Illiquidity or Credit Deterioration: A Study of Liquidity in the US Corporate Bond Market during Financial Crises

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Abstract

We use a unique data-set to study liquidity effects in the US corporate bond market, covering more than 20,000 bonds. Our analysis explores time-series and cross-sectional aspects of corporate bond yield spreads, with the main focus being on the quantification of the impact of liquidity factors, while controlling for credit risk. Our time period starts in October 2004 when detailed transaction data from the Trade Reporting and Compliance Engine (TRACE) became available. In particular, we examine three different regimes during our sample period, the *GM/Ford crisis* in 2005 when a segment of the corporate bond market was affected, the *sub-prime crisis* since mid-2007, which was much more pervasive across the corporate bond market, and the period in between, when market conditions were more normal.

We employ a wide range of liquidity measures and find in our panel-regression analysis that liquidity effects account for approximately one-tenth of the explained market-wide corporate yield spread changes. During periods of crisis, the economic impact of the liquidity measures increases significantly. Our data-set allows us to examine in greater detail liquidity effects in various sub-segments of the market: investment grade vs. speculative grade bonds, financial sector firms which have been particularly affected by the crisis vs. industrial firms, and retail vs. institutional trades. In addition, our cross-sectional analysis based on Fama-MacBeth regressions shows that liquidity explains an important part of the variation in yield spreads across bonds, after accounting for credit risk. These results yield important insights regarding the liquidity drivers of corporate bond yield spreads, particularly during periods of crisis.

JEL-Classification: G01, G12, G14.

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1 Introduction

The on-going global financial crisis had its origins in the US sub-prime mortgage market in 2006-2007, but has since spread to virtually every financial market around the world. The most important aspect of this crisis that sharply distinguishes it from previous crises is the rapidity and degree to which both the liquidity and credit quality of several asset classes have deteriorated. While clearly both liquidity and credit risk are key determinants of asset prices, in general, it is important to quantify their relative effects and, particularly, how much they changed during the crisis. It is also relevant to ask if there are interactions between these factors, and whether these relationships changed substantially in magnitude and quality from prior periods. In this paper, we study liquidity effects in the US corporate bond market for the period October 2004 to April 2008 including the GM/Ford downgrades and the on-going sub-prime crisis, using a unique data-set covering basically the whole US corporate bond market. We employ a wide range of liquidity measures to quantify the liquidity effects in corporate bond yield spreads. Our analysis explores the time-series and cross-sectional aspects of liquidity for the whole market, as well as various important segments, using panel and Fama-MacBeth regressions, respectively.

Most major financial markets, including those for equity, foreign exchange, credit and commodities, have been severely affected in terms of price and liquidity in the current sub-prime crisis. However, the impact has been disproportionately felt in the fixed income markets, including the markets for collateralized debt obligations (CDO), credit default swaps (CDS) and corporate bonds. An important point to note is that these securities are usually traded in over-the-counter (OTC) markets, where there is no central market place, or even a clearing house. Indeed, this aspect has come under regulatory scrutiny since the near-collapse of the CDS market, which was an opaque OTC market. It is the OTC structure of fixed income markets that makes research, especially on liquidity effects, difficult as traded prices and volumes are not readily available, and important aspects can only be analyzed based on quotations from individual dealers, which may not necessarily be representative of the market as a whole.

US corporate bonds trade in an important OTC market. This market is an ideal laboratory to examine liquidity and credit factors because of the following reasons: First, in contrast to most other OTC markets, detailed transaction data are available on prices, volumes and other market variables since 2004, through an effort of the Financial Industry Regulatory Agency (FINRA), known as the Trade Reporting and Compliance Engine (TRACE). This database aggregates virtually all transactions in the US corporate bond market, which is unusual for any OTC market. Second, the US corporate bond market bore the brunt of the sub-prime crisis in terms of credit deterioration, almost to the same extent as the credit derivatives market to which it is linked by arbitrage/hedging activities. Third, there is considerable variation in credit quality as well as liquidity in this market, both over time and across bonds, providing researchers with the opportunity to examine the differences arising out of changes in liquidity.

For our empirical analysis, we use all traded prices from TRACE, along with market valuations from Markit, bid-ask quotations and bond characteristics from Bloomberg, and credit ratings from Standard & Poor's. Our combined data-set is perhaps the most comprehensive one of the US corporate bond market that can be assembled to date, covering 21,585 bonds and 3,108 firms.

This data-set enables us to study liquidity effects for virtually the whole bond market, including bond segments that show very low trading activity.[1]

The main focus of our research in this paper is on the quantitative impact of liquidity factors, while controlling for credit risk and other bond characteristics. To do so, we focus on the yield spread of a corporate bond, defined as its yield differential relative to that of a risk-free benchmark of similar duration. The benchmark could be either the Treasury bond or the swap rate curve.

In order to measure liquidity, we consider several alternative proxies for liquidity. First, we employ *bond characteristics* that have been used as liquidity proxies in many studies. Second, we use directly observable *trading activity variables* (e.g., the number of trades). Third and most important, we employ several alternative *liquidity measures* proposed in the literature, i.e., the Amihud, Roll, zero-return, bid-ask spread and price dispersion measure.

In the first part of our analysis, we examine the time-series behavior of the individual bond yield spread changes and quantify the liquidity component in panel regressions, while controlling for credit risk. The credit factor in these regressions is based on the credit rating of the bond. We distinguish between credit and liquidity effects for the whole time-series, as well as for three different regimes during our sample period, i.e., the GM/Ford crisis, the sub-prime crisis and the period in between, when market conditions were more normal. In these regressions, we compare the results for the individual liquidity proxies and assess their quantitative impact on bond yield spread changes.

Overall, we find that the liquidity proxies account for about one-tenth of the explained time-series variation of the yield spread changes over time for individual bonds. The credit rating as well as all the liquidity proxies we consider exhibit statistically as well as economically significant results. While the trading activity variables are statistically significant in explaining the bond yield spread changes, the liquidity measures exhibit stronger effects in terms of statistical and economic significance. In particular, measures estimating trading costs based on transaction data show the strongest effects. Furthermore, we find that the effect of the liquidity measures is far stronger in both the GM/Ford crisis and the sub-prime crisis: the economic significance of the liquidity proxies increased by 25% in GM/Ford crisis compared to the normal period, and even doubled in the sub-prime crisis.

We then compare the liquidity for different sub-segments of the bond market. First, the liquidity impact is expected to be stronger for speculative grade bonds compared with investment grade bonds, if liquidity concerns cause investors to abandon the junk bond market in favor of investment grade bonds in a *flight-to-quality*. Furthermore, this comparison permits an analysis of the interaction of credit and liquidity factors. Second, the relative importance of credit and liquidity factors of financial bonds compared to industrial (i.e., non-financial) bonds might be different, particularly during the sub-prime crisis. Third, the liquidity effects are likely to vary acrosss investor groups. We analyze this issue by a detailed examination of retail (small) vs. institutional (large) trades to see if there were any differences in the liquidity impact in these two segments of the market.

Comparing investment grade with speculative grade bonds, we find lower liquidity for specu-

[1]This is a major difference between our research and other related recent papers on the financial crises that, in general, focus on the more liquid bonds (see Bao et al. (2009) and Dick-Nielsen et al. (2009), for example.)

lative grade bonds as well as a stronger reaction to changes in liquidity. In general, these results indicate that the liquidity component is far more important in explaining the change in the yield spread for speculative bonds. Regarding financial vs. industrial bonds, we only find differences in liquidity during the sub-prime crisis where the liquidity proxies indicate higher liquidity for financial bonds. Given the sharp increase in the yield spread for financial bonds, we thus find evidence that during the sub-prime crisis, this increase is driven relatively more by credit risk. Analyzing retail trades vs. institutional trades, we find that retail investors are confronted with far higher transaction costs (up to 50%), i.e., they perceive the corporate bond market to be relatively less liquid. However, institutional investors seem to react more strongly to liquidity changes than their retail counterparts.

In the second part of our empirical analysis, we examine the cross-sectional behavior of the yield spread using Fama-MacBeth regressions. In general, the cross-sectional results paint a picture similar to the time-series analysis, i.e., liquidity is an important driver of cross-sectional differences in yield spreads, with measures estimating effective trading costs showing the sharpest effects. Interestingly, in the cross-section, bond characteristics show significant effects as well. Overall, the liquidity proxies account for about 10% of the explained cross-sectional variation in bond yield spreads. This ratio is similar for all three sub-periods.

We present a survey of the relevant literature in Section 2 of the paper, focusing mainly on papers relating to liquidity effects in corporate bond markets, rather than liquidity effects in financial markets, in general. In Section 3, we explain, in detail, the composition of our dataset and the filters and matching procedures we employ in combining data from four different data sources. Section 4 discusses the alternative measures of liquidity that have been proposed and used in the literature and their pros and cons. We focus, in particular, on the relevance of these measures for a relatively illiquid, OTC market. In Section 5, we outline the methodology, together with the basic hypotheses being tested in the paper and the economic motivation behind them. Section 6 presents the time-series results, based on panel regressions, and the results for the cross-sectional analysis based on the Fama-MacBeth procedure. Section 7 concludes.

2 Literature Survey

The academic literature on liquidity effects on asset prices is vast. Much of this literature focuses on the impact of liquidity and liquidity risk on equity returns. An early paper was by Amihud and Mendelson (1986), who first made the conceptual argument that transaction costs result in liquidity premia in asset prices in equilibrium. In turn, this causes the expected returns for investors with different trading horizons to deviate to compensate for the differences in their transaction costs. Following from this argument, for securities in positive net supply, there is an implicit clientele effect in equilibrium, under which illiquid securities are cheaper and yield higher expected returns to compensate for their illiquidity, and are held by investors with longer horizons, while liquid securities have the opposite characteristics. In the cross-section of assets, we would, therefore, observe a relationship between illiquidity and expected returns on an asset, holding other factors constant. This conclusion has been extended and modified in different directions and also tested in a host of asset markets. This literature, focusing mainly on equity markets, is surveyed by

Amihud et al. (2006).

Recent papers on credit risk modeling provide evidence for this theoretical argument for the corporate bond market and show that risk-free interest rates and credit risk are not the only factors that drive corporate bond prices. This result has been established based on reduced-form models (see, for example Longstaff et al. (2005)), and structural models (see, for example Huang and Huang (2003)), i.e., neither credit risk measured by the prices of CDS contracts nor asset value information from the equity market, can fully explain corporate bond yields. These papers argue that liquidity is likely to be an important additional factor to consider. They provide some support for this conclusion, however, based on market-wide rather than on detailed bond-specific evidence.

The empirical literature on liquidity effects in corporate bonds is much smaller than that for equity markets, and mostly based on recent evidence. An early exception is the paper by Fisher (1959), who used the amount outstanding of a bond as a measure of its liquidity to show that the yield spreads on (illiquid) bonds with a low amount issued tend to be higher. Recent papers suggest a whole range of liquidity proxies in the context of corporate bond markets. Several authors study the impact of liquidity, based on corporate yields or yield spreads over a risk-free benchmark. Most of these papers rely on indirect proxies based on *bond characteristics* such as the coupon, age, amount issued, industry, and credit rating; some papers additionally use market-related proxies based on *trading activity* such trade volume, number of trades, number of dealers and the bid-ask spread, see e.g., Elton et al. (2001), Collin-Dufresne et al. (2001), Houweling et al. (2005), Perraudin and Taylor (2003), Eom et al. (2004), Liu et al. (2004), Longstaff et al. (2005), De Jong and Driessen (2006), Edwards et al. (2007), and Acharya et al. (2009). Basically, all these papers find that liquidity is priced in bond yields. However, they find different magnitudes and varying importance of these basic liquidity proxies, but mostly at the market-wide level.

In the more recent literature, several alternative *liquidity measures* that are estimators of transaction costs, market impact or turnover, have been proposed and applied to analyze liquidity in the corporate bond market at the level of individual bonds. The *Roll measure* (see Roll (1984) and Bao et al. (2009)) interprets the subsequent prices as arising from the "bid-ask bounce": thus, the covariance of price changes provides a simple liquidity measure. A similar idea to measure transaction costs is proposed and implemented in the *LOT measure* proposed by Lesmond et al. (1999). The *Amihud measure* (see Amihud (2002)) relates the price impact of a trade to the trade volume. Trading activity itself is used in the *zero-return measure* based on the number of unchanged sequential prices and the *no-trade measure* based on time periods without trading activity (see e.g., Chen et al. (2007)). Mahanti et al. (2008) propose another measure known as *latent liquidity* that is based on the institutional holdings of corporate bonds, which can be used even in the absence of transaction data, and show that this relationship is robust and correlates well with other measures of liquidity. Jankowitsch et al. (2008) develop the *price dispersion measure*, which is based on the dispersion of market transaction prices of an asset around its consensus valuation by market participants. This metric directly results from a microstructure model of an OTC market, in which market frictions such as search costs for investors and inventory costs for dealers result in dispersion of prices around the fundamental price of the asset. Thus, this measure provides an estimate of effective transaction costs and could potentially be a superior estimate of real transaction costs in OTC markets.

Most of the early papers on bond market liquidity are based only on quotation data as reasonably complete transaction data were not available until a few years ago. However, some papers use restricted samples of the transaction data for certain parts of the corporate bond market to analyze liquidity, including Chakravarty and Sarkar (1999), Hong and Warga (2000), Schultz (2001) and Hotchkiss and Ronen (2002). Many more researchers focused on the issue of liquidity in the corporate bond market since the TRACE data on US corporate bond transactions started to become available in 2002, with more complete transaction data for the whole market being generated since October 2004. This new source of bond price information allows researchers to analyze many different aspects of the US corporate bond market, see e.g., Edwards et al. (2007), Goldstein and Hotchkiss (2007), Mahanti et al. (2008), Jankowitsch et al. (2008), Nashikkar et al. (2009), and Ronen and Zhou (2009).

It is especially interesting to examine how liquidity affects the corporate bond market in times of financial crisis. This is the central research question of the this paper. While much of the research on the current financial crisis is probably in progress, two recent papers do provide some early evidence on the impact of liquidity in the US corporate bond market. These include Bao et al. (2009) and Dick-Nielsen et al. (2009). Since these papers are more directly related to our own research, we present a brief summary of these papers and discuss the additional insights our paper provides.

Bao et al. (2009) use the TRACE data to construct the Roll measure as a proxy for liquidity. They use only bonds that existed prior to October 2004 from Phase I and II of the TRACE project, when the bond coverage was incomplete (around 1,000 bonds). They show that illiquidity measured by the Roll measure is quite significant in this market and much larger than would be predicted by the bid-ask bounce. At the market-wide level, their measure correlates with measures of market sentiment such as the CBOE VIX measure of equity market volatility. They also show that their measure exhibits commonality across bonds, which tends to go up during periods of market crisis. Further, they show that their measure is smaller for higher trade sizes. Finally, they relate the Roll measure to bond yield spreads in a cross-sectional regression setup and provide evidence that part of the yield spread differences across bonds is due to illiquidity.

Dick-Nielsen et al. (2009) combine the TRACE data using straight bullet bonds (around 4,000 bonds), with accounting data and equity volatility, as proxies for credit risk. They use a panel regression based on quarterly data to study the effects of five different liquidity measures and the defined credit risk variables. In general, they find a significant effect of liquidity, which increased with the onset of the sub-prime crisis. The price impact of trades and transaction costs are the most important measures in their sample. However, their multivariate regression results show somewhat mixed results for different rating classes.

There are several important differences between these prior papers and our own research in this paper. First, we employ a much larger data-set on transaction data on US corporate bonds than any prior papers, as our sample of 21,585 bonds basically covers the whole traded market. This is a major difference even compared with the recent work of Bao et al. (2009) and Dick-

Nielsen et al. (2009), who cover only a certain, generally the more liquid, sub-segment of the market. While conclusions regarding the more liquid segments of the market are interesting, it is important to remember that liquidity effects are likely to be exacerbated in the segments with less trading activity, for which most of the prior work has no evidence to offer. Second, based on this data-set we are able to examine liquidity effects in important segments of the market such as investment versus speculative grade bonds, bonds of financial versus industrial firms, and retail versus institutional trades in greater detail. Third, our research explicitly covers two crisis periods, which are analyzed separately: the broader sub-prime crisis, which is on-going, and the earlier, GM/Ford crisis, which affected particular segments of the US corporate bond market. We contrast the behavior of liquidity and its pricing in bond yield spreads, during periods of crisis with more normal periods. Fourth, we include the additional information on the market's consensus valuation of bonds provided by Markit. These data permit us to estimate the price dispersion measure for the bonds in our sample and, thus, include an important additional measure of transaction costs. This is particularly relevant for our research question, as transaction cost measures appear to be especially important in explaining liquidity in OTC markets.

3 Data Description

In this section we present the unique data-set we have at hand for this liquidity study covering basically the whole US corporate bond market. Our data are drawn from several different sources:

1. Transaction data from the Trade Reporting and Compliance Engine (TRACE),
2. Consensus market valuations from Markit,
3. Credit ratings from Standard & Poor's,
4. Bond characteristics from Bloomberg,
5. Treasury and swap data from Bloomberg, and
6. Bid/ask quotations from Bloomberg.

Our time period starts with the date when TRACE was fully implemented on October 1, 2004, and covers the period until April 30, 2008. TRACE provides detailed information about all transactions in the US corporate bond market, i.e., the actual trade price, the yield based on this price as well as the trade volume for each transaction.[2] Phase I of TRACE was launched by the Financial Industry Regulatory Agency (FINRA) in July 2002, with the aim of improving transparency in the US corporate bond market. This phase covered only the larger and generally higher-credit quality issues. Phase II expanded the coverage and dissemination of information to smaller investment grade issues. Since the final Phase III was implemented on October 1, 2004, transactions of essentially all US corporate bonds have been reported. Hence, the TRACE database has been reasonably complete since its final implementation. This data source is almost

[2]The reported trade volume is capped at \$1 million for speculative grade and unrated bonds and at \$5 million for investment grade bonds.

unique for an OTC market, since in many other cases, price information usually must be obtained either from an individual dealer's trading book, which provides a very limited view of the market, or by using bid/ask quotations instead. In the US corporate bond market, reporting of any transaction to TRACE is obligatory for broker-dealers and follows a set of rules approved by the Securities and Exchange Commission (SEC), whereby all transactions must be reported within a time frame of 15 minutes.

We use certain filters for the TRACE data to eliminate potentially erroneous data points: First, we delete reported trades that are obviously incorrect and subsequently corrected or deleted.[3] Second, we follow Edwards et al. (2007) and apply a *median filter* and a *reversal filter* to eliminate further potential data errors. Whereas the median filter identifies potential outliers in reported prices within a certain time period, the reversal filter identifies unusual price movements.[4] Eliminating any potential errors in the reported transactions reduces the number of reported trades by roughly 5% to 20.7 million trades. We finally end up with a data sample consisting of 31,911 bonds from 4,482 issuers. Most bonds are not traded on a daily basis: on average, per day, we observe about 7,100 traded bonds, 25,000 trades, and $9.7 billion in volume.

An important additional source for the market's valuation of a bond is obtained from Markit Group Limited, a leading data provider, specialized in security and derivatives pricing. One of its services is to gather, validate and distribute end-of-day composite bond prices from dealer polls. Up to thirty contributors provide data from their books of record and from feeds to automated trading systems (see Markit (2006)). These reported valuations are averaged for each bond after eliminating outliers. Hence, this price information can be considered as a market-wide average of a particular bond price, reflecting the market consensus. The Markit valuations are used by many financial institutions to mark their portfolios to market and have credibility among practitioners. In total, we have 4,635,765 Markit quotes, covering 26,597 bonds in our database.

In order to control for default risk, we use credit ratings from Standard & Poor's (S&P). We focus on long-term, issue credit ratings as the market's current judgement of the obligor's creditworthiness with respect to a specific financial obligation. It should be noted, that in our descriptive statistics of the rating variable, we assign integer numbers to ratings, i.e., AAA=1, AA+=2, etc., to measure the "average" rating of certain groups of bonds or time periods. Our time-period contains 23,531 bonds, which have at least one S&P credit rating each. Note that credit risk could be measured using alternative approaches. Two prominent examples come to mind: using CDS spreads in the context of a reduced-form credit risk model, as in Longstaff et al. (2005), or using accounting based/equity related data in a structural model context, as in Huang and Huang (2003). We do not incorporate such proxies as this information is generally only available for a very small (presumably more liquid) segment of the market and our intention is to explicitly analyze liquidity effects for the whole market. In addition, the impact of the liquidity on these data inputs would also have to be taken into account, rendering the analysis far more complex, and hence, prone to additional error. This is particularly true during periods of crisis

[3]To be more precise, we eliminated any transaction that needed more than 20 days to settle, had a negative reported price, were reported multiple times (corrected or deleted transactions) or were simply test cases.

[4]The median filter eliminates any transaction where the price deviates by more than 10% from the daily median or from a nine-trading-day median centered at the trading day. The reversal filter eliminates any transaction with an absolute price change deviating from the lead, lag and average lead/lag price change by at least 10%.

when liquidity and counterparty risk considerations are exacerbated in the pricing of CDS as well as equity contracts. Hence, we apply the more parsimonious approach of using only the credit ratings, with their admitted shortcomings, in terms of their own error and failure to anticipate changes in credit risk.

For each of the 31,911 bonds available in TRACE, we additionally have issue/bond characteristics from Bloomberg at hand. These bond characteristics include the issue date, maturity, age, coupon, amount issued, industry sector and bond covenants. Most of these characteristics have been considered as simple liquidity proxies by previous studies. Furthermore, we use swap rates and Treasury rates for various maturities retrieved from Bloomberg as the benchmark for the risk-free interest rate curve to compute the corporate yield spreads.

Moreover we also have end-of-day bid/ask quotations from Bloomberg. Bid-ask spreads are widely used as a liquidity proxy in academic studies and they are an important, albeit noisy, price metric for OTC markets where trades are not reported to a central authority. However, we have bid/ask quotations available only for a sub-sample of 4,531 bonds with 511,475 quotations. These bonds represent relatively larger issues where Bloomberg quotations exist in acceptable quality. This sub-sample of bonds is comparable to the bond samples used by Bao et al. (2009) and Dick-Nielsen et al. (2009).

Given these data-sets we compose two different samples: First, we generate a large sample which is representative of the whole market by merging the daily trade observations from TRACE with end-of-day Markit-quotations, the available S&P ratings and the bond characteristics. This sample covers 21,585 bonds of 3,108 firms. We observe, on average, 6,624 traded bonds, 23,304 trades and 8.5 billion in volume, per day. Our panel data set covers approximately 90% of the overall trading activity in the US corporate bond market. We find that the market coverage is on this high level throughout the whole observation period, and hence, is highly representative of the whole US corporate bond market. Note that we do not add Bloomberg quotes to our large data sample since bid/ask quotations are only available for a limited number of bonds which would drastically reduce the sample size. However, we generate a second smaller sample in which we merge all data sources, including the Bloomberg bid/ask quotations, so that we are also able to compare the performance of this commonly used liquidity measure with other liquidity proxies. This sample contains 4,531 bonds of 700 firms for which we observe, on average, 1,376 traded bonds, 7,213 trades and 1.9 billion in volume per day, i.e. the market coverage is only about 25%, measured by trading activity. Note that most of our analysis focuses on the large sample as we are interested in liquidity effects for the whole US corporate bond market.

4 Liquidity Proxies

This section presents the various liquidity proxies that we use in the regression analysis as explanatory variables. A number of liquidity proxies have been proposed in the literature (see Section 2) which are not all equally viable, given the challenges of obtaining detailed and sufficiently frequent data in the relatively illiquid corporate bond market. Our data-set allows us to compare the efficacy of most of these proposed proxies in this empirical study. We classify the available proxies into three groups: *bond characteristics*, *trading activity variables* and *liquidity measures*.

Bond characteristics, such as the amount issued, are simple liquidity proxies which provide a rough indication of the potential liquidity of a bond. Trading activity variables, such as the number of trades, provide bond-specific information based on transaction data. Liquidity measures, such as the price dispersion and Amihud measure, are alternative estimators of transaction costs or market impact.

All these liquidity proxies can either be calculated on a daily basis, given that price information is observable for a particular bond, or are time-invariant (e.g., coupon) or change linearly with time (e.g., age). In the following sub-sections, we present the definitions of the various liquidity proxies that we use in our analysis and discuss the details of their computation.

4.1 Bond Characteristics

The bond characteristics we consider as liquidity proxies are the *amount issued*, *coupon*, *maturity*, *age*, and an *industry variable* identifying bonds issued by financial firms. These proxies, while admittedly crude measures, make intuitive sense. In general, we expect bonds with a larger amount issued to be more liquid and bonds with a larger coupon to be less liquid. Bonds with long maturities (over ten years) are generally considered to be less liquid since they are often bought by "buy-and-hold" investors, who trade infrequently. Similarly, we expect recently issued (on-the-run) bonds to be more liquid. The industry variable provides information about the different liquidity effects of financial compared to industrial firms. We consider these measures to be important only for our cross-sectional analysis, as most of these are either constant over time (e.g., coupon) or change linearly (e.g., maturity).

4.2 Trading Activity Variables

A bond's trading activity provides information about liquidity. In this sense, higher trading activity generally indicates higher liquidity. We consider the following trading activity variables: *number of trades*, *trade volume* and *trading interval.* We compute the number of trades and the trade volume of a particular bond on each day from the trading information given by TRACE. The trading interval is the elapsed time (measured in days) of a bond since the last day it was traded. Longer trade intervals indicate less trading activity and, thus, lower liquidity. Therefore, we expect liquidity to be higher for bonds with shorter time intervals between trading days.

4.3 Liquidity Measures

Amihud Measure. This is a well-known liquidity measure originally proposed for the equity market by Amihud (2002), which is conceptually based on Kyle (1985). It relates the price impact of trades, i.e., the price change measured as a return, to the trade volume. The Amihud measure at day t for a certain bond over a particular time period with N_t observed returns is defined as the average ratio between the absolute value of these returns r_j and its trading volumes v_j, i.e.,

$$\mathrm{Amihud_t} = \frac{1}{N_t}\sum_{j=1}^{N_t}\frac{|r_j|}{v_j}.$$

A larger Amihud measure implies that trading a bond causes its price to move more in response to a given volume of trading, in turn, reflecting lower liquidity. We use the daily volume-weighted average TRACE prices to generate the returns r_j and calculate the Amihud measure on a day-by-day basis.

Price Dispersion Measure. A new liquidity measure recently introduced for the OTC market is the price dispersion measure of Jankowitsch et al. (2008). This measure is based on the dispersion of traded prices around the market-wide consensus valuation. A low dispersion around the valuation indicates that the bond can be bought close to its fair value and, therefore, represents low trading costs and high liquidity, whereas high dispersion implies high transaction costs and hence low liquidity. This measure is derived from a market microstructure model and shows that price dispersion is the result of market frictions such as inventory risk for dealers and search costs for investors. It presents a direct estimate of trading costs based on transaction data. As in Jankowitsch et al. (2008) the traded prices are obtained from TRACE and the market valuations from Markit. The price dispersion measure is defined as the root mean squared difference between the traded prices and the respective market-wide valuation weighted by volume, i.e., for each day t and a particular bond, it is given by

$$\text{Price Dispersion}_t = \sqrt{\frac{1}{\sum_{k=1}^{K_t} v_k} \sum_{k=1}^{K_t} (p_k - m_t)^2 v_k},$$

where p_k and v_k represent the K_t observed traded prices and their trade volumes on date t and m_t is the market-wide valuation for that day. Hence, the price dispersion indicates the potential transaction cost for a trade.

Roll Measure. This measure developed by Roll (1984) shows that, under certain assumptions, adjacent price movements can be interpreted as a bid-ask bounce which, therefore, allows us to estimate the effective bid-ask spread. This bid-ask bounce results in transitory price movements that are serially negatively correlated and the strength of this covariation is a proxy for the round trip costs for a particular bond, and hence, a measure of liquidity. More precisely, the Roll measure is defined as

$$\mathrm{Roll_t} = 2\sqrt{-\operatorname{Cov}(\Delta p_t, \Delta p_{t-1})},$$

where Δp_t is the change in prices from $t-1$ to t. We compute the Roll measure based on the daily volume-weighted bond prices p_t from the TRACE data-set, where we use a rolling window of 60 days and require at least 8 observations to determine the covariance.

Bid-Ask Spread. The bid-ask spread is a simple measure of the transaction costs of bonds. The calculation is straightforward as this liquidity measure is estimated by the difference between the ask- and the bid-quote reported in Bloomberg. The bid-ask spread is based only on quotations and is used in most liquidity studies for OTC markets, where transaction data are generally not available. Thus, the comparison of this measure with the Roll and price dispersion measure is especially interesting.

Zero-Return Measure. The zero-return measure indicates whether we observe a zero price movement between trading days. The zero-return measure is set to 1 if we find an unchanged price, and to 0 otherwise. Bond prices that stay constant over long time periods are likely to be less liquid, as the information may be stale. Obviously, such a measure can only be based on price quotations or valuations, such as Markit quotes or Bloomberg mid-quotes in our case. Constant price information over time in these data sources reveal illiquidity as unchanged quotations may indicate an incomplete coverage of the bond.

5 Methodology

This section outlines our general approach to measuring the impact of liquidity and credit risk on pricing in the US corporate bond market. We present here our definitions of the bond yield spread. We define the sub-periods of interest as well as the market segments that we study in greater detail. We then present the specifications for our panel data regressions to explore the time-series properties, and the Fama-MacBeth regressions to explore the cross-sectional properties of our data. We also discuss the specific hypotheses we test.

5.1 Bond Yield Spread

The dependent variable in our setup is the corporate bond yield spread, represented by the yield differential relative to that of a risk-free benchmark. We define this benchmark as the yield of a risk-free zero-coupon bond with a maturity equal to the duration of the corporate bond. We compute this duration based on the reported yield in the TRACE database and the corporate bond's cash flow structure. Note that we do not incorporate adjustments for optionalities or covenants included in the bond structure to determine the duration. Overall, yield spreads based on this duration adjustment can be considered as a proxy for the zero-coupon yield spread taken from a more complete pricing model.[5]

We use both the Treasury yield curve and the swap curve as risk-free benchmarks to calculate the bond yield spreads. We find that the general structure of the resulting yield spread is basically identical for both benchmarks. However, as expected, the yield spread based on the swap curve is shifted downwards compared to the spread based on the Treasury curve, indicating that the swap curve represents market participants with AA ratings with greater credit risk, while the Treasury curve represents lower credit risk. We conduct all our regression analysis on both spread series; however, as the results are basically identical, we report only the results for the spreads against the Treasury benchmark in the empirical results section.

We calculate the bond yield spread for every price/yield observation in the TRACE data-set. Thus, we may have more than one spread observation for a given bond on a particular day, since

[5]Given the complexity of these models and the limited information available for their calibration, we presume that the resulting zero-coupon yield spread would not improve the economic interpretation of our results, in general. To test this assumption, we have employed regression analyses for a sub-sample of straight coupon, bullet bonds without any option-features. For this sub-sample, we find similar results, confirming our conjecture.

there may be multiple trades for the bond on that day. Hence, to get a single value for the yield spread for each day, we estimate the bond spread from the individual observations by calculating a volume-weighted average for the day, i.e., we implicitly assume that the spread information is reflected more strongly in large trades. These daily spread observations for each bond are the basic data used in our regressions.

5.2 Sub-Periods of Interest

We are interested in how the explanatory power of the independent variables differs in financial crises compared to normal market environments. Therefore, we define the following three sub-periods: The *GM/Ford crisis* (March 2005 to January 2006) when a segment of the corporate bond market was affected, the *sub-prime crisis* (July 2007 to April 2008), which was much more pervasive across the corporate bond market, and the *normal period* in between (February 2006 to June 2007). We choose the start and end dates of the sub-periods based on exceptional events that are believed to have affected market conditions (see Figure 1.)[6]

5.3 Sub-Segments of Interest

In addition to the market-wide data series, we analyze sub-segments of the market based on the following criteria to provide further insights into the issue of liquidity. First, we analyze investment grade bonds (AAA to BBB-) compared to speculative grade bonds (BB+ to C) allowing a comparison of the interaction of credit and liquidity factors.[7] Second, we compare the bonds issued by financial firms with bonds issued by industrial (i.e., non-financial) firms.[8] Even casual evidence suggests that financial firms were much more affected by the sub-prime crisis, which ought to be reflected in the relative importance of credit and liquidity factors for these bonds compared to those of other firms. Third, we compare bonds traded by retail versus institutional investors. We use the average trade size for each bond on each day as the basis for the classification of trades into these two groups. If the average trade size is below $75,000 for a particular bond, we consider it to be a bond with mainly retail trading on that day, and otherwise, we classify it as a mainly institutionally traded bond.[9]

[6] Alternative definitions of these sub-periods could have been used. Therefore, as a stability test, we varied the start and end dates of the sub-periods by up to one month. However, we find similar results, and hence, report only results for the three sub-periods defined above.

[7] We use this definition instead of the individual ratings because the more granular classification by the individual rating class would result in very high number of interaction terms in the regression analysis. However, regressions run for individual credit ratings show that the important stylized facts are already reflected by the investment/speculative grade grouping.

[8] We use the Bloomberg classification for this purpose. This classification is not based on the classification of the parent entity of the issuer, but the industry in which the particular subsidiary operates. For example, a bond issued by GE Capital would be classified as "financial" while one issued by GE, the parent, would be classified "industrial."

[9] As the TRACE database does not have an identifier for the type of trader, the trade size is the best available proxy. Trade size is admittedly a somewhat noisy metric of the type of trader, but is the best available. It is possible that institutional traders break up their trades into small lots. However, our size metric is small by institutional standards and so this may not be too much of a concern. As a robustness check, we have also estimated our time-series models using different trade size limits to separate retail from institutional trading. However, the results are basically identical.

5.4 Panel Data Regression

We rely on a panel data regression approach to analyze bond yield spread changes. We use first differences, as we observe that yield spreads are integrated. Since we observe autocorrelated yield spread changes, we add one autoregressive parameter to our specifications.[10] Of course, in this difference specification, the static bond characteristic variables drop out. Thus, our panel consists of the pooled time-series of the first differences of the bond yield spread. We use the first differences of the trading activity variables and of the liquidity measures as explanatory variables. Furthermore, we add changes in rating class dummies to the regression to consider credit risk related effects on the yield spread:

$$
\begin{aligned}
\Delta(\text{Yield Spread})_{i,t} \quad = \quad & \alpha_0 + \alpha_1 \cdot \Delta(\text{Yield Spread})_{i,t-1} + \boldsymbol{\beta} \cdot \Delta(\text{Rating Dummies})_{i,t} \\
& + \boldsymbol{\gamma} \cdot \Delta(\text{Trading Activity Variables})_{i,t} \\
& + \boldsymbol{\lambda} \cdot \Delta(\text{Liquidity Measures})_{i,t} + \epsilon_{i,t}
\end{aligned}
$$

Our basic time-series data are at a daily frequency. However, because of computational restrictions due to the large sample size, we create weekly averages of all variables from daily data for each bond. Thus, all the time-series regression results presented in the empirical results section below are based on weekly data.[11] Note that we use logarithmic values of the traded volume in the regressions, as is common practice.

5.5 Fama-MacBeth Cross-Sectional Regression

These regressions are at the bond level and, therefore, allow for somewhat different cross-sectional analysis compared to their panel data regression counterparts. In particular, we can test for the importance of static bond characteristics in explaining the cross-sectional differences in yield spread. The regressions are performed with the bond yield spreads in levels rather than changes with the following structure:

$$
\begin{aligned}
\text{Yield Spread}_i \quad = \quad & \alpha_0 + \boldsymbol{\alpha_1} \cdot \text{Rating Dummies}_i + \boldsymbol{\beta} \cdot \text{Bond Characteristics}_i \\
& + \boldsymbol{\gamma} \cdot \text{Trading Activity Variables}_i + \boldsymbol{\lambda} \cdot \text{Liquidity Measures}_i + \epsilon_i
\end{aligned}
$$

We run this regression based on weekly averages from the daily data of all variables. Thus, we have the cross-sectional regression result for each week and we use the Fama-MacBeth procedure to report the regression parameters and t-statistics. We present the results of this procedure for the sub-periods defined earlier. This approach allows us to analyze liquidity effects in times of regular market conditions and financial crises, across bonds. Again, we use logarithmic values of the traded volume and the amount issued in the regressions.

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[10] We investigated alternative specifications of the time-series model, including different lags of the autoregressive parameters, and find that the results are very similar for these specifications.

[11] As a robustness check we compared our results for the small sample by additionally running the regressions based on daily frequency data. We find very similar results.

5.6 Hypotheses

Based on the methodology presented above, various hypotheses regarding the effect of liquidity in the US corporate bond market can be tested. In the following, we give an overview of the hypotheses we analyze in the results section.

The main issue we study is whether liquidity is priced in the US corporate bond market, in general, and whether the effect of liquidity is stronger in times of financial crises. Our hypothesis is that liquidity is an important priced factor, and an even more important one in financial crises. The panel data regressions would examine whether changes in liquidity measures, *over time*, can explain yield spread movements; the Fama-MacBeth regressions explore whether the liquidity proxies can explain yield spread differences *across bonds*. Additionally, the three sub-periods can show the relative importance of the different measures during financial crises compared with the period of more normal market conditions.

The second research question is whether the credit rating is related to liquidity effects. In this analysis, we will particularly focus on investment grade vs. speculative grade bonds. Our hypothesis is that liquidity is generally better in the investment grade sector; thus we expect to find an interaction between credit and liquidity risk.

The third question is whether bonds of financial firms react differently to liquidity in periods of crises than industrial bonds. Our conjecture is that, in general, financial bonds are more liquid, on average; however, we presume that bonds issued by financial firms are particularly affected in periods of financial crisis, such the sub-prime crisis.

The fourth question compares retail trading to institutional trading. Our hypothesis is that retail traders are confronted with higher transaction costs, and thus, lower liquidity, compared with institutional traders. We presume that this difference would be less pronounced in times of crisis.

6 Empirical Results

6.1 Descriptive Statistics

This section provides summary statistics for the US corporate bond market based on our matched data sample of 21,585 bonds (see Section 3).[12] Table 1 reports the cross-sectional variation of the main variables used in our empirical analysis, i.e. the yield spread, the credit rating and the liquidity proxies (bond characteristics, trading activity variables and liquidity measures). For time-varying explanatory variables, the statistics are computed as the time-averages for each individual bond. The table reports the 5th, 25th, 50th, 75th and 95th percentiles, as well as the mean and standard deviation of each variable. It provides an aggregate picture of the substantial cross-sectional variation of the variables.

For example, the yield spread between the 5th and 95th percentiles ranges from 46 to 519 bp with a mean of 179 bp. Part of this enormous variation is obviously due to credit risk given that

[12] Note that we also report numbers for the bid/ask spread and the zero return measure based on Bloomberg data in the tables presented. These numbers are obviously only available based on the bonds of our small sample and, therefore, cannot be directly compared to the other summary statistics. Due to space limitations, we do not report all the descriptive statistics for both samples.

our sample contains bonds with credit ratings all the way from AAA (=1) to C (=21). The average credit rating is roughly 7 which corresponds to A- and a standard deviation of approximately 4 rating notches.

As is to be expected, there is a reasonable variation in the bond characteristics of amount issued, coupon, maturity, and age across bonds, e.g. the amount issued varies from 10 million to 1.15 billion between the 5th and 95th percentile. Regarding trading activity variables we find, that the average frequency of bond trading is every 5 days. For a bond that is traded on a particular day, we observe an average of 3.3 trades with an average trade size of roughly 1.6 million dollars, with substantial cross-sectional variation.

Concerning the liquidity measures, the mean value of the Amihud measure is $36 \cdot 10^{-6}$, which indicates that trading one million dollars in a particular bond shifts the price by 36 bp on average. The variation is remarkably high and ranges between 0.44 and 127 bp, a factor of around 300 for the 5th and the 95th percentiles. The price dispersion indicates the cost of a single transaction for which we observe a mean of around 43 bp with similar variation across bonds as the Amihud measure. For the Roll measure, which corresponds to the round-trip costs, we observe an average value of 134 bp. Interestingly, this mean value is more than twice as large as the mean value of the price dispersion measure. Another measure of round-trip costs is the bid-ask spread for which we find a mean value across bonds of roughly 41 bp and a variation between 10 and 85 bp for the 5th and the 95th percentiles. Considering the zero-return measures, we find that these are mostly zero, indicating very few observations of stale prices or quotations.

To gain a better understanding of the time-series behavior of the bond yield spread over the whole time period, we compute the count-weighted average of the daily yield spreads over all bonds in our sample.[13] Figure 2 shows this time-series of the market-wide average corporate bond yield spread, indicating the dramatic increase of the spreads, during the two crisis periods, and especially in the sub-prime crisis.

To focus the role of liquidity risk in financial crises, we next analyze three different sub-periods of our overall sample. We present the results for the two different crisis periods (the GM/Ford crisis and the sub-prime crisis) and compare them with those for the period in-between, which can be considered as a period with more normal market conditions. The analysis of the means and standard deviations of the variables in these three periods allows us to gain some important insights into the causes of the variation (see Table 2.) The top panel of the table presents information about the yield spread and the credit rating as well as the daily market-wide trading activity (i.e., number of traded bonds, trades and volume). The bottom panel provides the liquidity proxies computed for each sub-period.

The average yield spread in the normal period of 1.78% is less than in the GM/Ford crisis with 2.21%, and even less so than in the sub-prime crisis with 3.28%, documenting the strong impact of the on-going crisis on yield spreads for the whole market. This evidence is also shown in Figure 2. As expected, the yield spreads are more volatile in the crisis periods.

The averages of the market-wide trading activity variables are also illustrative. During the GM/Ford crisis, trading activity is slightly higher in terms of trades and volume than in the normal

[13]We also examine the behavior of bond yield spreads, weighted by the volume of trading and by the amount outstanding of the individual bonds, both of which show a similar pattern.

period. However, in the sub-prime crisis, we find a considerable reduction (of approximately 15%) in the three trading activity variables compared to the prior periods. For example, the number of bonds traded each day dropped during the sub-prime crisis, from roughly 7,000 on average, to a little under 6,000. The volume of trading as well as the number of trades showed a similar decline. Perhaps the type of liquidity changes that occurred during the two crisis periods was structurally different. During the GM/Ford crisis, there was some shuffling of bond portfolios to account for the shifts in credit ratings, particularly in the automobile sector. In contrast, during the sub-prime crisis, overall market liquidity was affected. This is also evidenced by the changes in the average credit rating in the different sub-periods. The credit rating of the average bond traded during the GM/Ford crisis was somewhat worse than during normal times. In contrast, the credit rating of the average bond traded during the sub-prime crisis was slightly better than during normal times, indicating a *flight-to-quality* during the sub-prime crisis: the average rating is 8.20 for the GM/Ford crisis, 7.94 for the normal period, and 7.54 for the sub-prime crisis.

The bottom panel of Table 2 presents similar evidence for the averages of the daily bond-level liquidity proxies. Considering the average price dispersion measure, as one example, we find that the average value is higher in both crises (48.82 bp in the GM/Ford crisis and 83.53 bp in the sub-prime crisis) compared to the normal period (40.72 bp). It is noteworthy that the price dispersion, Amihud and Roll measures, all appear to increase during the two crisis periods, whereas we do not observe a similar change in the bid-ask spread. With regard to the trading activity variables we find that the average daily volume at the bond-level is higher in the GM/Ford crisis and lower in the sub-prime crisis compared to the normal period, which is consistent with the level of market-wide trading activity. Interestingly, the number of trades increases in both periods of crisis, from which we can conclude that, in the sub-prime crisis, a higher number of smaller volumes were traded. We do not observe significant differences in the trading interval. Additionally, we find that the liquidity proxies are more volatile in the crisis periods.

Table 3 presents the correlations between the various liquidity proxies within our panel data. Overall, we find the expected patterns: in general, there is positive correlation among the trading activity variables (e.g. the correlation between volume and number of trades is 0.37) and among the liquidity measures estimating trading costs (i.e., the correlation between Amihud, Roll, price dispersion measure and bid-ask spread is between 0.07 and 0.19). However, the general level of correlation appears to be relatively low. Thus, correlation measured at the individual bond level over time shows that the liquidity proxies have substantial idiosyncratic movements. This suggests that the various liquidity proxies are measuring somewhat different aspects of liquidity empirically, although at a conceptual level they are related.[14] Therefore, for our empirical work, the issues of multi-collinearity may not be as severe as one may suspect, at first glance. Note that once correlations in our sample are measured at a more aggregate level (e.g., averaging across time or across bonds) the correlations are much higher. Thus, it is important not to analyze the bond market based solely on aggregated data, but also at the level of individual bonds, as we do here, to distinguish between the effects of the various liquidity proxies.

[14] Along the same lines, a principal component analysis (not reported here) shows that the liquidity proxies can only be represented by a relatively large number of components.

6.2 Panel Data Regressions

In this section, we present the empirical results for the panel data analysis exploring the time-series properties of the bond yield spread changes based on the credit rating, the liquidity proxies introduced in Section 4 and the methodology presented in Section 5. We analyze the overall time-period as well as the three sub-periods defined earlier (GM/Ford crisis, normal period, and sub-prime crisis.) In the second part of the empirical analysis, we investigate the impact of liquidity for various sub-segments of the market: investment grade vs. speculative grade bonds, financial vs. industrial bonds, and retail vs. institutional trades.

The regressions are based on our large sample of data consisting of 637,502 bond-week observations. The results are given in Table 4. This table presents four different specifications. In Regression 1, we use a specification without the liquidity proxies, which can be compared to the other specifications, allowing us to explore the increase in explanatory power after including liquidity proxies. Note that there is reasonable explanatory power in this specification, which includes the information contained in the dummy variables based on the credit ratings and the persistence of bond yield spreads in terms of first differences measured by the lagged term. The next three specifications present the results of the panel regressions using the liquidity proxies (i.e. trading activity variables and liquidity measures).[15] Regression 2 reports the results with the trading activity variables only, while Regression 3 reports them with the liquidity measures only. Regression 4 includes both types of liquidity proxies.

Focusing on the model including all variables, the results of Regression 4 show that all the liquidity proxies are statistically significant in explaining the changes in the bond yield spreads. Among the trading activity variables, changes in the volume and trading interval have the highest t-statistics, while among the liquidity measures, changes in the Amihud measure and the price dispersion measure are the most important. Interestingly, despite the correlation across the liquidity measures, they are sufficiently different across bonds and time that they are all incrementally relevant in explaining the changes in the bond yield spreads. All variables have the expected signs except for two liquidity proxies: the number of trades and the zero-return measure. With regard to the zero-return measure, its economic significance is very low, as discussed below. Thus, we conclude that this measure might not be meaningful. Regarding the number of trades, we find that an increase in the number of trades increases the yield spread. Given a certain volume, this result could either arise due to sell-side pressure, as more institutional orders are broken up to be placed in the market, or it could indicate an increase in retail trading, as might be the case during the GM/Ford crisis.

In terms of the improvement in R^2, the liquidity measures are more important (a relative improvement of about 7%) compared to the trading activity variables (a relative improvement of about 5%). When both sets of variables are included, the R^2 improves by around 10%. The Amihud measure turns out to be the most important explanatory variable in these regressions in economic terms. A one standard deviation in the change in the Amihud measure explains about

[15] Since the regressions are based on the *change* in the bond yield spread, the static bond characteristics, such as coupon, drop out of the specification since they are fixed effects. Others, such as age, vary linearly with time and are absorbed in the constant term.

4.1 basis points of the change in the bond yield spread in Regression 4.[16] Similar statistics for the price dispersion measure, trading interval, and volume are 1.6, 2.5 and 2.6 bp respectively. The smallest impact is provided by the Roll measure (0.2 bp) and the zero-return measure (0.6 bp). These two measures seem not be particularly relevant given their low economic significance. Considering all liquidity proxies together, a one standard deviation move in the direction of greater illiquidity in all proxies would increase the spread by 12.8 bp. When compared with the volatility of the yield spread changes of 55.7 bp, these numbers show that liquidity is an important factor driving yield spread changes.

In addition to the liquidity proxies obtained from transaction data, we also obtained data on the bid-ask quotes from Bloomberg. Based on these quotes, we compute the bid-ask spread for each bond and the zero-return measure. Unfortunately, these data are only available for a sub-sample of bonds. The inclusion of these two variables, therefore, causes the sample size to be reduced dramatically from 637,502 to 138,540.

Despite this substantial reduction in sample size, we nevertheless run the panel regressions once again, with the two additional variables (i.e. the bid-ask spread and the Bloomberg zero-return measure.) The results are reported in Table 5. The overall findings are quite similar to those for the full sample. Interestingly, the two measures with the lowest economic impact in the large sample (i.e. the Roll measure and the Markit zero-return measure) are not significant in this sub-sample, strengthening the view that these measures are of minor importance. The change in the bid-ask spread is statistically significant, while the change in the Bloomberg zero-return measure is only marginally so. Both parameters exhibit the expected sign. However, the R^2 improves only marginally when the proxies based on the bid/ask quotations are included. The economic significance of these two proxies is relatively low with an impact of 0.3 and 0.5 bp, respectively, for a move by one standard deviation.

Thus, we find that the inclusion of proxies based on the bid/ask quotations only provides marginal improvements in the explanatory power. This result indicates that it is essential to have liquidity proxies based on transaction data available, which is generally not possible for most OTC markets. This stresses the importance of market transparency resulting from the dissemination of price information, which is being proposed by various legislators and regulators, in the aftermath of the financial crisis.

We next analyze the behavior of the changes in the yield spreads in the different sub-periods, using the same specification as before, but with dummy variables for the sub-periods.[17] More importantly, we include interaction terms between the liquidity proxies with the dummy variables for the two crisis sub-periods. This setup allows us to analyze whether the yield spread changes are more sensitive to liquidity changes in times of crises. The results are presented in Table 6.

Overall, we find that liquidity is far more important in times of crises. During the sub-prime crisis period, we find that nearly all the liquidity proxies have a statistically significantly higher impact on the changes in the bond yield spreads. The most important ones are the price dispersion

[16]Note that the calculation of the economic significance is based on the standard deviation of the first differences of the variables. Due to space limitations we do not report details concerning these statistics for the first differences.

[17]Since the inclusion of proxies based on the bid/ask quotations results in a substantial shrinkage in sample size, with only a modest improvement in explanatory power, we present the remaining analyzes only for the full sample, without using the Bloomberg bid- and ask-quotes.

and Amihud measure, where the coefficient of the price dispersion increases by 300% and that of the Amihud measure by about 25%. A similar result can be found for the GM/Ford period, although the effects are not quite as strong. We do not observe a statistically significant increase in all proxies for the GM/Ford period, and also, the magnitude of the increase seems to be smaller. However, an F-test shows that we can reject at a 1% level the hypothesis that the interaction terms for each period of crisis are jointly zero.

In terms of the improvement in R^2, we find that the inclusion of the interaction terms leads to a relative increase of about 5%, highlighting the importance of adding these terms. Considering the economic significance, a one standard deviation move in all proxies in the direction of greater illiquidity would increase the spread by 8.7 bp in the normal period compared to 10.9 bp and 18.5 bp in the GM/Ford and sub-prime crisis periods, respectively. Thus, we find a far higher impact of the liquidity proxies in the crisis periods: the economic significance doubles during the sub-prime crisis and increases by 25% in the GM/Ford crisis. The ranking of the economic importance of the individual liquidity proxies in the different time periods stays approximately the same with the Amihud measure showing the highest impact in all periods (3.5 bp in the normal period, 4.0 bp in the GM/Ford period and 5.0 bp in the sub-prime period).

In sum, we find a significant increase, in both statistical and economic terms, of the liquidity component in the crisis periods. The next section presents our results for various sub-segments of the market showing the liquidity impact for individual groups of bonds.

6.2.1 Investment vs. Speculative Grade

In this section, we analyze the time-series properties of bond yield spreads grouped by rating classes. We divide the bonds into investment grade (AAA to BBB-) and speculative grade (BB+ to C/CCC), expecting the liquidity effects of speculative grade bonds to be more pronounced. This analysis allows us to explore the interaction between credit and liquidity risk.

Figure 3a shows the yield spreads for the two time-series at the market-wide level. As expected, the bond yield spread for investment grade bonds is always lower than that for speculative bonds. However, we stress three important points here: First, the GM/Ford crisis is mainly reflected in the speculative grade yield spreads, as the GM/Ford bonds were downgraded to junk bond status and probably had spillover effects in the whole corporate bond market; second, in the normal period, the difference between investment and speculative grade spreads systematically shrinks over time, reflecting the decreasing risk premiums, which received widespread attention in the popular press; third, in the sub-prime crisis, basically both spread series increase dramatically by a factor of about three.

Table 7a presents the descriptive statistics of the yield spread, rating and market-wide trading activity for the two sub-segments in the three different periods. We find that, in general, trading is focused on the investment grade segment. In the GM/Ford crisis, we find for the speculative grade segment a higher trading activity compared with the normal period, perhaps due to the trade volume caused by a shuffling of bonds, due to clientele preferences as a consequence of the downgrades. In the sub-prime crisis, we find lower trading activity for both segments. However, only the investment grade segment shows a flight-to-quality indicated by trading in better rated bonds compared to the normal period.

Table 7b presents the descriptive statistics of the liquidity proxies for the two sub-segments. In general, we find that the liquidity proxies clearly indicate lower liquidity for speculative grade bonds, e.g., the price dispersion measure is 52.0 bp vs. 35.8 bp for investment grade bonds in the normal period. In the crisis periods, the liquidity of bonds in both groups deteriorates. Interestingly, the difference in the liquidity proxies between the two groups is less pronounced in the crisis periods among the bonds that are traded, i.e., the liquidity decreases relatively more for the investment grade segment especially in the sub-prime period, e.g., we observe a price dispersion measure of 80.4 bp for investment grade vs. 91.1 bp for speculative grade bonds in this period.

Regression 1 in Table 10 presents the results for the panel data regressions using a dummy variable for speculative grade bonds and, more importantly, including interaction terms between this dummy and the liquidity proxies. Overall, we find that speculative grade bonds react more strongly to changes in liquidity. Thus, we find a significant interaction between credit and liquidity risk. On average, bonds with higher credit risk are less liquid and react more strongly to liquidity changes. We find that the Amihud measure and the trading activity parameters are significantly higher (in absolute terms) for speculative grade bonds. The other parameters stay at the same level. An F-test reveals that we can reject at a 1% level the hypothesis that the interaction terms between credit and liquidity risk are jointly zero.

6.2.2 Financial vs. Industrial Bonds

In this section, we analyze the time-series properties of bond yield spreads of financial vs. industrial bonds. Financial crises are obviously stress scenarios for firms in the financial industry. Especially during the sub-prime crisis, the financial industry was hit by severe losses in financial instruments often related to credit risk, starting with the (structured) sub-prime market and spreading rapidly to other markets. Therefore, it is an interesting research question whether yield spreads of corporate bonds issued by firms in the financial industry show a different relation to liquidity and credit risk, compared with their industrial counterparts.

Figure 3b shows the time-series of the yield spreads for financial and industrial bonds. In the normal period, financial firms have lower bond yield spreads compared with industrial firms, whereas in times of crises, these differences are closer to zero, and are even negative sometimes, indicating that the yield spread of financial firms reacts strongly in such periods.

Table 8a presents the yield spread, rating and market-wide trading activity for the two sub-segments in the three different periods. We find that, in general, in the industrial segment, a higher volume in lower rated bonds is traded compared to the financial segment. Both segments show an increase in trading activity measured by the volume and number of trades in the GM/Ford crisis and a significant reduction in the sub-prime crisis. Interestingly, in the sub-prime crisis, financial bonds with better-than-average ratings are traded. This indicates a flight-to-quality for the financial segment.

Table 8b presents the descriptive statistics of the liquidity proxies for the two sub-segments. Particularly in the sub-prime period, we find that the liquidity proxies clearly indicate lower liquidity for industrial bonds (with the exception of the Roll measure, which is slightly higher for financial bonds). Given the sharper increase in yield spread for financial bonds (see Figure 3b) in the sub-prime crisis, this may indicate that the spread increase for financial firms was induced relatively more by higher credit risk compared to industrial firms. In the normal and the GM/Ford crisis periods, neither the trading activity variables nor the liquidity measures exhibit similar differences in terms of liquidity.

Regression 2 in Table 10 presents the results for the panel data regressions using dummies for financial bonds and interaction terms between these dummies and the liquidity proxies. Overall, we find that financial bonds react more strongly to changes in trading activity variables. For the liquidity measures we either find no difference in the reaction to liquidity changes, or mixed results, e.g., a higher parameter value for the price dispersion measure, but lower parameter values for the Amihud measure. This could indicate that financial bonds show the same reaction to trading cost changes as their industrial counterparts, but they react more strongly to a general reduction of trading activity, i.e., the potential to trade larger volumes seems to be of importance for investors in financial bonds. An F-test reveals that we can reject at a 1% level the hypothesis that the interaction terms between the industry and liquidity risk are jointly zero, indicating that there is a difference in liquidity perception based on the trading activity variables, between industrial and financial bonds.

6.2.3 Retail vs. Institutional Trades

In this section we analyze whether bonds that are mainly traded by retail traders are less liquid than bonds traded by institutional investors. We define two groups based on the average trade size as explained in Section 5.

Figure 3c shows the yield spread for the two groups. Basically, the average yield spreads are identical with one exception: at the end of 2005, the spread increase is more pronounced for the retail-traded bonds, as many GM/Ford bonds were mainly traded by retail investors. In the sub-prime crisis, the level of the yield spread is identical for both groups.

Table 9a shows the descriptive statistics of the yield spread, rating and market-wide trading activity for the two sub-segments in the three different periods. We find that, on average, quite a large number of bonds, around 50%, fall in the retail trade category and that retail traders invest, on average, in better rated bonds. In the sub-prime crisis, the average rating in the retail and the institutional segment improved, indicating a flight-to-quality by both types of investors, however the effect is stronger in the retail segment. For both sub-segments, we observe a general reduction in trading activity in the sub-prime period. However, we find that the reduction in volume is more pronounced for the institutional investors.

Table 9b presents the descriptive statistics of the liquidity proxies for the two sub-segments. Overall, we find that basically all liquidity proxies indicate that retail traded bonds are far less liquid than institutionally-traded bonds. The results indicate that transaction costs are higher by 20% to 50% for retail traders. This difference in liquidity is persistent in all periods. For example, the price dispersion measure is 33.9 bp for institutional investors vs. 56.1 bp for retail investors; both numbers increase in the sub-prime period (76.8 bp vs. 96.9 bp) with the difference staying on the same level.

Regression 3 in Table 10 presents the results for the panel data regressions, using dummies for retail traded bonds and interaction terms between these dummies and the liquidity proxies. Overall, we find that the parameters of the liquidity proxies are significantly smaller for retail investors indicating that liquidity changes are, in general, more important for institutional trades. Thus, institutional traders react more strongly to liquidity changes, although the bond market is generally more liquid for them. Again, an F-test reveals that we can reject at a 1% level the hypothesis that the interaction terms between the type of investor and liquidity risk are jointly zero, indicating the important difference in liquidity perception, between institutional and retail traders.

6.3 Cross-Sectional Analysis

In this section, we explore the cross-sectional differences in explaining the bond yield spreads over the Treasury rate by considering the liquidity proxies presented in Section 4, i.e., bond characteristics, trading activity variables and liquidity measures. Additionally, rating class dummies are used to explain credit risk related differences in spreads across bonds. We use the Fama-MacBeth procedure to report the results for the three sub-periods, i.e., the GM/Ford crisis, the normal period and the sub-prime crisis.

Table 11 provides the detailed results. The findings for the individual measures basically confirm the results of the panel-data analysis, i.e., based on the t-statistics liquidity measures are more important than trading activity variables, and among the liquidity measures, the Amihud measure and the price dispersion measures are the most important proxies. As in the panel-data analysis, we find an unexpected sign for the number of trades and for the zero-return measure (with again, marginally economic significant results for the zero-return measure.) Interestingly, the bond characteristics are important liquidity proxies in explaining the cross-section, as well. The most important one is the amount issued with the highest overall t-statistic. Thus, high outstanding amounts indicate higher liquidity. The age and coupon of the bond show higher liquidity for newly issued bonds with lower coupons. As expected, a longer maturity indicates lower liquidity for bonds in the normal period and in the GM/Ford crisis. However, the effect is marginally negative for the sub-prime period. This could indicate that for “buy-and-hold”-bonds with long maturities, the selling pressure was not as high as for bonds with shorter maturities resulting in marginally lower spreads.

The cross-sectional variation of the yield spread measured by the standard deviation is 160.9 bp. Considering the economic effect of the liquidity proxies, we find significant results: e.g., the amount issued and the price dispersion measure show strong effects; a one standard deviation change explains around 21.2 bp and 11.3 bp respectively. The effects are more pronounced in the crisis periods compare to the normal period, e.g. for the amount issued the economic significance is 16.1 bp in the normal period vs. 20.4 and 27.1 bp in the GM/Ford and sub-prime crisis. Again, the zero-return measure shows the lowest economic effect of around 1.4 bp. A one standard deviation move in all proxies in the direction of greater illiquidity would increase the spread by 82.4 bp in the normal period compared to 98.2 bp and 106.5 bp respectively in the GM/Ford and sub-prime crisis periods. Thus, we find a higher impact of the liquidity proxies in the crises periods.

We observe that a large part of the cross-sectional differences in the yield spread across bonds can be explained, indicated by an R^2 ranging between 63.2% to 68.2% in the three sub-periods. The relative improvement in R^2 when considering the liquidity proxies (not presented in the tables) is around 10%. Interestingly, this ratio stays at the same level in all three sub-periods. Thus, we cannot observe an increase of explanatory power due to liquidity proxies in the crisis periods. It seems that especially in the sub-prime crisis, the spread levels of *all* bonds increased, and thus, the cross-sectional variation has not dramatically changed. Thus, we do not observe the same increase in importance for the liquidity proxies as we do in the panel-data analysis.

Considering the credit risk component of the yield spreads, the results clearly show the importance of the rating class dummies in the cross-section, as the remaining 90% of the explanatory power stems from this credit risk proxy. However, the lower R^2 in the sub-prime crisis results from a decrease in the explanatory power of the credit ratings, indicating that ratings might have reacted rather slowly to the increase in credit risk.

Overall, the cross-sectional regressions provide additional insights and confirm the important results of the panel-data analysis: Liquidity is priced in our samples and liquidity measures related to transaction costs are important in capturing this effect, whereas in the cross-section simple bond characteristic, such as the amount issued, are also of importance.

7 Conclusion

Financial economists have been concerned with the impact of liquidity and liquidity risk on the pricing of assets for at least two decades. During this period, several issues relating to liquidity effects in asset prices have been analyzed at a theoretical and empirical level by academic researchers, particularly in the context of US equity markets. More recently, the focus on liquidity has been broadened to include a wider class of assets such as derivatives and fixed income securities. This trend has accelerated since the onset of the on-going sub-prime crisis, as the discussion of liquidity has attracted much interest among academics, practitioners and regulators. While the crisis has manifested itself in almost every financial market in the world, the most stressed markets, by far, have been those for fixed income securities and their derivatives, particularly those with credit risk, including corporate bonds, CDSs and CDOs. These developments require that the scope of the discussion of liquidity be extended to include the interplay between liquidity and credit.

Corporate bond markets are far less liquid than related equity markets, since only a very small proportion of the universe of corporate bonds trades even as often as once a day. In addition, corporate bonds trade in an over-the-counter market, where there is no central market place. Hence, conventional transaction metrics of liquidity such as bid-offer quotes do not have the same meaning in this market compared to exchange-traded markets. The issue of liquidity in this relatively illiquid, OTC market is fundamentally different from that in liquid, exchange-traded markets: Thus, it is necessary to use measures of liquidity that go beyond the standard transaction-based measures common in research in more liquid, exchange-traded markets.

We employ a wide range of liquidity measures to quantify the liquidity effects in corporate bond yield spreads. Our analysis explores the time-series and cross-sectional aspects of liquidity using panel and Fama-MacBeth regressions, respectively. We find that the liquidity proxies in the specified regression models accounts for about one-tenth of the explained time-series variation of the yield spread changes. The credit rating as well as all the liquidity proxies considered exhibit statistically as well as economically significant results. In particular, measures estimating trading costs based on transaction data show the strongest effects. Furthermore, we find that the effect of the liquidity measures is far stronger in both the GM/Ford crisis and the sub-prime crisis, e.g. the economic effect doubles in the sub-prime crisis.

Comparing investment grade to speculative grade bonds, we find lower liquidity for speculative grade bonds as well as a stronger reaction to changes in liquidity. These results show that bonds with higher credit risk also are more exposed to liquidity risk. We also find that the overall liquidity of bonds issued by financial firms is higher on average, than those of industrial firms. Thus, we find evidence that during the sub-prime crisis, the yield spread increase for financial firms compared to industrial firms is driven relatively more by credit risk. Analyzing retail trades vs. institutional trades, we find that retail investors are confronted with far higher transaction costs, i.e., they perceive the corporate bond market to be relatively less liquid. However, institutional investors seem to react more strongly to liquidity changes than their retail counterparts.

Our cross-sectional results based on the Fama-MacBeth procedure paint a picture similar to the panel-data analysis, i.e., liquidity is an important driver of bond-specific differences in yield spreads, with the measures estimating effective trading costs showing the sharpest effects. Overall, our time-series and cross-section results provide important insights concerning the effects of liquidity in the US corporate bond market. These results are useful for many practical applications, particularly pricing and risk management, and also have implications for regulatory policy. They also highlight the importance of transparency of trades for OTC markets, with reporting to a central authority being a crucial element for price discovery.

A Tables and Figures

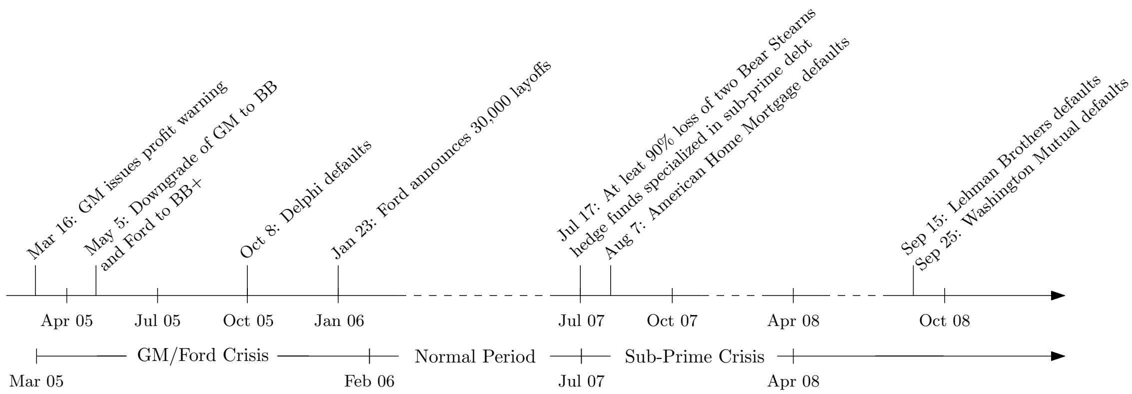

Figure 1: Time-line showing important events in the U.S. corporate bond market, since March 2005. Based on these events we identified three different regimes: the GM/Ford crisis between March 2005 and January 2006, the normal period from February 2006 to June 2007, with no exceptional events and the sub-prime crisis that started in July 2007.

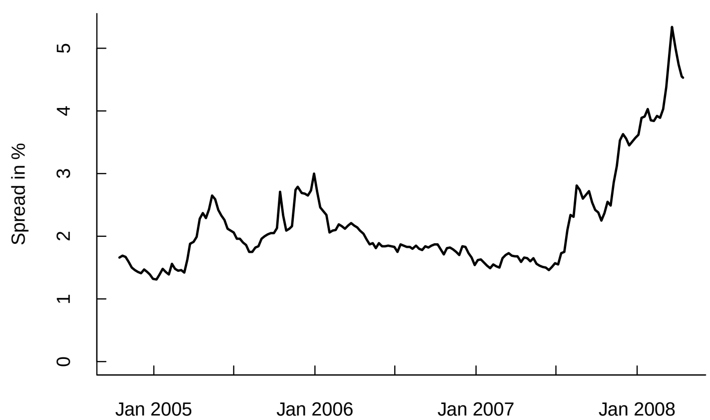

Figure 2: This figure shows the market-wide corporate bond yield spread between October 2004 and April 2008 computed by averaging the bond yield spreads across bonds traded. Corporate bond yield spreads are measured relative to the Treasury yield curve and are given in percentage points. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

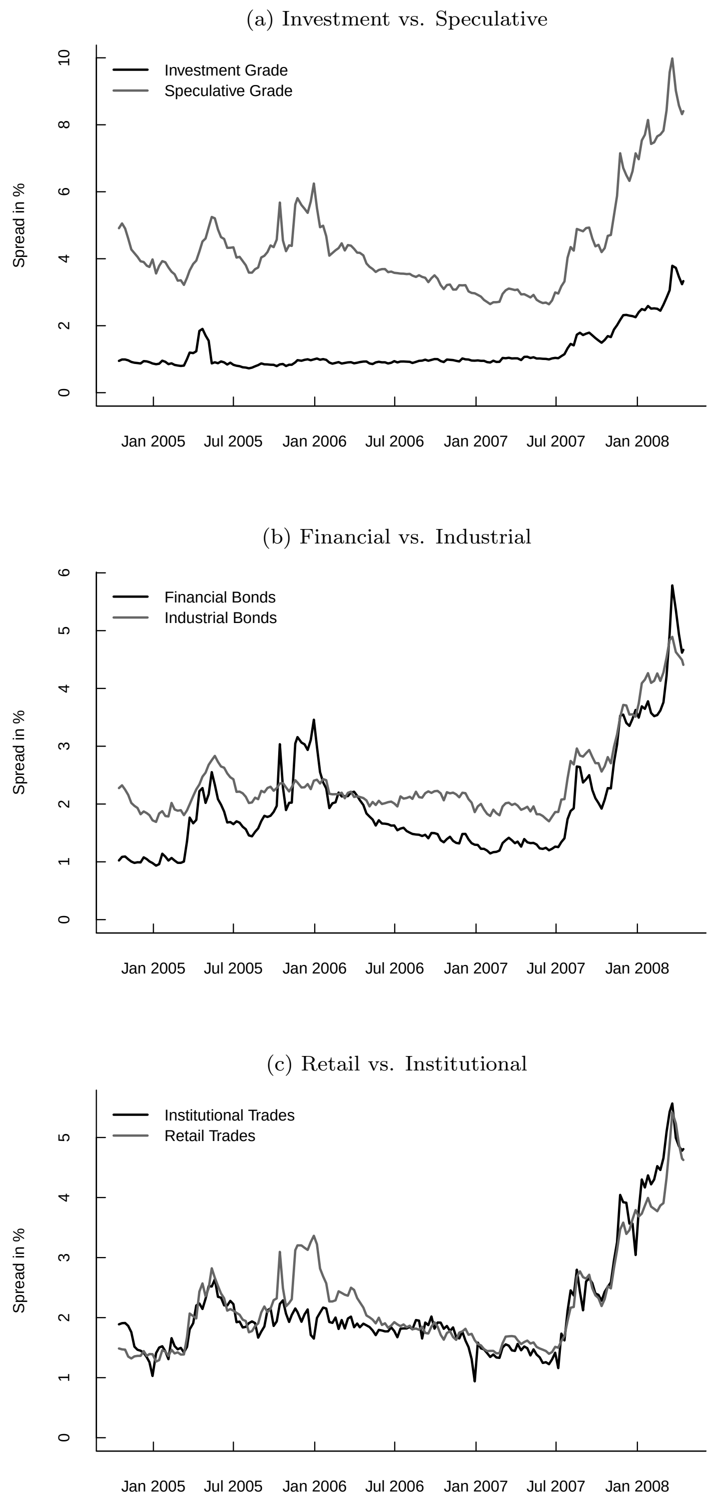

Figure 3: Market-wide bond yield spreads of investment grade vs. speculative grade bonds (a), financial vs. industrial bonds (b), and retail vs. institutional traded bonds (c). We define retail trades as trades with an average trade volume of less than \$75,000 and institutional trades as trades of more than \$75,000. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

		$Q_{0.05}$	$Q_{0.25}$	$Q_{0.50}$	$Q_{0.75}$	$Q_{0.95}$	Mean	Std. Dev.
	Yield Spread (%)	0.46	0.84	1.24	2.06	5.19	1.79	1.65
	Rating	1.00	4.00	6.00	9.00	15.00	6.99	4.11
Bond Characteristics	Amount Issued (bln)	0.01	0.05	0.23	0.45	1.15	0.34	0.43
	Coupon (%)	3.30	5.15	6.20	7.38	9.50	6.29	1.84
	Maturity (yr)	0.61	2.31	5.69	10.49	25.86	8.24	7.90
	Age (yr)	0.59	1.67	3.12	5.74	11.47	4.30	3.87
Trading Activity Variables	Volume (mln)	0.03	0.11	1.10	2.21	5.24	1.59	1.89
	Trades	1.48	1.99	2.43	3.32	8.47	3.31	2.93
	Trading Interval (dy)	1.49	2.45	4.05	6.21	10.58	4.94	4.45
Liquidity Measures	Amihud (10^{-6})	0.44	5.69	18.03	47.59	127.08	35.79	48.40
	Price Dispersion (bp)	0.35	7.08	24.48	59.78	149.35	42.97	52.83
	Roll (bp)	56.35	94.15	120.28	157.74	261.54	134.13	62.20
	Bid-Ask Spread (bp)	10.00	25.00	37.13	54.18	84.59	41.07	21.85
	Zero-Ret. (Markit) (%)	0.00	0.00	0.00	0.01	0.12	0.02	0.06
	Zero-Ret. (Bloomb.) (%)	0.00	0.00	0.00	0.01	0.13	0.02	0.07

Table 1: This table reports the cross-sectional descriptive statistics for the yield spread, the credit rating, the bond characteristics, the trading activity variables, and the liquidity measures (see Section 4 for the definitions of the various liquidity proxies.) Time-varying variables are averaged across time for each individual bond. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

(a) Yield-Spread, Rating, and Market-Wide Trading Activity

	Mean			Standard Deviation		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Yield Spread (%)	2.21	1.78	3.28	0.37	0.20	0.97
Rating	8.20	7.94	7.54	0.14	0.29	0.10
Traded Bonds (thd)	6.78	6.94	5.88	0.46	0.42	0.64
Market-Wide Trades (thd)	25.51	23.27	20.85	2.70	1.72	2.51
Market-Wide Volume (bln)	9.38	8.96	6.80	1.57	1.24	1.30

(b) Liquidity Proxies

	Mean			Standard Deviation		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Amount Issued (bln)	0.47	0.50	0.58	0.03	0.03	0.04
Coupon (%)	6.49	6.43	6.34	0.05	0.06	0.04
Maturity (yr)	7.55	7.75	7.79	0.18	0.14	0.19
Age (yr)	4.25	4.51	4.87	0.08	0.12	0.17
Volume (mln)	1.89	1.84	1.69	0.26	0.21	0.28
Trades	4.24	4.14	4.50	0.21	0.16	0.48
Trading Interval (dy)	3.25	3.34	3.34	0.46	0.45	0.51
Amihud (10^{-6})	24.49	21.37	28.40	3.53	2.59	3.27
Price Dispersion (bp)	48.82	40.72	83.53	5.40	3.16	14.48
Roll (bp)	118.86	107.12	144.21	6.02	5.74	17.36
Bid-Ask Spread (bp)	40.88	45.35	44.70	2.66	1.04	3.24
Zero Return Markit (%)	0.02	0.02	0.03	0.01	0.01	0.01
Zero Return Bloomberg (%)	0.03	0.02	0.01	0.02	0.01	0.00

Table 2: Panel (a) shows the mean and standard deviation for the yield spread, the credit rating, and the daily market-wide trading activity in the three regimes (GM/Ford crisis, normal period, and sub-prime crisis). Panel (b) shows the mean and the standard deviation for the bond characteristics, the trading activity variables, and the liquidity measures. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

	Amount Issued	Coupon	Maturity	Age	Volume	Trades	Trading Interval	Amihud	Price Disp.	Roll	Bid-Ask Spread	Zero-Ret. Markit	Zero-Ret. Bloomb.
Amount Issued	1.00												
Coupon	−0.10	1.00											
Maturity	−0.01	0.11	1.00										
Age	−0.15	0.26	−0.01	1.00									
Volume	0.37	−0.04	0.09	−0.21	1.00								
Trades	0.52	−0.09	−0.08	−0.03	0.37	1.00							
Trading Interval	−0.25	0.06	0.06	0.04	−0.09	−0.25	1.00						
Amihud	−0.17	0.02	0.15	0.13	−0.19	−0.16	0.05	1.00					
Price Disp.	−0.02	0.09	0.30	0.06	−0.07	0.06	−0.06	0.19	1.00				
Roll	−0.13	0.01	0.08	0.02	−0.08	−0.06	0.01	0.13	0.10	1.00			
Bid-Ask Spread	−0.16	0.40	0.29	−0.03	−0.07	−0.10	0.06	0.07	0.18	0.07	1.00		
Zero-Ret. Markit	−0.04	0.16	−0.02	−0.05	−0.05	−0.09	0.01	−0.01	0.01	0.00	0.15	1.00	
Zero-Ret. Bloomb.	−0.07	0.15	0.00	−0.01	−0.04	−0.04	0.02	0.02	0.00	0.01	0.12	0.11	1.00

Table 3: Correlation matrix of bond characteristics, trading activity variables, and liquidity measures based on the panel-data for pairwise complete observations. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

	(1)	(2)	(3)	(4)
Intercept	0.0416^{***}	0.0414^{***}	0.0415^{***}	0.0414^{***}
	(65.5681)	(60.4256)	(61.6144)	(63.6946)
Lagged ΔYld.Spr.	-0.3881^{***}	-0.3825^{***}	-0.3830^{***}	-0.3790^{***}
	(-76.0154)	(-71.7827)	(-72.9607)	(-72.7481)
ΔVolume		-0.0212^{***}		-0.0142^{***}
		(-32.9287)		(-23.8154)
ΔTrades		0.0051^{***}		0.0049^{***}
		(15.2584)		(14.7555)
ΔTrading Interval		0.3148^{***}		0.3107^{***}
		(21.1323)		(21.0395)
ΔAmihud			0.0360^{***}	0.0315^{***}
			(33.6524)	(30.5027)
ΔPrice Dispersion			0.0169^{***}	0.0151^{***}
			(18.3478)	(16.7159)
ΔRoll			0.0021^{***}	0.0020^{***}
			(2.8428)	(2.7505)
ΔZero-Return Markit			-0.0397^{***}	-0.0419^{***}
			(-6.5470)	(-6.9227)
ΔRating Dummies	Yes	Yes	Yes	Yes
R^2	0.1345	0.1407	0.1430	0.1467
Observations	637,502	637,502	637,502	637,502

Table 4: This table reports the panel-data regression models explaining the yield spread changes based on weekly averages using rating dummies to control for credit risk. In Regression (1) we use a specification without the liquidity proxies. Regression (2) reports the results with the trading activity variables only, while Regression (3) reports them with the liquidity measures only. In Regression (4) we add both type of liquidity proxies. The t-statistics are given in parenthesis and are calculated from Newey and West (1987) standard errors, which are corrected for heteroskedasticity and serial correlation. In addition, the table also reports each model's R^2 and the number of observations. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

	(1)	(2)	(3)	(4)	(5)
Intercept	0.0284***	0.0283***	0.0283***	0.0282***	0.0282***
	(33.4537)	(36.6672)	(37.4944)	(36.1107)	(36.2017)
Lagged ΔYld.Spr.	−0.3984***	−0.3933***	−0.3885***	−0.3856***	−0.3856***
	(-49.7773)	(-46.2305)	(-45.6600)	(-45.9057)	(-45.8644)
ΔVolume		−0.0173***		−0.0102***	−0.0101***
		(-18.4150)		(-11.3512)	(-11.2091)
ΔTrades		0.0025***		0.0026***	0.0026***
		(6.2489)		(6.4452)	(6.4501)
ΔTrading Interval		0.1740***		0.1814***	0.1810***
		(7.3056)		(7.7039)	(7.6644)
ΔAmihud			0.0617***	0.0569***	0.0568***
			(18.9752)	(17.5097)	(17.5071)
ΔPrice Dispersion			0.0226***	0.0216***	0.0215***
			(11.6132)	(11.3207)	(11.3012)
ΔRoll			0.0022	0.0022	0.0022
			(1.4779)	(1.5326)	(1.4992)
ΔZero-Return Markit			0.0073	0.0053	0.0030
			(0.3400)	(0.2474)	(0.1382)
ΔBid-Ask Spread					0.0336***
					(2.7400)
ΔZero-Return Bloomberg					0.0535*
					(1.8847)
ΔRating Dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.1418	0.1479	0.1577	0.1607	0.1609
Observations	138,540	138,540	138,540	138,540	138,540

Table 5: This table reports the panel-data regression models explaining the yield spread changes based on weekly averages for which observations on the bid-ask spreads are available. We control for credit risk by using rating dummies. In Regression (1) we use a specification without the liquidity proxies. Regression (2) reports the results with the trading activity variables only, while Regression (3) reports them with the liquidity measures only. In Regression (4) we add both type of liquidity proxies. In Regression (5) we additionally use liquidity measures based on Bloomberg bid/ask quotations. The t-statistics are given in parenthesis and are calculated from Newey and West (1987) standard errors, which are corrected for heteroskedasticity and serial correlation. In addition, the table also reports each model's R^2 and the number of observations. This data set is based on our small sample which contains Bloomberg bid/ask quotations and covers 4,531 bonds traded over the period October 2004 to April 2008.

Intercept	0.0384^{***}	(65.7535)
Lagged ΔYld.Spr.	-0.3775^{***}	(-72.7268)
ΔVolume	-0.0135^{***}	(-19.9843)
ΔTrades	0.0037^{***}	(9.3006)
ΔTrading Interval	0.0396^{***}	(2.6576)
ΔAmihud Measure	0.0287^{***}	(21.7332)
ΔPrice Dispersion	0.0063^{***}	(5.4861)
ΔRoll Measure	-0.0020^{**}	(-2.3011)
ΔZero-Return Markit	-0.0514^{***}	(-6.4931)
Δ(GM/Ford Dummy · Volume)	-0.0020^{*}	(-1.8384)
Δ(GM/Ford Dummy · Trades)	0.0020^{***}	(3.1636)
Δ(GM/Ford Dummy · Trading Interval)	0.1354^{***}	(3.5354)
Δ(GM/Ford Dummy · Amihud Measure)	0.0030	(1.5214)
Δ(GM/Ford Dummy · Price Dispersion)	0.0063^{***}	(3.7524)
Δ(GM/Ford Dummy · Roll Measure)	0.0025^{*}	(1.6628)
Δ(GM/Ford Dummy · Zero-Return Markit)	0.0140	(0.9614)
Δ(Sub-prime Dummy · Volume)	-0.0007	(-0.4633)
Δ(Sub-prime Dummy · Trades)	0.0030^{***}	(3.4903)
Δ(Sub-prime Dummy · Trading Interval)	0.5332^{***}	(15.2841)
Δ(Sub-prime Dummy · Amihud Measure)	0.0067^{***}	(3.0210)
Δ(Sub-prime Dummy · Price Dispersion)	0.0185^{***}	(9.7369)
Δ(Sub-prime Dummy · Roll Measure)	0.0087^{***}	(4.4938)
Δ(Sub-prime Dummy · Zero-Return Markit)	0.0199	(1.2703)
ΔRating Dummies	Yes	
F-Statitics $\mathcal{H}_0$: Δ(GM/Ford Dummy · Liquidity Proxies) = 0	(5.6161)	
F-Statitics $\mathcal{H}_0$: Δ(Sub-prime Dummy · Liquidity Proxies) = 0	(51.8910)	
R^2	0.1546	
Observations	637,502	

Table 6: This table reports the panel-data regression model explaining the yield spread changes based on weekly averages. We control for credit risk by using rating dummies and, additionally, we add interaction terms between sub-period dummies and the liquidity proxies. The t-statistics are given in parenthesis and are calculated from Newey and West (1987) standard errors, which are corrected for heteroskedasticity and serial correlation. We provide an F-test to test whether the interaction terms of the dummy variable with the liquidity proxies are jointly zero. The standard errors of the F-statistics are also Newey and West (1987) corrected. In addition, the table also reports the model's R^2 and the number of observations. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

(a) Yield-Spread, Rating, and Market-Wide Trading Activity

	Investment Grade			Speculative Grade		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Yield Spread (%)	0.97	0.96	2.15	4.50	3.35	6.16
Rating	5.97	5.55	5.39	13.25	13.50	13.52
Traded Bonds (thd)	4.68	4.86	4.33	2.10	2.09	1.55
Market-Wide Trades (thd)	16.15	15.71	15.38	9.36	7.56	5.46
Market-Wide Volume (bln)	6.83	6.97	5.32	2.55	1.99	1.48

(b) Liquidity Proxies

	Investment Grade			Speculative Grade		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Volume (mln)	1.95	2.00	1.82	1.73	1.50	1.40
Trades	4.22	4.17	4.78	4.26	4.06	3.85
Trading Interval (dy)	3.32	3.33	3.26	3.08	3.34	3.53
Amihud (10^{-6})	26.03	22.20	28.78	20.60	19.35	27.40
Price Dispersion (bp)	42.41	35.82	80.39	64.93	52.04	91.17
Roll (bp)	116.80	106.91	142.58	123.83	107.50	142.58
Zero Return Markit (%)	0.01	0.00	0.00	0.05	0.06	0.09

Table 7: This table reports the mean of the yield spread, the credit rating, and the daily market-wide trading activity in Panel (a) for investment grade and speculative grade bonds for the three different regimes (GM/Ford crisis, normal period, and sub-prime crisis). Panel (b) provides the averages for the trading activity variables and the liquidity measures. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

(a) Yield-Spread, Rating, and Market-Wide Trading Activity

	Industrial Bonds			Financial Bonds		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Yield Spread (%)	2.31	2.04	3.43	2.06	1.52	3.09
Rating	9.81	9.90	9.77	6.90	6.47	5.83
Traded Bonds (thd)	3.00	2.99	2.55	3.78	3.96	3.33
Market-Wide Trades (thd)	11.84	10.82	8.99	13.66	12.44	11.86
Market-Wide Volume (bln)	5.69	5.45	3.97	3.69	3.51	2.83

(b) Liquidity Proxies

	Industrial Bonds			Financial Bonds		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Volume (mln)	1.97	1.88	1.66	1.73	1.77	1.76
Trades	3.90	3.80	3.86	4.89	4.82	5.85
Trading Interval (dy)	3.32	3.47	3.53	3.12	3.07	2.93
Amihud (10^{-6})	21.98	20.03	28.44	29.21	23.88	28.03
Price Dispersion (bp)	54.39	45.92	88.68	37.99	30.21	73.47
Roll (bp)	118.12	104.26	141.78	120.01	112.68	148.83
Zero Return Markit (%)	2.35	2.64	3.95	0.72	0.62	0.01

Table 8: This table reports the mean of the yield spread, the credit rating, and the daily market-wide trading activity in Panel (a) for bonds of industrial and financial firms for the three different regimes (GM/Ford crisis, normal period, and sub-prime crisis). Panel (b) provides the averages for the trading activity variables and the liquidity measures. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

(a) Yield-Spread, Rating, and Market-Wide Trading Activity

	Institutional Traded			Retail Traded		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Yield Spread (%)	2.04	1.66	3.46	2.37	1.80	3.29
Rating	9.19	9.07	8.84	7.38	7.05	6.62
Traded Bonds (thd)	3.03	3.08	2.43	3.76	3.87	3.45
Market-Wide Trades (thd)	14.93	12.76	10.90	10.58	10.51	9.95
Market-Wide Volume (bln)	9.10	8.69	6.54	0.28	0.28	0.26

(b) Liquiditiy Proxies

	Institutional Traded			Retail Traded		
	GM/Ford Crisis	Normal Period	Sub-prime Crisis	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Volume (mln)	2.67	2.59	2.47	0.12	0.13	0.14
Trades	4.56	4.35	4.73	3.51	3.64	4.03
Trading Interval (dy)	3.01	3.17	3.19	3.78	3.72	3.64
Amihud (10^{-6})	10.98	10.01	13.35	54.60	47.06	57.56
Price Dispersion (bp)	41.72	33.88	76.81	64.75	56.14	96.88
Roll (bp)	109.47	100.01	139.00	139.63	122.92	153.69
Zero Return Markit (%)	2.13	2.40	3.70	1.07	0.97	1.34

Table 9: This table reports the mean of the yield spread, the credit rating, and the daily market-wide trading activity in Panel (a) for retail and institutional traded bonds for the three different regimes (GM/Ford crisis, normal period, and sub-prime crisis). Panel (b) provides the averages for the trading activity variables and the liquidity measures. We define retail trades as trades with an average trade volume of less than $75,000 and institutional trades as trades of more than $75,000. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

	(1)	(2)	(3)
Intercept	0.0413***	0.0413***	0.0414***
	(63.7615)	(64.6358)	(61.3919)
Lagged ΔYld.Spr.	-0.3786***	-0.3788***	-0.3787***
	(-72.6554)	(-73.1776)	(-71.5213)
ΔVolume	-0.0122***	-0.0131***	-0.0046***
	(-19.5802)	(-18.7717)	(-6.8136)
ΔTrades	0.0048***	0.0047***	0.0040***
	(12.6786)	(11.9176)	(12.0680)
ΔTrading Interval	0.2904***	0.3775***	0.2791***
	(20.1822)	(13.3441)	(8.5801)
ΔAmihud Measure	0.0305***	0.0353***	0.0369***
	(28.1590)	(21.1645)	(16.4837)
ΔPrice Dispersion	0.0151***	0.0108***	0.0187***
	(15.3681)	(10.4240)	(18.5557)
ΔRoll Measure	0.0019**	0.0012	0.0029***
	(2.3224)	(1.2421)	(3.3614)
ΔZero-Return Markit	-0.0744***	-0.0236***	-0.0192***
	(-5.6791)	(-3.5774)	(-3.0527)
Δ(Dummy $\cdot$ Volume)	-0.0118***	-0.0033***	-0.0185***
	(-6.7845)	(-2.5843)	(-11.4435)
Δ(Dummy $\cdot$ Trades)	0.0015**	0.0003	0.0014***
	(2.0717)	(0.4454)	(3.2730)
Δ(Dummy $\cdot$ Trading Interval)	0.3687***	0.0945***	0.0419
	(3.6671)	(2.8715)	(1.1438)
Δ(Dummy $\cdot$ Amihud Measure)	0.0073**	-0.0066***	-0.0092***
	(2.1559)	(-3.1282)	(-3.7657)
Δ(Dummy $\cdot$ Price Dispersion)	-0.0013	0.0124***	-0.0067***
	(-0.6470)	(6.2767)	(-5.1686)
Δ(Dummy $\cdot$ Roll Measure)	0.0009	0.0019	-0.0015
	(0.4507)	(1.2654)	(-1.0879)
Δ(Dummy $\cdot$ Zero-Return Markit)	0.0436***	-0.0797***	-0.0668***
	(2.9538)	(-4.9521)	(-4.9347)
ΔRating Dummies	Yes	Yes	Yes
Sub-segment Dummy	Speculative	Financial	Retail
F-Statitics	(10.9923)	(14.2006)	(31.3039)
$\mathcal{H}_0$: $\Delta(\text{Dummy} \cdot \text{Liquidity Proxies}) = 0$			
R^2	0.1472	0.1473	0.1470
Observations	637,502	637,502	637,502

Table 10: This table reports panel-data regression models explaining the yield spread changes based on weekly averages where we include rating dummies to control for credit risk and interaction terms between a sub-segment dummy and the liquidity proxies. Regression (1) shows the specification where we use speculative grade bonds as the sub-segment dummy, in Regression (2) the dummy variable refers to bonds of financial firms, and in Regression (3) it refers to retail traded bonds. The t-statistics are given in parenthesis and are calculated from Newey and West (1987) standard errors, which are corrected for heteroskedasticity and serial correlation. We provide an F-test to test whether the interaction terms of the dummy variable with the liquidity proxies are jointly zero. The standard errors of the F-statistics are also Newey and West (1987) corrected. In addition, the table also reports the model's R^2 and the number of observations. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

	GM/Ford Crisis	Normal Period	Sub-prime Crisis
Intercept	2.4160***	1.8489***	3.0816***
	(26.0088)	(38.2624)	(23.7661)
Amount Issued	−0.1336***	−0.0977***	−0.1565***
	(-27.9898)	(-27.7233)	(-25.5205)
Coupon	0.0410***	0.0413***	0.0644***
	(3.1539)	(10.2451)	(8.6958)
Maturity	0.0241***	0.0272***	−0.0151*
	(9.4616)	(6.1340)	(-1.9271)
Age	0.0300***	0.0151***	0.0160***
	(20.2693)	(6.6984)	(6.1782)
Volume	−0.0112***	−0.0118***	0.0112**
	(-4.2453)	(-5.7967)	(2.1660)
Trades	0.0511***	0.0371***	0.0432***
	(14.7381)	(9.2017)	(16.1346)
Trading Interval	−0.0007	−0.0014***	−0.0045***
	(-1.4707)	(-4.2217)	(-6.4144)
Amihud	0.0474***	0.0462***	0.0774***
	(23.2169)	(18.7223)	(8.6192)
Price Dispersion	0.1247***	0.0972***	0.1177***
	(8.6648)	(14.7005)	(12.0102)
Roll	0.0264***	0.0160***	0.0166***
	(8.4802)	(6.9107)	(2.5413)
Zero-Return Markit	−0.0130	−0.1408***	−0.3603***
	(-0.3988)	(-8.9566)	(-8.3619)
Rating Dummies	Yes	Yes	Yes
R^2	0.6731	0.6822	0.6316
Observations	4,161	4,412	3,629

Table 11: This tables reports the cross-sectional regression models explaining the weekly averages of yield spreads, estimated in the three regimes (GM/Ford crisis, normal period, and sub-prime crisis) based on the Fama-MacBeth procedure. Bond characteristics, the trading activity variables, and the liquidity measures are the explanatory variables in these models. We use dummy variables to control for credit risk. The t-statistics are given in parenthesis and are calculated from Newey and West (1987) standard errors, which are corrected for heteroskedasticity and serial correlation. The table also reports each model's R^2 and the number of bonds. The data-set consists of 21,585 bonds traded over the period October 2004 to April 2008.

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