	252.50	0.90
Cash	0.12	0.09	0.24	0.10	0.07	0.17	0.11	0.09	0.12	0.11	0.10	0.10
Leverage	0.34	0.31	0.34	0.41	0.44	0.88	0.33	0.36	0.61	0.35	0.35	0.63
Bond financing	0.78	0.75	0.85	0.75	0.68	0.20	0.76	0.70	0.52	0.77	0.73	0.14
Long-term debt 1Y	0.10	0.10	0.45	0.10	0.09	0.38	0.08	0.09	0.68	0.08	0.09	0.22
Granularity	2.31	2.31	0.88	2.10	2.11	0.81	2.31	2.37	0.99	2.25	2.30	0.32
Profitability	0.11	0.12	0.64	0.13	0.11	0.72	0.11	0.11	0.90	0.11	0.12	0.96
Q	0.35	0.21	0.94	0.31	0.39	0.72	0.43	0.31	0.65	0.44	0.34	0.22
Intangibility	0.19	0.18	0.94	0.17	0.16	0.84	0.21	0.19	0.49	0.19	0.19	0.28
Investment	0.05	0.06	0.63	0.05	0.05	0.54	0.05	0.05	0.85	0.05	0.05	0.77
Retained earnings	0.24	0.37	0.64	0.24	0.33	0.80	0.26	0.31	0.32	0.25	0.33	0.65
β	1.11	1.10	0.29	1.08	1.09	0.89	1.05	1.08	0.22	1.08	1.04	0.35
Size	23.48	23.76	0.34	23.55	23.80	0.72	23.16	23.43	0.35	23.36	23.64	0.14
Industry	3.81	3.30	0.76	4.30	3.82	0.78	4.11	3.94	0.99	4.05	3.64	0.69

Table 6: Matched difference-in-differences. This table presents 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 from the beginning of 2009 to the end of 2009. The dependent variable is the change in the yield spread over the period from August 2008 to December 2008 (average yield spread in the respective month). The explanatory variable is a dummy indicating whether treatment occurs or not. Three levels of the rollover rate for the assignment to the treatment groups are considered (at least 10%, 15% and 20%) with the results of the average treatment effect (ATE) for each of these rollover rates given in rows. In Columns (1) to (3), the ATE is given for the underlying bonds exhibiting different maturities including long-term (more than 15 years) given in (1), medium-term (between 5 to 15 years) given in (2) and short-term (between 1 to 5 years maturity) given in (3). Moreover, Column (4) gives the pooled ATE, hence, across the entire term-structure of yield spreads. Panel A presents results for all firms while Panel B presents the results for the sub-sample of investment-grade firms. 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

Panel A

		(1)	(2)	(3)	(4)
		ATE All Firms			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	65	1.5935*	1.0663**	1.3399***	0.9876**
		(0.9405)	(0.5589)	(0.4841)	(0.4727)
$\phi = 15\%$	39	2.5624*	2.1651**	1.9133***	1.9656***
		(1.5142)	(1.1122)	(0.7969)	(0.7779)
$\phi = 20\%$	23	4.7370**	3.1750**	2.4550**	2.7785**
		(2.5360)	(1.6940)	(1.1359)	(1.3346)

Panel B

		(1)	(2)	(3)	(4)
		ATE Investment-Grade Firms			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	46	1.2279*	0.4174*	0.0043	0.7180**
		(0.6855)	(0.2454)	(0.6048)	(0.3518)
$\phi = 15\%$	25	2.0462*	1.2613*	1.0587*	1.4115**
		(1.1484)	(0.7122)	(0.6104)	(0.7832)
$\phi = 20\%$	14	2.8205*	2.1140**	1.7138**	1.9117**
		(1.6330)	(1.1380)	(0.9398)	(1.0294)

Table 7: Changes in the price dispersion measure. This table reports the results for the price dispersion measure on a quarterly basis. 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 A1 in the Internet Appendix. Model (1) only controls for the changes in the price dispersion measure and changes in credit risk. Model (2) includes the interaction term of the changes in 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 industry, 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

	(1)	(2)	(3)	(4)	(5)
Intercept	−0.1360***	−0.3808***	0.0868	0.1410	−0.1664
	(0.0269)	(0.0373)	(0.1049)	(0.3176)	(0.3620)
ΔDispersion	2.4045***	1.4876***	1.2557***	0.9627***	0.9602***
	(0.0537)	(0.0893)	(0.0895)	(0.0897)	(0.1041)
ΔDispersion × Rollover Rate		0.1741***	0.1892***	0.1951***	0.1922***
		(0.0061)	(0.0059)	(0.0060)	(0.0067)
ΔCredit Risk	0.2258***	0.2182***	0.2011***	0.2227***	0.2239***
	(0.0048)	(0.0048)	(0.0047)	(0.0052)	(0.0061)
Rollover Rate		0.0222***	0.0127***	0.0081	0.0002
		(0.0023)	(0.0022)	(0.0052)	(0.0039)
Adjusted R^2	0.15	0.17	0.23	0.25	0.33
Observations	115892	115892	115892	115892	115892
Industry FE	No	No	Yes	No	Yes
Firm FE	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Controls	No	No	No	No	Yes

Table 8: Changes in the Amihud measure. This table reports the results for the Amihud measure on a quarterly basis. 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 A1 in the Internet Appendix. Model (1) only controls for the changes in the Amihud measure and changes in credit risk. Model (2) includes the interaction term of the changes in 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 industry, 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

	(1)	(2)	(3)	(4)	(5)
Intercept	−0.1283***	−0.2659***	0.0921	0.3798	−0.1503
	(0.0260)	(0.0355)	(0.0997)	(0.3050)	(0.3475)
ΔAmihud	0.5122***	0.1356***	0.2440***	0.2930***	0.1800***
	(0.0082)	(0.0147)	(0.0143)	(0.0143)	(0.0159)
ΔAmihud × Rollover Rate		0.0271***	0.0279***	0.0270***	0.0269***
		(0.0009)	(0.0010)	(0.0010)	(0.0010)
ΔCredit Risk	0.2262***	0.2154***	0.1927***	0.2098***	0.2178***
	(0.0047)	(0.0046)	(0.0045)	(0.0050)	(0.0059)
Rollover Rate		0.0139***	0.0043**	0.0022	−0.0014
		(0.0021)	(0.0021)	(0.0031)	(0.0037)
Adjusted R^2	0.20	0.23	0.29	0.31	0.33
Observations	114904	114904	114904	114904	114904
Industry FE	No	No	Yes	No	Yes
Firm FE	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Controls	No	No	No	No	Yes

Table 9: Changes in the Roll measure. This table reports the results for the Roll measure on a quarterly basis. 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 A1 in the Internet Appendix. Model (1) only controls for the changes in the Roll measure and changes in credit risk. Model (2) includes the interaction term of the changes in 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 industry, 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database.* The firm data are 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.

	(1)	(2)	(3)	(4)	(5)
Intercept	−0.2032***	−0.3573***	0.3538	0.3019	−0.2277
	(0.0296)	(0.0398)	(0.3077)	(0.3468)	(0.3745)
ΔRoll	0.4437***	0.3907***	0.1462***	0.1730***	0.1633***
	(0.0172)	(0.0268)	(0.0258)	(0.0261)	(0.0283)
ΔRoll × Rollover Rate		0.0033*	0.0077***	0.0045***	0.0044**
		(0.0017)	(0.0016)	(0.0016)	(0.0017)
ΔCredit Risk	0.2515***	0.2476***	0.2200***	0.2477***	0.2446***
	(0.0050)	(0.0050)	(0.0048)	(0.0053)	(0.0064)
Rollover Rate		0.0133***	0.0030	0.0037	−0.0014
		(0.0024)	(0.0023)	(0.0034)	(0.0040)
Adjusted R^2	0.12	0.13	0.22	0.24	0.31
Observations	105152	105152	105152	105152	105152
Industry FE	No	No	Yes	No	Yes
Firm FE	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
Controls	No	No	No	No	Yes

Table 10: Cross-section of corporate bond yield spread changes. This table reports the results for the complete regression specification on a quarterly basis. 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 other control variables such as trading activity variables, bond characteristics and firm fundamentals described in Table A1 in the Internet Appendix. All models contain industry, firm and year fixed effects. Model (1) shows changes in the liquidity measures and changes in credit risk, Model (2) shows the interaction term given by changes in the price dispersion measure with the rollover rate, Model (3) shows the interaction term given by changes in the Amihud measure with the rollover rate and Model (4) shows the interaction term given by changes in the Roll measure with the rollover rate. Model (5) includes the complete set of liquidity measures and their interaction terms with the rollover rate. Models (6) and (7) include the effects of bond maturity and the level of credit risk, respectively. Model (8) shows the complete specification. 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 and amounts to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	−0.1175	−0.1133	−0.1035	−0.1132	−0.3756	−0.1539	−0.1379	−0.3841
	(0.3492)	(0.3490)	(0.3442)	(0.3489)	(0.3435)	(0.3836)	(0.2412)	(0.3221)
ΔDispersion	1.1947***	0.9215***	1.1831***	1.1750***	0.8359***	0.8116***	0.7888***	0.7311***
	(0.0595)	(0.1016)	(0.0586)	(0.0594)	(0.1017)	(0.1075)	(0.0987)	(0.1031)
ΔAmihud	0.3544***	0.3473***	0.1900***	0.3493***	0.1834***	0.1666***	0.1345***	0.1221***
	(0.0086)	(0.0086)	(0.0158)	(0.0086)	(0.0159)	(0.0235)	(0.0161)	(0.0239)
ΔRoll	−0.0312	−0.0303	−0.0286	−0.0033	−0.0056	−0.0091	−0.0101	−0.0102
	(0.0230)	(0.0237)	(0.0231)	(0.0343)	(0.0340)	(0.0411)	(0.0325)	(0.0385)
ΔDispersion × Rollover Rate		0.1697***			0.1266***	0.1228***	0.1207***	0.1185***
		(0.0066)			(0.0067)	(0.0090)	(0.0020)	(0.0122)
ΔAmihud × Rollover Rate			0.0261***		0.0246***	0.0221***	0.0205***	0.0302***
			(0.0009)		(0.0010)	(0.0013)	(0.0011)	(0.0020)
ΔRoll × Rollover Rate				0.0026***	0.0020***	0.0016***	0.0009***	0.0006
				(0.0002)	(0.0004)	(0.0004)	(0.0003)	(0.0004)
[ΔDispersion × Rollover Rate] × Maturity						0.0003***		0.0008***
						0.0001		(0.0002)
[ΔAmihud × Rollover Rate] × Maturity						0.0009***		0.0004***
						(0.0001)		(0.0001)
[ΔRoll × Rollover Rate] × Maturity						0.0001		0.0001
						0.0001		0.0001
[ΔDispersion × Rollover Rate] × Credit Risk							0.0108***	0.0104***
							0.0001	0.0006
[ΔAmihud × Rollover Rate] × Credit Risk							0.0036***	0.0034***
							0.0001	0.0001
[ΔRoll × Rollover Rate] × Credit Risk							0.0008***	0.0008***
							0.0002	0.0002
ΔCredit Risk	0.2407***	0.2343***	0.2287***	0.2534***	0.2370***	0.2284***	0.1829***	0.1811***
	(0.0062)	(0.0062)	(0.0061)	(0.0063)	(0.0063)	(0.0062)	(0.0060)	(0.0060)
Adjusted R^2	0.36	0.38	0.38	0.37	0.39	0.41	0.46	0.47
Observations	94244	94244	94244	94244	94244	94244	94244	94244
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

B Internet Appendix

Internet Appendix

to

Rolling over Corporate Bonds:

How Market Liquidity affects Credit Risk

Table A1: 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 and amounts to approximately 22 million transactions with an aggregate volume of \$7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

Variable	**Definition**
Yield spread	Yield differential relative to a risk-free benchmark (US swap rate), given as a percentage
Yield	Corporate bond yield provided by *TRACE*, given as a percentage
US swap rate	Duration matched rate used as risk-free benchmark, given as a percentage, see Feldhütter and Lando (2008)
Dispersion	Price dispersion measure based on Jankowitsch, Nashikkar, and Subrahmanyam (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. $AAA = 1$, $AA+ = 2$, ..., $D = 21$) of the three major rating agencies (*Fitch*, *Moody's*, *Standard and Poor's*)
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 quarter
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 · prc)
Bond financing	(overall bond amount outstanding) / (dlc + dltt)
Long-term debt 1Y	dd1 / (dlc + dltt)
Granularity	Based on measure *Gran1* in Choi, Hackbarth, and Zechner (2015)
Profitability	ni / at
Q	(dlc + dltt + shrout · 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 A2: Nearest neighborhood matching for treatment group: Investment-grade firms 10 % rollover rate. This table provides summary statistics for investment-grade firms as given by the average values of the matching variables of the treatment groups (T) and the control groups (C) as well as the p-values of the Kolmogorov-Smirnov test (K-S), which allows to compare the distributional differences between treatment and control groups after the nearest neighborhood matching is performed. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The cutoff for treatment is given by a rollover rate of at least 10% resulting in 46 treated firms. 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, also a pooled matching is performed by including bonds across 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Long-Term			**Medium-Term**			**Short-Term**			**Pooled**		
	T	C	K-S	T	C	K-S	T	C	K-S	T	C	K-S
Dispersion	0.49	0.49	0.14	0.47	0.46	0.39	0.28	0.28	0.99	0.38	0.38	0.90
Amihud	0.29	0.26	0.56	0.41	0.45	0.88	0.16	0.15	0.57	0.16	0.17	0.54
Roll	0.46	0.49	0.38	0.39	0.40	0.25	0.22	0.23	0.30	0.35	0.39	0.25
Credit risk	6.83	7.14	0.96	6.60	6.60	0.47	6.55	7.13	0.62	6.65	7.45	0.11
Volume	1.49	1.48	0.62	1.47	1.48	0.83	1.45	1.42	0.57	1.47	1.46	0.48
Trades	4.99	4.58	0.31	7.68	7.68	0.83	6.32	3.96	0.19	6.30	4.43	0.17
Days	124.39	99.27	0.10	137.15	137.15	0.38	141.07	123.17	0.43	134.52	120.93	0.14
Coupon	5.77	5.86	0.98	5.47	5.47	0.93	5.70	5.99	0.51	5.65	5.80	0.96
Maturity	26.58	25.10	0.42	8.61	8.61	0.92	2.89	2.99	0.73	12.24	12.14	0.20
Amount outstanding	305.10	298.50	0.97	310.00	310.00	1.00	279.25	276.50	0.95	297.75	279.75	0.47
Cash	0.07	0.06	0.42	0.06	0.06	0.59	0.06	0.05	0.47	0.06	0.06	0.13
Leverage	0.40	0.40	0.76	0.43	0.43	0.40	0.40	0.40	0.69	0.41	0.41	0.41
Bond financing	0.68	0.67	0.48	0.66	0.66	0.12	0.68	0.67	0.85	0.67	0.66	0.15
Long-term debt 1Y	0.10	0.10	0.50	0.09	0.09	0.21	0.11	0.11	0.13	0.09	0.09	0.30
Granularity	2.15	2.11	0.90	2.10	2.05	0.75	2.35	2.37	0.97	2.30	2.26	0.62
Profitability	0.11	0.12	0.27	0.11	0.11	0.45	0.12	0.12	0.86	0.11	0.11	0.22
Q	0.34	0.34	0.53	0.32	0.29	0.10	0.29	0.28	0.44	0.28	0.28	0.93
Intangibility	0.20	0.21	0.18	0.20	0.20	0.33	0.22	0.23	0.76	0.21	0.21	0.31
Investment	0.05	0.06	0.48	0.06	0.06	0.34	0.05	0.05	0.76	0.05	0.06	0.25
Retained earnings	0.33	0.31	0.24	0.34	0.34	0.77	0.38	0.29	0.34	0.35	0.30	0.20
β	1.00	0.99	0.28	0.99	0.99	0.16	0.98	1.00	0.25	0.99	0.99	0.25
Size	24.14	24.00	0.88	24.12	24.12	0.57	23.84	23.78	0.92	24.02	23.76	0.11
Industry	3.72	3.65	1.00	3.85	3.85	0.99	3.71	3.62	1.00	3.76	3.56	0.86

Table A3: Nearest neighborhood matching for treatment group: Investment-grade firms 15 % rollover rate. This table provides summary statistics for investment-grade firms as given by the average values of the matching variables of the treatment groups (T) and the control groups (C) as well as the p-values of the Kolmogorov-Smirnov test (K-S), which allows to compare the distributional differences between treatment and control groups after the nearest neighborhood matching is performed. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The cutoff for treatment is given by a rollover rate of at least 15% resulting in 25 treated firms. 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, also a pooled matching is performed by including bonds across 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Long-Term			**Medium-Term**			**Short-Term**			**Pooled**		
	T	C	K-S	T	C	K-S	T	C	K-S	T	C	K-S
Dispersion	0.52	0.45	0.95	0.45	0.44	0.82	0.30	0.25	0.90	0.38	0.37	0.83
Amihud	0.20	0.21	0.92	0.18	0.18	0.81	0.17	0.17	0.73	0.19	0.18	0.33
Roll	0.59	0.56	0.98	0.55	0.50	0.91	0.25	0.25	0.87	0.40	0.38	0.30
Credit risk	6.69	6.88	0.84	6.56	6.56	0.76	6.86	7.08	0.87	6.72	7.10	0.37
Volume	1.46	1.45	0.51	1.46	1.46	0.48	1.43	1.40	0.44	1.50	1.45	0.92
Trades	5.16	4.46	0.79	6.40	6.40	0.90	5.69	4.91	0.65	5.72	5.10	0.37
Days	105.11	91.64	0.23	136.69	136.69	0.55	119.61	122.20	0.92	119.82	111.32	0.16
Coupon	5.67	5.89	1.00	5.79	5.79	0.40	5.84	5.95	0.69	5.77	5.86	0.75
Maturity	29.24	24.28	0.80	9.71	9.71	0.61	2.99	3.09	0.90	13.16	11.92	0.50
Outstanding	294.00	297.50	0.97	300.00	300.00	0.82	255.25	253.80	0.91	280.10	284.00	0.29
Cash	0.06	0.07	0.49	0.06	0.06	0.69	0.06	0.06	0.21	0.06	0.06	0.26
Leverage	0.41	0.40	0.57	0.44	0.44	0.80	0.39	0.42	0.57	0.41	0.43	0.24
Bond Financing	0.69	0.69	0.77	0.66	0.66	0.77	0.70	0.70	0.84	0.68	0.67	0.37
Long-term debt 1Y	0.11	0.11	0.95	0.09	0.09	0.35	0.11	0.11	0.95	0.08	0.09	0.36
Granularity	2.10	2.11	0.97	2.00	2.05	0.77	2.40	2.37	0.97	2.31	2.27	0.62
Profitability	0.13	0.13	0.56	0.13	0.13	0.94	0.14	0.13	0.69	0.13	0.13	0.21
Q	0.35	0.34	0.25	0.30	0.30	0.18	0.31	0.32	0.26	0.28	0.28	0.31
Intangibility	0.20	0.19	0.86	0.19	0.19	0.88	0.21	0.21	0.97	0.20	0.18	0.25
Investment	0.06	0.06	0.22	0.06	0.06	0.79	0.06	0.05	0.89	0.06	0.06	0.28
Retained earnings	0.16	0.17	0.37	0.15	0.15	0.32	0.16	0.16	0.21	0.15	0.15	0.10
β	1.03	0.99	0.52	1.02	1.02	0.16	1.01	0.99	0.35	1.02	0.98	0.21
Size	23.93	23.96	0.91	23.89	23.89	0.54	23.48	23.54	0.91	23.74	23.71	0.18
Industry	3.39	3.63	1.00	3.62	3.62	1.00	3.52	3.86	1.00	3.51	3.57	1.00

Table A4: Nearest neighborhood matching for treatment group: Investment-grade firms 20 % rollover rate. This table provides summary statistics for investment-grade firms as given by the average values of the matching variables of the treatment groups (T) and the control groups (C) as well as the p-values of the Kolmogorov-Smirnov test (K-S), which allows to compare the distributional differences between treatment and control groups after the nearest neighborhood matching is performed. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The cutoff for treatment is given by a rollover rate of at least 20% resulting in 14 treated firms. 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, also a pooled matching is performed by including bonds across 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are retrieved from *COMPUSTAT*.

	Long-Term			**Medium-Term**			**Short-Term**			**Pooled**		
	T	C	K-S	T	C	K-S	T	C	K-S	T	C	K-S
Dispersion	0.50	0.52	0.52	0.41	0.40	0.71	0.26	0.26	0.25	0.38	0.38	0.75
Amihud	0.20	0.19	0.27	0.16	0.16	0.92	0.14	0.14	0.94	0.16	0.16	0.35
Roll	0.50	0.50	0.39	0.38	0.38	0.26	0.20	0.20	0.31	0.35	0.34	0.35
Credit risk	6.33	6.33	0.96	5.92	5.92	0.47	6.49	7.38	0.49	6.30	6.02	0.28
Volume	1.42	1.39	0.52	1.41	1.41	0.84	1.41	1.38	0.63	1.41	1.42	0.54
Trades	4.31	3.78	0.10	4.76	4.76	0.70	4.31	3.90	0.63	4.42	4.67	0.28
Days	87.30	88.50	0.75	100.14	100.14	0.97	80.75	97.56	0.96	87.69	94.27	0.76
Coupon	5.07	5.33	0.75	6.15	6.15	0.88	5.84	5.69	0.89	5.65	5.74	0.76
Maturity	33.16	30.39	0.26	10.95	10.95	0.51	2.71	2.75	0.63	15.20	14.73	0.58
Amount outstanding	244.00	246.50	0.89	262.25	262.25	0.84	209.10	252.10	0.37	234.25	243.25	0.55
Cash	0.08	0.07	0.65	0.07	0.07	0.53	0.07	0.07	0.16	0.07	0.07	0.21
Leverage	0.28	0.29	0.55	0.32	0.32	0.98	0.29	0.34	0.63	0.29	0.30	0.68
Bond financing	0.77	0.74	0.86	0.75	0.75	0.58	0.76	0.73	0.37	0.76	0.75	0.29
Long-term debt 1Y	0.11	0.11	0.45	0.10	0.10	0.15	0.11	0.11	0.13	0.09	0.09	0.20
Granularity	2.11	2.11	0.97	2.10	2.15	0.77	2.40	2.40	0.97	2.21	2.27	0.61
Profitability	0.15	0.15	0.22	0.15	0.15	0.86	0.14	0.13	0.77	0.15	0.15	0.36
Q	0.34	0.34	0.25	0.31	0.31	0.28	0.32	0.32	0.36	0.29	0.29	0.35
Intangibility	0.19	0.18	0.68	0.19	0.19	0.77	0.21	0.22	0.63	0.20	0.21	0.33
Investment	0.07	0.07	0.38	0.06	0.06	0.36	0.06	0.05	0.63	0.06	0.06	0.29
Retained earnings	0.24	0.27	0.38	0.28	0.28	0.26	0.32	0.36	0.19	0.31	0.25	0.21
β	1.02	1.00	0.30	0.98	0.98	0.26	0.99	0.93	0.49	1.00	0.92	0.23
Size	23.75	23.88	0.71	23.79	23.79	0.56	23.34	23.35	0.77	23.59	23.66	0.30
Industry	3.30	3.39	0.96	4.14	4.14	0.68	3.83	4.28	0.96	3.72	3.52	0.11

Table A5: Robustness: matched difference-in-differences. This table presents a robustness test of the matched difference-in-differences analysis in which matching is performed at the end of 2006. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The dependent variable is the change in the yield spread over the period from August 2008 to December 2008 (average yield spread in the respective month). The explanatory variable is a dummy indicating whether treatment occurs or not. Three levels of the rollover rate for the assignment to the treatment groups are considered (at least 10%, 15% and 20%) with the results of the average treatment effect (ATE) for each of these rollover rates given in rows. In Columns (1) to (3), the ATE is given for the underlying bonds exhibiting different maturities including long-term (more than 15 years) given in (1), medium-term (between 5 to 15 years) given in (2) and short-term (between 1 to 5 years maturity) given in (3). Moreover, Column (4) gives the pooled ATE, hence, across the entire term-structure of yield spreads. Panel A presents results for all firms while Panel B presents the results for the sub-sample of investment-grade firms. 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

Panel A

		(1)	(2)	(3)	(4)
		ATE All Firms			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	65	1.4399**	1.0390**	1.4401***	0.8936**
		(0.6104)	(0.5438)	(0.3585)	(0.4788)
$\phi = 15\%$	39	2.7029**	2.3256*	1.6290***	2.0810***
		(1.2881)	(1.2866)	(0.6477)	(0.7569)
$\phi = 20\%$	23	4.6455**	2.6815**	2.3437**	2.6346**
		(2.5420)	(1.1361)	(1.0332)	(1.1260)

Panel B

		(1)	(2)	(3)	(4)
		ATE Investment-Grade Firms			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	46	1.0175**	0.5100*	0.0321	0.6251*
		(0.4696)	(0.2861)	(0.4696)	(0.3508)
$\phi = 15\%$	25	1.9411**	1.5538*	1.2335**	1.2374**
		(1.0691)	(0.8637)	(0.5436)	(0.6157)
$\phi = 20\%$	14	2.7410*	2.3656**	1.5731**	2.0075**
		(1.5950)	(1.0743)	(0.7325)	(0.9718)

Table A6: Rating changes: matched difference-in-differences. This table presents 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 from the beginning of 2009 to the end of 2009. The dependent variable is the bond rating change over the period from August 2008 to December 2008. The explanatory variable is a dummy indicating whether treatment occurs or not. Three levels of the rollover rate for the assignment to the treatment groups are considered (at least 10%, 15% and 20%) with the results of the average treatment effect (ATE) for each of these rollover rates given in rows. In Columns (1) to (3), the ATE is given for the underlying bonds exhibiting different maturities including long-term (more than 15 years) given in (1), medium-term (between 5 to 15 years) given in (2) and short-term (between 1 to 5 years maturity) given in (3). Moreover, Column (4) gives the pooled ATE, hence, across the entire term-structure of outstanding bonds. Panel A presents results for all firms while Panel B presents the results for the sub-sample of investment-grade firms. 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

Panel A

		(1)	(2)	(3)	(4)
		ATE All Firms			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	65	0.4167**	0.3111**	0.1580	0.3271**
		(0.2192)	(0.1496)	(0.1642)	(0.1527)
$\phi = 15\%$	39	0.6937***	0.5074**	0.3168	0.6474***
		(0.1812)	(0.2575)	(0.2600)	(0.1427)
$\phi = 20\%$	23	1.3452***	1.3464***	0.7886**	1.1829***
		(0.4827)	(0.4813)	(0.3502)	(0.4432)

Panel B

		(1)	(2)	(3)	(4)
		ATE Investment-Grade Firms			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	46	0.2195	0.1624	0.0764	0.0463
		(0.1490)	(0.1265)	(0.1210)	(0.0694)
$\phi = 15\%$	25	0.5522**	0.4171**	0.3465*	0.3375**
		(0.2738)	(0.1800)	(0.2018)	(0.1702)
$\phi = 20\%$	14	0.6087**	0.4893**	0.3062*	0.4011***
		(0.2994)	(0.2234)	(0.1801)	(0.1613)

Table A7: Liquidity reversion: matched difference-in-differences. This table presents additional results of the matched difference-in-differences analysis in which the subset of bonds with low average reversion in the liquidity measures (dispersion, Amihud, Roll) is used. Treatment is defined by the fraction of bond financing that needs to be rolled over (rollover rate) in the period from the beginning of 2009 to the end of 2009. The dependent variable is the change in the yield spread over the period from August 2008 to December 2008 (average yield spread in the respective month). The explanatory variable is a dummy indicating whether treatment occurs or not. Three levels of the rollover rate for the assignment to the treatment groups are considered (at least 10%, 15% and 20%) with the results of the average treatment effect (ATE) for each of these rollover rates given in rows. In Columns (1) to (3), the ATE is given for the underlying bonds exhibiting different maturities including long-term (more than 15 years) given in (1), medium-term (between 5 to 15 years) given in (2) and short-term (between 1 to 5 years maturity) given in (3). Moreover, Column (4) gives the pooled ATE, hence, across the entire term-structure of yield spreads. Panel A presents results for all firms while Panel B presents the results for the sub-sample of investment-grade firms. 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 and amounts to approximately 22 million transactions with an aggregate volume of $7,100 billion. US swap rate data are obtained from *Bloomberg* and the corporate bond data are obtained from the *Mergent Fixed Income Securities Database*. The firm data are 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.

		(1)	(2)	(3)	(4)
		ATE Low Liquidity Reversion			
Rollover	# Treated	Long-Term	Medium-Term	Short-Term	Pooled
$\phi = 10\%$	65	1.6361**	1.2790**	1.1233***	1.3049**
		(0.6905)	(0.5896)	(0.3550)	(0.5930)
$\phi = 15\%$	39	2.8652**	2.7800**	2.0440**	2.4908***
		(1.4820)	(1.2157)	(1.0390)	(0.8684)
$\phi = 20\%$	23	5.5861***	3.8380***	3.0907**	3.6153***
		(2.1990)	(1.4451)	(1.6448)	(1.3735)